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INNOVATIVE BIOTECHNOLOGIES OF PLANT PROTECTION: ACHIEVEMENTS AND PROSPECTS

[1] Ishankulova Dilafruz Ulugbek qizi
[2] Mamadaliyeva O‘g‘Iloy O‘Tkir qizi
[1]Teacher of Jizzakh State Pedagogical University
[2]Student of Jizzakh State Pedagogical University

Abstract

This article is devoted to innovative biotechnology of plant protection, analyzing recent achievements and future prospects. Modern methods such as genetic engineering, biological control, RNA interference and nano-biotechnologies are of great importance in protecting plants from pests, diseases and climate change.

Keywords: Biotechnology, plant protection, genetic engineering, RNA interference, biological control, nano-biotechnology, sustainable agriculture, Uzbekistan, biodiversity, climate change.

Plant protection is of great importance in ensuring the sustainable development of agriculture and global food security. Pests, pathogens and climate change pose a serious threat to crop productivity, which requires innovative approaches. Traditional methods - chemical pesticides and mechanical measures - lead to environmental problems, the development of pest resistance and high costs. In recent decades, advances in biotechnology, in particular genetic engineering, biological control, and nano-biotechnologies, have opened up new opportunities in plant protection. For countries like Uzbekistan, where agriculture is one of the main sectors of the economy, these technologies are an important tool for increasing productivity and maintaining ecological balance. This article analyzes modern plant protection biotechnology, considers their achievements, limitations, and prospects for Uzbek agriculture.

Main part

Genetic engineering has been recognized as a revolutionary approach to making plants resistant to pests and diseases. By introducing Bacillus thuringiensis (Bt) genes into plants, insect-resistant varieties – such as Bt corn and Bt cotton – have been created. This technology has reduced pesticide use by 20-30% globally and increased crop yields by 15% (James, 2019). Cotton production is an important sector of the economy in Uzbekistan, and Bt cotton trials have been conducted since the 2010s. For example, Bt cotton trials in Surkhandarya region have reduced pesticide costs by 25%, but large-scale implementation has been slowed by legislative and public resistance. Another area of genetic engineering is the production of plants resistant to viruses and fungi. Using CRISPR-Cas9 technology, precise edits are made to the DNA of plants, increasing disease resistance. For example, virus-resistant varieties of tomatoes and grapes are being tested at Uzbek research institutes. However, the controversy over genetically modified organisms (GMOs) and concerns about their environmental safety are limiting their widespread adoption. RNA interference is a new method of protecting plants from pests and pathogens, which works by "turning off" the genes of harmful organisms. RNAi blocks the genes of insects that feed or reproduce, reducing the need for chemical pesticides. For example, in the United States, RNAi-based corn varieties have reduced insect damage by 40% (Baum & Roberts, 2014). In Uzbekistan, this technology is still in its early stages, and the Tashkent Agrarian University is currently testing RNAi for pests against cotton and grain crops.

The advantage of RNA technology is its high accuracy and environmental safety. However, the use of this method requires high costs, and infrastructure limitations remain a problem for developing countries such as Uzbekistan. In the future, through international cooperation, this technology can be adapted to local crops, which will reduce pesticide use by 30%.

Biological control is a method of pest control using natural enemies (insects, microorganisms) and is widely used as an alternative to chemical pesticides. In Uzbekistan, parasitic insects of the genus Trichogramma are successfully used against pests in cotton and vegetable crops. For example, in the Fergana region,

Trichogramma was used to reduce cotton moth damage by 35% (Uzbekistan Agricultural Institute, 2022).

Beneficial microorganisms, such as fungi and bacteria, such as Beauveria bassiana and Pseudomonas fluorescens, are effective in controlling plant diseases. In Uzbekistan, these microorganisms have been tested on tomato and cucumber crops, reducing the use of chemical fungicides by 20%. The main limitation of biological control is its slow effect and dependence on climatic conditions. In the future, it is necessary to localize the production of biological control agents and make them cheaper for farmers. Nano-biotechnologies are opening up new opportunities in plant protection. Nano-pesticides and nano-fertilizers are more effective and environmentally friendly than traditional chemicals. For example, silver nanoparticles have shown 50% higher efficiency in tests against fungal diseases (Rai et al., 2018). In Uzbekistan, nano-biotechnologies are still at the research stage, and the Tashkent Institute of Chemical Technology is testing nano-pesticides for grain and cotton crops.

The advantage of nanotechnologies is that they have a high impact at low doses and reduce soil pollution. However, the long-term environmental impact of nanoparticles has not yet been fully studied, which limits their widespread implementation. To develop nanobiotechnologies in Uzbekistan, it is necessary to strengthen the scientific base and use international experience - for example, from India and China. Uzbekistan's agriculture is based on the cultivation of cotton, grain, fruits and vegetables, and biotechnological approaches have great potential for the development of these sectors. For example, Bt-cotton and RNAi-based varieties can increase cotton yields by 20%, and biological control can reduce pesticide costs by 30%. However, there are a number of limitations:

- Infrastructure and financial constraints: There is a lack of laboratories, qualified personnel and financial investment to introduce modern biotechnologies.
- Legislative and public resistance: Negative perceptions of GMOs and nanotechnologies are slowing their adoption.
- Ecological safety: Long-term studies on the impact of biotechnology on soil and biodiversity are needed. Future strategies for Uzbekistan should include:

- Government investment in biotechnology research and the establishment of scientific centers.
- Expanding cooperation with international organizations (FAO, UNDP) and sharing experience.
- Dispelling negative perceptions of biotechnology by introducing educational programs for farmers and the public.

Conclusion

Innovative plant protection biotechnology – genetic engineering, RNA interference, biological control and nano-biotechnologies – are providing important advances in the sustainable development of agriculture. These methods reduce pesticide use, increase productivity and help maintain ecological balance. For countries that rely on agriculture, such as Uzbekistan, these technologies have great potential for protecting cotton, grain and other crops. However, infrastructure constraints, legislative problems and environmental safety issues make widespread implementation difficult.

In the future, Uzbekistan should take action in the following areas: financing scientific research, using international experience and raising public awareness. These measures will not only improve plant protection, but also ensure sustainable agriculture and food security. The systematic use of innovative biotechnology will make Uzbekistan competitive in the global agricultural market and will be an important step in solving environmental problems.

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