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# Current Strategies in Pest Control Using Biological Agents

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**Abstract**

Agricultural pests are defined as animals that cause damage and death to crop plants. In recent decades, there has been an increase in the number of pests, including aphids, beetles and locusts, resulting in significant crop losses. Consequently, contemporary agriculture is increasingly reliant on efficacious and secure crop protection products. While various methods of pest control exist, both chemical and biological, it is the former that is more commonly used in practice. These chemical insecticides can exist in a variety of aggregate states (liquid or solid) and are both fast-acting and affordable. However, their significant disadvantage is their ability to accumulate in plants, which can negatively affect the health of consumers.
Consequently, there has been a surge in the development of biological plant protection products, which exhibit a milder and safer action profile. One such agent is a bacterial insecticide based on Bacillus thuringiensis (Bt). This microorganism was first isolated by Berliner in 1915 from dead caterpillars of the miller's fireweed. Subsequent research revealed that the Bt exotoxin (phospholipase C) is responsible for the death of insects, and that its endotoxin, initially non-toxic, is activated in the digestive tract of insects by the action of alkaline proteases and transformed into an active toxin.
Bt insecticides are selective and effective against various pests such as caterpillars, mosquitoes and midges. Due to their targeted activity and environmental safety, Bacillus thuringiensis-based formulations are widely used in biological plant protection. Subsequent reports will address contemporary methodologies for pest management that exhibit high efficiency while causing minimal harm to the environment and human health.

***Keywords***: Insecticides, Microorganism, Toxins.

## Introduction

The widespread increase in agricultural pests in recent decades poses a serious threat to global food supply and sustainable agriculture. Currently, agriculture faces a number of pressing challenges, one of which is to maintain crop yields while ensuring environmental and food security. One of the key factors negatively affecting the productivity of agrocenoses remains pests - insects, mites, nematodes and other organisms that can cause large yield losses and reduce the quality of products. According to the UN Food and Agriculture Organisation (FAO), up to 20-40% of the world's yield is lost annually due to pests, which makes pest control a strategically important task. For many decades, chemical pesticides have been the main method of pest control. Due to their rapid action, wide spectrum of activity and relative ease of application, they have provided stable crop protection under conditions of intensive agriculture.
However, the widespread use of synthetic insecticides has led to a number of serious consequences: establishment of resistant pest populations, destruction of natural ecosystems, death of non-target organisms (including pollinators and natural enemies of pests), contamination of soil and water bodies, and potential threats to human health. These circumstances have necessitated a review of existing approaches to plant protection. With the growing interest in ecologically sound and sustainable agriculture, biological pest control methods are receiving increasing attention. Biological agents are organisms or substances of biological origin that are used to suppress pest populations.
These include bacteria (e.g. Bacillus thuringiensis), entomopathogenic fungi (Beauveria bassiana, Metarhizium anisopliae), viruses (nucleopolyhedroviruses, granuloviruses), parasitoids (trichogramma, horseflies), and predatory insects and mites. The use of such agents provides targeted pest control with minimal impact on the environment and non-target organisms. Biological control can be carried out in various ways: through introduction and acclimatisation of natural enemies, conservation and stimulation of their populations in agrocenoses, as well as the use of biopreparations based on living organisms or their metabolites. Modern biotechnological achievements, including genetic engineering approaches, contribute to the expansion of the arsenal of biological plant protection products and increase their efficiency [1].

The aim of this article is to provide a comprehensive overview of current biological pest management strategies, advantages and limitations. Special attention is given to innovative developments in microbiological preparations, integrated crop protection and the prospects for sustainable agriculture with minimal use of chemicals. The relevance of the topic is due to the need to transition to ecologically balanced farming systems that meet the challenges of climate change, biodiversity and human health. A comprehensive review of modern biological pest management strategies

**Modern approaches to biological pest control represent a multilevel system of measures aimed at reducing the number of pests by means of natural enemies or products of their vital activity.**

Biological strategies can be conditionally classified into three main directions: classical (introduction), conservation and applied (or augmentative) biological control. Each of these directions has its own goals, methods of application and area of greatest effectiveness [2].

