Available online at
http://currentagriculturetrends.vitalbiotech.org/

ISSN (E): 2583 – 1933

Curr. Agri.Tren.:e- Newsletter, (2026) 5(1), 16-18

Current Agriculture Trends: *e-Newsletter*

Article ID: 532

Biological Pest Control Methods: An Integrated Approach

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Article History
Received: 25. 12.2025
Revised: 30. 12.2025
Accepted: 4. 1.2026

INTRODUCTION

Pest infestation is a significant barrier to agricultural productivity worldwide, resulting in considerable yield and quality losses in field crops, horticultural crops, and stored products. Conventional pest management practices have relied heavily on synthetic chemical pesticides because of their quick effectiveness and ease of use. However, long-term dependence on these chemicals has led to serious issues such as pest resistance, the rise of secondary pests, destruction of beneficial organisms, soil and water contamination, and negative effects on human and animal health.

In response to these challenges, biological pest control has emerged as a sustainable alternative that uses living organisms to keep pest populations below economic thresholds. Integrating biological control with other compatible pest management practices forms the backbone of modern IPM strategies. This approach balances agricultural productivity with the goals of environmental protection and food safety.

2. Principles of Biological Pest Control

Biological pest control is grounded in basic ecological principles that stress maintaining a natural balance between pests and their natural enemies in agro-ecosystems. Key principles include:

- ✓ Using naturally occurring beneficial organisms to control pest populations
- ✓ Protecting and enhancing existing natural enemies through habitat management
- ✓ Reducing pesticide use, especially broad-spectrum chemicals that harm beneficial species
- ✓ Promoting biodiversity and ecological interactions to maintain agro-ecosystem stability

These principles support sustainable pest control rather than complete pest eradication, thereby minimizing environmental disturbance.

3. Types of Biological Pest Control Methods

3.1 Predators

Predators are free-living organisms that eat multiple prey during their lifetime, making them effective in reducing pest populations. They are especially useful for controlling outbreaks of soft-bodied insects.

Common examples include:

- ✓ Ladybird beetles (*Coccinella* spp.) that feed on aphids, mealybugs, and scale insects
- ✓ Green lacewings (*Chrysoperla* spp.), whose larvae hunt aphids, thrips, and whiteflies
- ✓ Spiders and predatory mites that manage a wide range of insect pests and mites

Predators play an important role in both open-field and protected cultivation systems.

3.2 Parasitoids

Parasitoids are insects that develop in or on a host insect, ultimately killing it. They are highly specific to their hosts and effective at controlling pest populations.

Notable parasitoids include:

- ✓ Trichogramma spp., egg parasitoids targeting lepidopteran pests in crops like sugarcane, cotton, and vegetables
- ✓ Braconid and Ichneumonid wasps, which parasitize caterpillars and borers

Parasitoids are important for long-term pest control programs.

3.3 Pathogens (Microbial Control)

Microbial control agents include bacteria, fungi, viruses, and protozoa that cause diseases in insect pests. These agents are specific and safe for the environment.

Key microbial agents include:

- ✓ *Bacillus thuringiensis* (Bt) for managing caterpillars, mosquitoes, and beetles
- ✓ Nuclear Polyhedrosis Virus (NPV) for pests like Helicoverpa and Spodoptera
- ✓ Entomopathogenic fungi such as *Beauveria bassiana* and *Metarhizium anisopliae*

Microbial pesticides are widely used in organic and IPM-based farming.

3.4 Botanical and Semiochemical-Based Control

Botanical pesticides and semiochemicals support biological control by lowering pest pressure without harming natural enemies.

Examples include:

- ✓ Neem-based products (azadirachtin), which act as repellents, antifeedants, and growth regulators
- ✓ Sex pheromone traps for pest monitoring, mass trapping, and disrupting mating

These tools improve the effectiveness of biological control within integrated systems.

4. Integrated Approach to Biological Pest Control

4.1 Conservation Biological Control

This method focuses on protecting and enhancing naturally occurring beneficial organisms by limiting pesticide use, maintaining refuges, and planting flowering plants that offer nectar and pollen. Conservation biological control is both cost-effective and environmentally sustainable.

4.2 Augmentative Biological Control

In this approach, beneficial organisms are mass-produced and periodically released into the field to increase natural enemy populations. It is commonly practiced in greenhouses, polyhouses, and high-value crops.

4.3 Classical Biological Control

Classical biological control involves introducing exotic natural enemies to manage invasive pests. This method requires strict quarantine measures and ecological risk assessments to avoid unintended consequences.

5. Integration with Other Pest Management Strategies

Biological pest control is most effective when combined with other IPM components, including:

- ✓ Cultural practices like crop rotation, intercropping, sanitation, and timely sowing
- ✓ Mechanical methods such as hand picking, traps, and barriers
- ✓ Using resistant or tolerant crop varieties
- ✓ Need-based and selective chemical control with biopesticides or safer pesticides

Such integration supports sustainable and long-term pest management.

6. Advantages of Integrated Biological Pest Control

- ✓ Environmentally safe and non-polluting

ISSN (E): 2583 – 1933

- ✓ Reduces pesticide residues in food and the environment
- ✓ Supports biodiversity and beneficial organisms
- ✓ Delays the rise of pest resistance
- ✓ Cost-effective over the long term
- ✓ Well-suited for organic and sustainable farming systems

7. Limitations and Challenges

Despite its benefits, biological pest control has limitations, including slower action compared to chemical pesticides, sensitivity to weather, the need for technical knowledge, and limited accessibility of quality bio-control agents. Increasing farmer awareness and improving infrastructure remain key challenges.

8. Role in Sustainable and Climate-Smart Agriculture

Biological pest control supports climate-smart agriculture by reducing greenhouse gas emissions linked to pesticide production and application. It boosts ecosystem resilience, promotes soil health, and encourages sustainable intensification in agricultural practices.

9. Future Prospects and Way Forward

Future improvements in biotechnology, molecular tools, mass-rearing techniques, and formulation development are expected to increase the effectiveness and adoption of biological pest control. Strengthening extension services, policy support, and combining with digital pest tracking and decision-support systems will enhance its impact further.

CONCLUSION

Biological pest control, when applied through an integrated approach, provides an effective, sustainable, and environmentally friendly solution to pest management challenges in agriculture. Promoting its adoption is crucial for ensuring safe food production, preserving biodiversity, protecting the environment, and achieving long-term agricultural sustainability.

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