PLANT PROTECTION AND STORAGE PRODUCTS

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ELECTRO-OPTICAL INSTALLATIONS IN THE GARDEN PLANT PROTECTION SYSTEM

Research article

Abstract

The article describes the methods used to protect garden plants against pests. The analysis showed that the application of the electrophysical method is the most promising. There has been presented an overview of electro-optical converters to protect garden plants against pests. An analysis of the properties of pulsed infrared radiation indicates to their possible using as well to control diseases of garden plants. Thereby, technical means used to implement the electrophysical method can provide a comprehensive plant protection against pests and diseases.

The application of electro-optical installations to protect garden plants helps to increase the quality of the crop.

Keywords: methods of garden plant protection, pulsed infrared radiation, pests, pest attraction, electro-optical installations.

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ЭЛЕКТРООПТИЧЕСКИЕ УСТАНОВКИ В СИСТЕМЕ ЗАЩИТЫ САДОВЫХ РАСТЕНИЙ

Научная статья

Аннотация

В статье приведены способы, используемые в системе защиты садовых растений от насекомых-вредителей, анализ которых показал, что наиболее перспективным является использование электрофизического способа. Представлен обзор электрооптических преобразователей для защиты садовых растений от насекомых-вредителей. Анализ свойств импульсного инфракрасного излучения показывает на возможность использования его и для борьбы с болезнями садовых растений, в связи с этим технические средства используемые для реализации электрофизического способа могут обеспечить комплексную защиту растений и от насекомых вредителей и от болезней.

Применение электрооптических установок в системе защиты садовых растений способствует увеличению качества урожая.

Ключевые слова: способы защиты садовых растений, импульсное инфракрасное излучение, насекомые-вредиели, привлечение насекомых, электрооптические установки.

1. Methods of garden plant protection against pests

The main production task of garden plants protection is to increase productivity by reducing yield losses resulting from the nutrition of various pests /9/.

Being fast-acting and relative effective, a chemical method is considered to be one of the most common methods of garden plant protection against pests. However, it has a number of major drawbacks.

To implement measures of chemical plant protection, a large amount of equipment is required, aviation is involved. The other significant drawback of the chemical method is its limited use on different weather conditions, since after rains one should carry out repeated chemical treatments, because pesticides are washed off. In addition, it leads to the formation of resistant and cross-resistant races of pests /9/. In turn, sanitary standards limit the possibility of using chemical methods to protect garden plants in the period preceding the harvest (20–40 days before harvesting). However, in the southern part of Russia the considered period faces a partial appearance of the second generation and a massive flying of the third one of the codling moth, while some other leaf-eating species still continue to harm.

In addition, the use of the chemical method causes significant damage to insect pollinators, and measures to prevent their damage are labor-intensive and rather complicated.

The biological method, developing in two main directions, allows us to get rid of some of these drawbacks: the artificial cultivation of entomophages with the subsequent mass introduction of their quantity in the agroecosystem of the industrial garden and the regulation of the number of pest populations using hormonal, biological, microbiological, and pheromone preparations.

However, the biological method also has some drawbacks. So, when artificially growing entomophages, there arise difficulties of a purely technical kind, such as the lack of processes mechanization of their mass breeding, seasonal prevalence of operations, the inability to determine the exact timing of their cultivation, the difficulty of transporting entomophages to the place of their settlement. The practical use of this method made it clear that it is impossible to control the stability of the quantitative and qualitative ratio of pest population, which makes it impossible to stabilize the economic efficiency of entomophages. The regulation of the number of pest populations by introducing hormonal and pheromone preparations is not widely used due to the fact that pheromone baits affect only on one type of pests and they are most effective in the first 3-4 days, after that their effectiveness sharply drops.

The use of hormones to protect garden plants is also not widespread, since they have a selective effect, their application is limited to a small period of insects' sensitivity to them. There is evidence that pests become resistant to hormones.

Biological and microbiological preparations are not widely used because of their high cost and the absence of preparations whose effectiveness would not depend on environmental conditions. In addition, the biological method conflicts with the chemical and mechanical methods, the use of which leads to the death of both harmful and beneficial insects.