***Classical biological control***

The classical strategy consists in the introduction (introduction) of exotic natural enemies of pests into new habitats where the latter lack natural population regulators. It is most effective in controlling invasive pest species. A successful example is the introduction of Encarsia formosa to control whitefly in greenhouse farms. The main advantage of the method is its long-term effect after a single infestation of the enemy, but the effectiveness depends on the degree of adaptation of the biological agent to the new biotope.

***Conservation biological control***

A conservation strategy aims to preserve and stimulate populations of natural enemies of pests already existing in the agrocenosis. This may include creating favorable habitat for entomophagy, reducing the use of chemical insecticides, ensuring the availability of alternative food sources (e.g. nectar-bearing plants) and conserving landscape diversity. Such measures have proven effective in integrated plant protection systems and contribute to restoring ecological balance in agroecosystems.

***Applied (augmentative) biological warfare***

The applied strategy consists of mass multiplication of biological agents in laboratory conditions and their subsequent release into the environment. Depending on the objective, inoculative (single release at early stages of infestation) and inundate (mass release at high pest levels) approaches are distinguished. Trichogramma (parasitic webworms) are widely used to control scale pests, as well as entomopathogenic fungi, bacteria and viruses. A significant achievement in recent years is the commercial production of Bacillus thuringiensis (Bt)-based biopreparations with narrow specificity, environmental safety and proven efficacy against a number of insects [3].

***Microbiological and viral preparations***

Microbiological plant protection agents based on the action of bacteria, fungi and viruses have become increasingly important in the structure of biological protection in recent years. Preparations based on Bacillus thuringiensis are effective in controlling larvae of scales and bivalves. Viral agents such as nucleopolyhedroviruses (NPVs) are used to control caterpillars of pest moths, demonstrating high specificity and safety. The development of preparations based on symbiotic nematodes in combination with bacteria of the genus Xenorhabdus and Photorhabdus is underway, which expands the possibilities of point control of soil pests [6].

***Genetic engineering and biotechnology***

A significant contribution to biological defence comes from the use of genetically modified organisms. The best known are transgenic plants expressing Bt-toxins that are resistant to a number of pests. Although the use of such crops is a matter of scientific and public debate, they have already proven effective in reducing the use of chemical insecticides, especially in cotton and maize production [3].

***Integrated strategies and sustainable agriculture***

The most promising approach is Integrated Pest Management (IPM), which combines biological methods with agronomic, breeding and, where necessary, limited use of chemicals. This approach allows achieving high control efficiency while maintaining ecological sustainability and reducing environmental impact. IPM requires systematic monitoring of pest populations, predicting outbreaks and adapting strategies to current conditions.

***Advantages and limitations of modern biological pest control strategies***

Modern biological pest control methods are considered as an important alternative to chemical pesticides in the transition to sustainable agriculture [4]. However, despite the obvious advantages, biological control is not a universal solution and has its limitations that need to be taken into account when designing and implementing plant protection systems.
*Advantages: E*nvironmental safety. Biological agents are generally highly specific and do not adversely affect non-target organisms, including beneficial insects (pollinators, entomophages), animals and humans. This makes them

attractive in programs to protect biodiversity and reduce anthropogenic pressure on ecosystems. The lack of resistance in pests (if applied correctly) is also an important factor.

Unlike chemical insecticides, to which pests quickly develop resistance, biological agents - especially in integrated strategies - create more complex selection pressures that reduce the likelihood of resistance [5]. Compatibility with organic farming.

Biological products and methods based on the use of living organisms are authorized in most organic certification systems (e.g. EU, USDA Organic), making them indispensable in organic agro-technologies. Selectivity of action. Most biological agents affect only certain groups of pests, thus preserving beneficial fauna and natural population regulators in agrocenoses. Reduction of residues in products. Biological preparations do not accumulate in plants and the environment, which improves the quality and safety of agricultural products, reduces health risks for consumers and facilitates export to countries with strict phytosanitary requirements.

*Limitations:* Slow and condition-dependent action.