An integrated method of plant protection is currently the most effective, which is primarily characterized by a biocenotic approach, that is, taking into account not individual species, but faunistic complexes of interrelated organisms, the relationships between which can significantly affect the number of organisms. The integrated plant protection involves the use of selective pest control means. These preparations should ensure the maximum preservation and strengthening of the natural mechanisms of regulating the number of pests /8/.

An integrated method of plant protection is to regulate the number of pests at a certain economically atrractive level. One should be stressed out that an integrated method of plant protection provides for the data gathering on the number of populations of both harmful and beneficial insects in the entire garden, determining the numerical ratio of harmful and beneficial insects (biotic index), settling the timing of the harmfulness of insects, deciding on the need for protective measures and planning the timing of their implementation. In this case, there should be selected only those pesticides affecting pests in their harmful phase /8/.

The development of an integrated pest control system requires detailed and accurate information on the number of pests. Studies to obtain this information are carried out on large areas and often with geographically separated populations. To get a qualitative forecast, reliable information about the ecological situation in the garden is needed.

Based on this, it is possible to say that the use of electrophysical protection methods is considered as promising, among which two main options can be distinguished: the use of electro-optical transducers for direct control of pests and the use of electro-optical transducers to determine the dynamics of pest emergence.

The second option uses electro-optical converters in combination with the treatment of plants with chemicals, but the number of chemical treatments is significantly reduced, since chemical means of protection are used only if the number of pests exceeds the economic threshold of harmfulness. A positive side of the second option is the possibility of using selective pest control means, the ability to take into account the natural mechanisms for regulating the number of insects /3.7/. Such an application of electrophysical plant protection can be applied at any phase of plant development. Its application allows you to record sharp population outbreak of specific types of pests and adjust the timing of protective measures. In addition, the application of the electrophysical method does not violate either the ecological balance or the ecological situation in the industrial garden. These statements in particular are confirmed by the results of experimental studies performed by V.S. Gazalov.

Thus, the analysis of technologies of garden plant protection against pests allows us to speak about the availability of optical radiation in this direction / 3.7 /.

2. Electro-optical installations in the garden plant protection system against pests

All electro-optical installations (converters) consist of the following main units: attracting and damaging devices.

The lack of well-developed lighting requirements for electro-optical installations, and requirements for the damaging element gave rise to a wide variety of designs. The principle of operation of existing electro-optical converters for combating pests is as follows.

At night, pests are attracted by optical radiation, which has a positive phototaxis effect, to electro-optical converters, get into the zone of coverage of the damaging device and are destroyed.

By the type of the damaging device applied, the installations can be divided into following types: installations with an aerodynamic damaging device; installations in which a high-voltage grid is used as the damaging element; installations with passive shields.

Electro-optical converters with passive shields work as follows. Pests, rushing to the source of optical radiation, hit passive shields, lose flight stability and fall into the insect collector. The «Pennsylvania» trap turns out to be one of the most successful modifications of electro-optical converters; the installation consists of four passive shields, a pest collector and one 15-watt ultraviolet lamp. In Russia, the Moscow plant «Emitron» used to produce similar installations of the SEPC-3 type (stationary electric pest catcher). SEPC-8ED (electric drive) catchers designed by VSKhI (All-Russian Agricultural Institute), SEP-15SL (sunlamp), SEP-15A (modidfication) designed by ACHIMSKH (Azov-Black Sea Institute of Agricultural Mechanization), EFI-2 (electrophysical installation of plant protection) designed by the Institute of Applied Physics of the Academy of Sciences, the Moscow Soviet Socialist Republic also belong to the installations of this type.

The installations with an aerodynamic damaging element differ from those ones with passive shields in the way a fan is installed between the optical radiation source and the pest collector, which sucks into together with the air stream the pests flying to the optical radiation source. The effectiveness of this damaging element is many times greater than that of passive shields. A significant effect is obtained by the use of aerodynamic damage when catching small active pests. Large pests are crushed by fan blades. To avoid this, there have been installed the nets located in front of the fan. However, this leads to a weakening of the air flow. Despite this, aerodynamic damaging elements are the most promising for electro-optical installations, which serve to warn against the emergence of pests // and to directly combat them (Figure 1).

Installations with high-voltage grids serving as damaging elements (Figure 2) are used for direct pest control. High-voltage grids are placed around the source of optical radiation or radially towards it. The pest, touching two adjacent electrodes, receives an electric shock and dies.

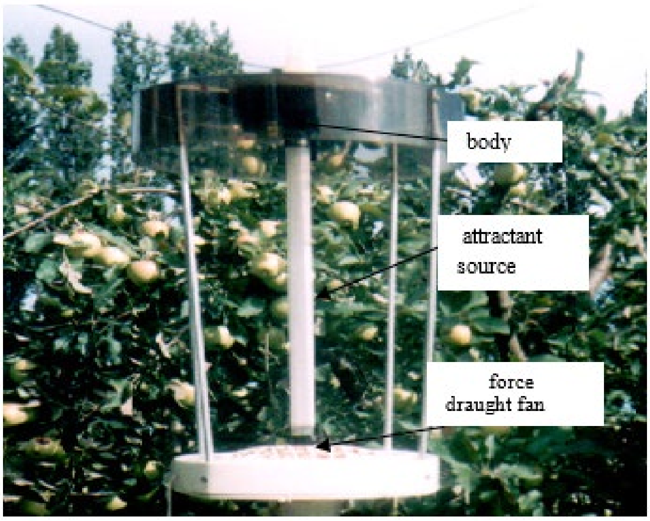

Figure 1 – Aerodynamical electro-optical converter

This type of installations includes AELT (aerodynamical electric light trap) designed by VIZR (All Russian Institute of Plant Protection), IEPP-2M (installation of electrophysical plant protection) designed by the Institute of Applied Physics, the Academy of Sciences of the Moldavian Soviet Socialist Republic, ES-1600 designed by VIESH (All-Russian Institute of Agricultural Electrification), EIWIC (stationary electrical installation with improved chromaticity) – (250, 500) and electric traps for the plant garden protection with high voltage damaging element designed by MIISP (Moscow Institute of Agricultural Engineers) – TSHA (Moscow Timiryazev Agricultural Academy), SEPC-2 and SEPC-2a designed by VIZR, Electric Trap-15 designed by ACHIMSKH.

Figure 2 – Types of designs of electro-optical converters with high-voltage damaging element

Based on the research conducted at the Chair for Application of Electric Energy in Agriculture, the Azov-Black Sea State Agroengineering Academy, a number of installations for the electrophysical garden plant protection against pests were developed. The installations differ from each other in damaging devices, in the way they create a moving optical field, and in the presence of additional attractants. For a number of years, all installations have been used to protect industrial gardens in the Rostov Region and Krasnodar Territory /3.7/.

Stationary electro-optical installation SL-1-01 in Figure 3 (Inventors Certificate No. 1327204) developed by Professor Gazalov V.S., Professor Simonov N.M., Associated Professor Kuprienko A.G., Associated Professor Shcherbayeva L.P. consists of attractant sources, an aerodynamic damaging device and a control unit. Attractant sources are a sunlamp and an incandescent electric lamp.

The stationary electro-optical installation USL-15 consists of optical radiation sources and a damaging device. The damaging device consists of a passive shield covered with non-drying glue.

The most effective damaging devices are aerodynamic. However, when using them, one should clean the pest collector of the installation. The installation with a combined damaging device developed by Professor Gazalov V.S., Professor Simonov N.M., Associated Professor Kuprienko A.G., Associated Professor Shcherbayeva L.P. is equipped with a high-voltage damaging device and a fan (Figure 4). This allows you to fully automate the operation of the installation and reduces the cost of its operation.

The drawbacks of existing installations include the non-use of optical radiation to combat diseases of garden plants and the use of light sources with a negative phototaxic effect.