Unlike chemical insecticides, biological agents often act more slowly, especially under unfavorable weather conditions (high temperature, drought, UV radiation), which can be critical when pest populations increase dramatically. High specificity.

While specificity is an advantage, it also limits the use of a single product against different pest species. This requires accurate diagnosis of the problem and often more complex logistics in application. Storage and transport difficulties.

Many biologics (especially live crops) are sensitive to storage conditions (temperature, humidity), which limits their shelf life and requires strict adherence to transport conditions. The need for an integrated approach and monitoring.

To achieve high efficiency of biological control, a systematic approach is required: monitoring pest numbers, forecasting outbreaks, understanding the biology of the enemy and the agent. This requires qualified personnel and scientific support [7]. Limited number of registered drugs.

In some countries and regions, the market for biological defense products is underdeveloped. There are fewer registered effective and available preparations than chemical analogues, which restrains the widespread adoption of bio methods. Development and implementation costs.

The development and commercialization of new biological agents requires significant investment in research, laboratory production and field trials, which can stifle innovation in this area [8]. Despite some limitations, biological pest management represents an important part of a sustainable and ecologically oriented agricultural system. Given the global challenges - climate change, soil degradation, increasing pest resistance to chemicals - biological strategies are becoming increasingly important. The introduction of integrated plant protection systems combining biological, agronomic and, if necessary, chemical measures is the most rational way to a sustainable and environmentally friendly agriculture of the future [9].

**Innovative development of microbiological preparations in the system of integrated plant protection as a basis for sustainable farming with minimal use of chemical agents**

Sustainable farming in modern conditions requires transition from intensive use of chemical means of plant protection to more environmentally friendly and safe technologies. One of the key directions of such transition is the development and introduction of microbiological preparations in the system of integrated plant protection. These preparations are based on the use of natural microorganisms - bacteria, fungi, actinomycetes and viruses, which have the ability to suppress phytopathogens, stimulate plant growth, improve soil structure and enhance crop immunity [10]. Innovative new-generation biopreparations are developed taking into account specific agroecological conditions, biological compatibility with crops and effectiveness against certain pests. The most widely used strains are Bacillus subtilis, Pseudomonas fluorescens, Trichoderma harzianum, Metarhizium anisopliae and others.

Thanks to the development of biotechnology, forms of preparations with prolonged action, resistance to temperature fluctuations and UV radiation are created, which increases their practical value. Integration of such preparations into the plant protection system makes it possible to significantly reduce or completely replace chemical fungicides, insecticides and nematicides. This, in turn, reduces environmental pollution, preserves useful soil microflora, improves the quality of agricultural products and contributes to the restoration of the natural balance. The use of microbiological means and requires a systematic approach: monitoring of pathogens, selection of optimal time of treatment, crop rotation and combination with other methods of protection. Thus, innovative microbiological developments are becoming an integral part of biologisation of agriculture and the basis for sustainable, environmentally oriented agricultural production [11].

**Conclusion**

Modern strategies of plant pest protection are increasingly oriented towards environmentally safe and sustainable approaches, among which biological control occupies a special place. In contrast to the traditional use of chemical insecticides, biological methods are based on the use of living organisms - entomophages, pathogenic microorganisms (viruses, bacteria, fungi), as well as natural regulators - pheromones and plant extracts. Biological means not only provide effective suppression of pests, but also contribute to the preservation of ecological balance in the agro-ecosystem.

One of the key advantages of these methods is the lack of resistance in pests when properly applied, making biological defence a sustainable tool in the long term. Modern biosecurity strategies involve the integration of different approaches: release and conservation of populations of beneficial insects, use of microbiological preparations (based on Bacillus thuringiensis, Metarhizium anisopliae, Beauveria bassiana, etc.), use of pheromone traps and attractants for pest monitoring and management. The development of technologies for mass production of entomophages and biopreparations, as well as precise planning of their application using modern digital platforms, also plays an important role. With global climate change and increasing pest resistance to chemistry, biologicals are becoming an integral part of integrated crop protection strategies. Their use in combination with agronomic measures and modern monitoring systems opens the way to sustainable and environmentally friendly agriculture of the future.

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