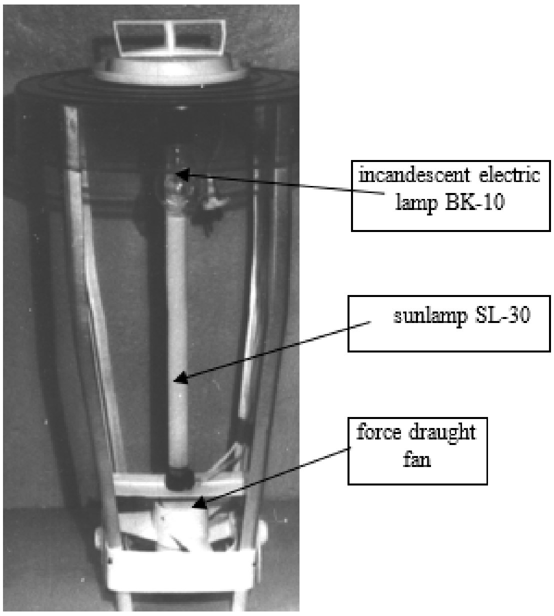

Figure 3 – Electro-optical converter of plant protection SL-1-01

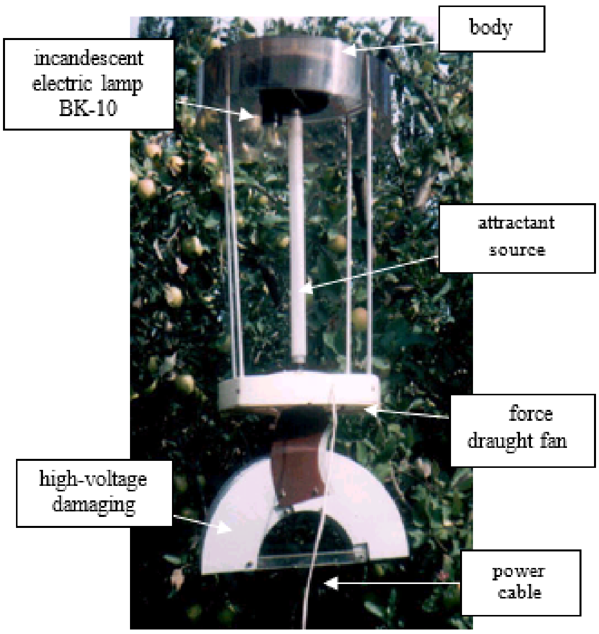

Figure 4 – Electro-optical converter with combined damaging device

The most effective damaging devices are aerodynamic. However, when using them, one should clean the pest collector of the installation. The installation with a combined damaging device developed by Professor Gazalov V.S., Professor Simonov N.M., Associated Professor Kuprienko A.G., Associated Professor Shcherbayeva L.P. is equipped with a high-voltage damaging device and a fan (Figure 4). This allows you to fully automate the operation of the installation and reduces the cost of its operation.

The drawbacks of existing installations include the non-use of optical radiation to combat diseases of garden plants and the use of light sources with a negative phototaxic effect.

3. The use of sources of pulsed infrared radiation in electro-optical installations in the garden plant protection system

The increase in the resistance of the fruit to disease, when exposed to infrared laser radiation, is the result of changes in the physiological and biochemical processes that occur in a cell. A number of researchers (V.V. Sergeev, L.V. Barybkina, A.A. Shakhov, A. Dancheva.) believe that the non-photosynthetic use of infrared laser radiation by cells of plant tissues is associated with an increase in their energy potential /7/.

To identify the effect of laser treatment, A.S. Gordeev, A.V. Aksenovsky, I.A. Trunov (Michurinsk State Agrarian University) carried out an experiment. Its purpose was to study the influence of infrared laser radiation with a wavelength of 890 nm on the quality indicators of fruit and the dynamics of catalase changes during storage / 1 /.

The object of the study was the apple variety – Antonovka vulgaris. This variety is characterized by a high susceptibility to physiological and microbiological diseases. Fruits are especially severely affected by fungal rot. The variety is not colored, differs in a high titratable acidity (1.1-1.3%), a moderate sugar content (8-10%). There is often a lack of calcium in the fruit, as well as a high content of the enzyme catalase.

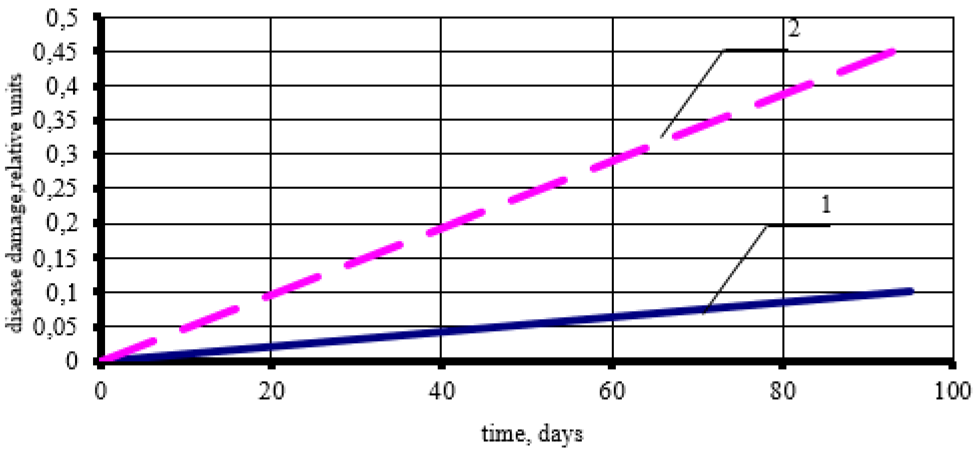

Figure 5 – Disease damage to apple fruits over time (row *1* - irradiated fruits; row *2* - untreated fruits)

Every 27-30 days, an inspection and analysis of the preservation of the fruit were carried out. In this case, all the fruits according to the options of the experiment were divided into two groups: healthy ones and those affected by fungal rot. The largest transverse diameter was measured using a sliding caliper. Basically, the differences began to appear on the 14th day of storage and tended to increase, reaching their maximum on the 95th day, where the difference in the disease damage between treated and untreated fruits was 70% (Figure 5).

Treated fruits have got the rate of damage growth to diseases 23.5 times lower than that one of the untreated ones. Therefore, we can assume that infrared laser radiation with a wavelength of 890 nm reduces the incidence with fruit rot during storage /1/.

Studies of the bactericidal properties of pulsed infrared radiation indicate to using this radiation to combat diseases of garden plants. Bactericidal activity is usually associated with UV radiation of the spectral range λ = 0.2-0.3 μm or hard electromagnetic radiation (x-ray γ-rays), which are widely used in biology and medicine to sterilize objects. It is generally accepted that long-wavelength optical radiation (λ> 0.3 μm), as a rule, does not inhibit the growth of microorganisms, except cells sensitized by coloring pigments.

V.G. Loktev and other researchers showed that in terms of bacterial inactivation efficiency, pulsed light radiation is comparable to bactericidal UV radiation, while the dose of bactericidal UV radiation being required to inactivate Bakillus Subtilis bacteria by three orders of magnitude is 22 mJ / cm2. In experiments with color filters there has been detected no dependence of inactivation on the spectrum of the active radiation.

The irradiator (Figure 6) was made in the form of a semicylindrical cavity with reflective walls containing a pulsed lamp of the IFL-120 type.

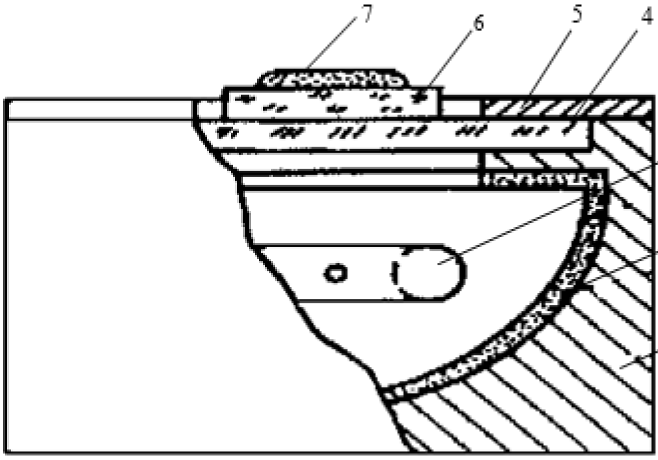

Figure 6 – The design of the irradiator

The radiation of the lamp exited through the window (12x36 mm) blocked by a replaceable 40x40 mm optical filter (BS12 glass of a certain type or SZS25, KS19, IKS5 colored glasses of a specific modification). The dose was increased by the number of pulses. To carry out our research, there have been selected spores of hay bacillus bacteria *Bakillus Subtilis* and *Bakillus Licheniformis*, which have increased resistance to bactericidal UV radiation and high temperatures, were selected.

Based on the calculation, there have been received the dose characteristics of the inactivation of the studied microorganisms.

The results are shown in Figure 7 in the form of the dependences $lg(N_D/N_0)=f(D)$. The figure shows that the number of viable bacteria decreases 400–1000 times after one pulse with D>10 mJ /cm^2, that is, in terms of bacterial inactivation efficiency, pulsed light radiation is comparable to bactericidal UV radiation. The dose of bactericidal UV radiation necessary for the inactivation of bacteria *Bakillus subtilis* by three orders of magnitude is 22 mJ/ cm^2. In experiments with color filters there has been detected no dependence of inactivation on the spectrum of the active radiation.

Thus, the results of the work show a high bactericidal efficiency of pulsed radiation in the visible and infrared ranges and can be used to create high-speed disinfection and sterilization units.

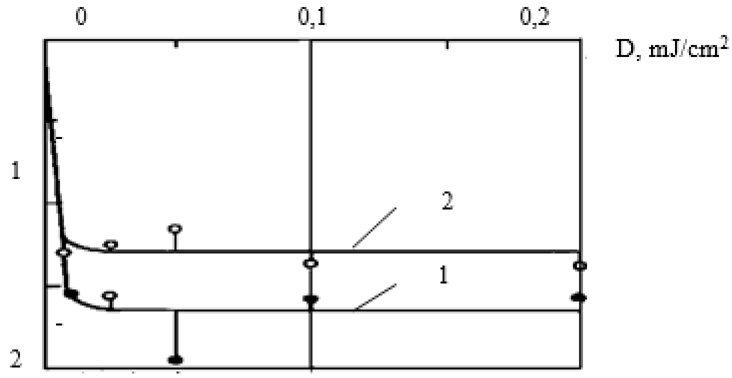

Figure 7 – Dose characteristics of bacterial inactivation

In this regard, there have been conducted studies to determine the bactericidal effectiveness of pulsed radiation in the visible and infrared ranges to combat scab and powdery mildew in garden plants /2/.

The microorganisms of scab and powdery mildew belong to cumulative photobiological receptors, therefore bactericidal efficiency should be proportional to the product of irradiation by time, i.e. it should be determined by exposure. A quantitative assessment of the bactericidal action J_{bc} is characterized by the damaged surface area from the sample of one hundred apples.

The dependence of bactericidal efficiency J_{bc} on exposure of radiation H_{bc} can be expressed using an equation that reflects the well-known Weber-Fechner law, which establishes a relationship between the physical effect on a biological object and its reaction /4,5/:

$$J_{bc} = (a \ln Hbc + b), \quad \% \tag{1}$$

where *a* and *b* are the coefficients determined empirically.

An experiment determined the area of damaging surface from a sample of one hundred apples from each tree of the experimental plot depending on the exposure to radiation, which is directly proportional to the daily number of impulsive flares of IFL-120.

The obtained equations correspond to the Weber-Fechner law for scab (2) and powdery mildew (3).

$$Z^{n} = -18{,}11\ln(Y) + 115{,}39; \tag{2}$$

$$Z^{p.m.} = -239{,}2\ln(Y) + 1504{,}4 \tag{3}$$

The approximation confidence value for expression (2) R^2=0,76 and for expression (3) R^2=0,78.
The resulting dependencies (2) and (3) are transformed to the form:

$$Y = \exp\left[\frac{115{,}39 - Z^{n}}{18{,}11}\right]; \tag{4}$$

$$Y = \exp\left[\frac{1504{,}4 - Z^{p.m.}}{239{,}2}\right]. \tag{5}$$

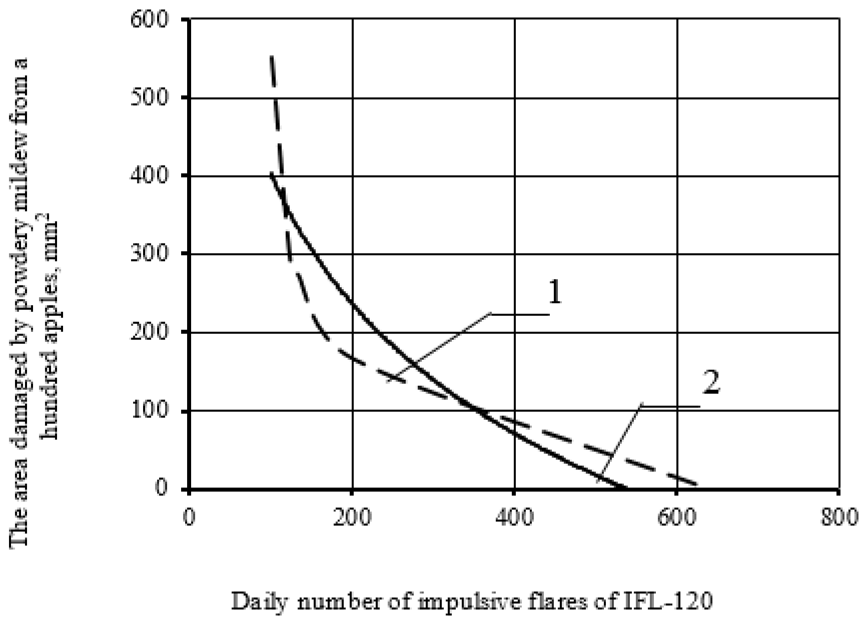

Figure 8 – Dependence of the area damaged by the scab from the sample of a hundred apples on the daily number of impulsive flares of IFL-120 (*1* – experimental dependence, *2* – trend line)

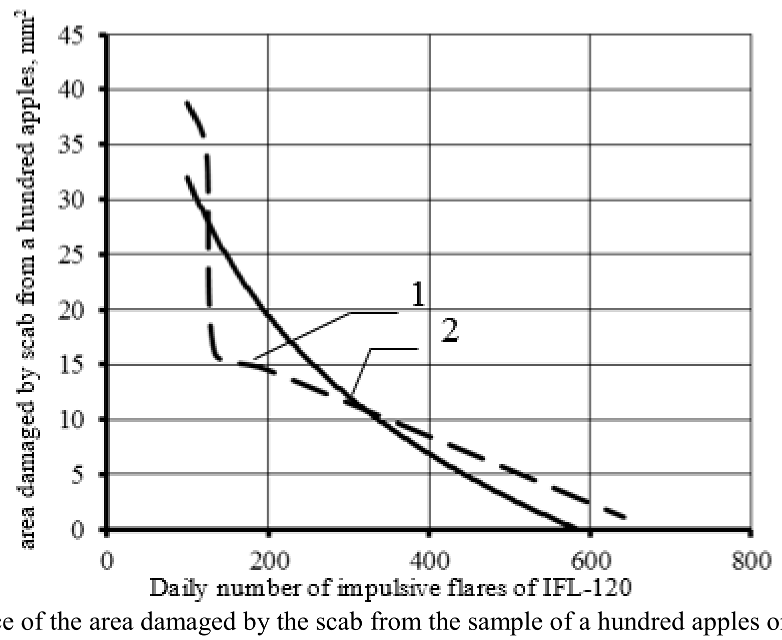

Figure 9 – Dependence of the area damaged by the scab from the sample of a hundred apples on the daily number of impulsive flares of IFL-120 (*1* – experimental dependence, *2* – trend line)

Expressions (4) and (5) make it possible to determine the required daily number of impulsive flares of IFL-120 /2/ for the required damage level of the apple tree fruits with diseases.

4. Conclusion

An analysis of the methods of garden plant protection against pests and diseases allows to speak about the prospects of using electrophysical plant protection equipment, in particular electro-optical installations.

The greatest efficiency of applying electro-optical installations in the garden plant protection system against pests is achieved with the combined use of installations that have a positive and negative phototaxic effect. This will improve the quality of protective measures.

The use of electro-optical converters, incorporating sources of pulsed infrared radiation, can significantly reduce the infection of garden plants with diseases.

Conflict of Interest

None declared.

Конфликт интересов

Не указан.

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