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Rise of Biological Control: Why Farmers Are Turning Toward Natural Enemies

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Abstract

Biological control has emerged as a key component of sustainable agriculture as farmers worldwide seek alternatives to synthetic pesticides. Growing concerns over environmental degradation, pest resistance, and market demands for residue-free produce have accelerated the adoption of natural enemies such as predators, parasitoids, and microbial agents. Advances in mass production, application technologies, and ecological research have improved the reliability and scalability of biological control across diverse cropping systems. Supported by government policies, extension programs, and increasing commercial availability, biological control offers a cost-effective and environmentally safe approach to pest management. Although challenges such as variable field performance, knowledge gaps, and supply constraints persist, biological control is becoming an essential tool for resilient, ecologically balanced crop production.

Introduction

Biological control is the use of natural enemies such as predators, parasitoids, and pathogenic microorganisms to suppress agricultural pests, has become an increasingly important pillar of sustainable crop production worldwide. Over the past two decades, the rising environmental, economic, and regulatory costs associated with synthetic pesticides have encouraged farmers to adopt pest-management strategies grounded in ecological principles. Biological control forms the backbone of Integrated Pest Management (IPM), a globally promoted approach that minimises reliance on chemicals while sustaining crop yields (FAO, 2020). As awareness of biodiversity loss, pesticide resistance, and market requirements for residue-free produce intensifies, biological control is gaining momentum as a practical, effective, and long-term solution for farmers.

Drivers Behind the Rise of Biological Control

Environmental Concerns and the Need for Sustainability

Excessive use of synthetic pesticides has been linked to several ecological problems, including the decline of pollinators, contamination of soil and water bodies, and harm to beneficial arthropods. Bale *et al*. (2008) highlighted that chemical pesticides often disrupt natural enemy populations, which leads to secondary pest outbreaks and further increases pesticide dependency. The environmental hazards associated with chemical pest control have prompted stricter regulations globally and strengthened the push toward biological alternatives.

Biological control agents help restore ecological balance by preserving functional biodiversity. For instance, predators and parasitoids regulate pest populations naturally, reducing the need for repeated chemical interventions. According to Cock *et al*. (2016), classical biological control has been one of the most environmentally beneficial pest-management strategies, offering long-term suppression without ecological harm.

Economic Incentives and Market Demand

The global rise in demand for organic and low-residue products has been a major factor driving farmer interest in biological control. Export markets, especially for fruits and vegetables, increasingly impose strict maximum residue limits (MRLs), making chemical-intensive farming risky for producers. Biological control offers a residue-free solution that aligns with consumer and regulatory expectations.

Moreover, biological agents are becoming more cost-effective due to improvements in mass production. The global biocontrol market is expanding at more than twice the growth rate of the synthetic pesticide market, driven by increased adoption by farmers and advances in commercialization (Leung *et al*., 2020). In many cases, biological control also reduces long-term costs by preventing resistance development and minimising repeated pesticide applications.

Technological and Scientific Advances

Rapid technological progress has made biological control more practical and reliable. Improved mass-rearing techniques for parasitoids such as *Trichogramma* spp., drone-based release technologies, and the use of banker-plant systems have helped ensure successful deployment at larger scales (van Lenteren *et al*., 2018). Meanwhile, microbial biopesticides, including Bacillus-based and entomopathogenic fungal formulations, have become easier to store, transport, and apply.

Scientific research has also advanced the understanding of natural enemy ecology, allowing for better integration of biological agents within IPM systems. Conservation biological control—

managing habitats and cropping systems to support naturally occurring enemies—has gained prominence due to its compatibility with smallholder farming systems (Gurr *et al*., 2017).

Examples of Successful Biological Control

Trichogramma Parasitoids in Field Crops

The use of egg parasitoids of the genus *Trichogramma* is one of the most successful examples of augmentative biological control. In Brazil, *Trichogramma pretiosum* releases in maize increased yields by nearly 20% while reducing chemical insecticide use significantly (Figueiredo *et al*., 2015). Similar successes are reported in China and India for rice and cotton, where parasitoid releases have become part of large-scale IPM programs.

Predatory Mites and Ladybird Beetles in Horticulture

In protected cultivation systems, predatory mites (*Phytoseiulus persimilis*, *Amblyseius swirskii*) and ladybird beetles (*Coccinellidae*) are widely used to manage spider mites, whiteflies, and aphids. According to van Lenteren (2012), commercial biological control in greenhouses is adopted in more than 50 countries and covers millions of hectares, showcasing its global applicability.

Microbial Biocontrol Agents

Entomopathogenic fungi such as *Beauveria bassiana* and *Metarhizium anisopliae* have shown strong effectiveness against a variety of pests, including stem borers, fruit flies, and soil-borne insects. Their safety to humans and beneficial insects enhances their appeal to farmers seeking alternatives to chemical pesticides (Vega *et al*., 2009).

Policy and Institutional Support

Government agencies, international organizations, and extension systems play crucial roles in promoting biological control. The FAO and IPPC encourage countries to adopt biological strategies as part of sustainable intensification to address food security and environmental challenges (FAO, 2020). Many nations have developed regulatory pathways that streamline registration of biocontrol products and ensure quality standards.

Public–private partnerships are also growing. For example, national biocontrol programs in India and China support mass production of parasitoids and provide subsidies for biological inputs. These initiatives reduce barriers for farmers and expand access to high-quality agents.

Challenges in Adoption

Despite its advantages, biological control faces certain constraints:

1. Field-level variability: Effectiveness of biological agents may vary with temperature, humidity, and landscape structure (Gurr *et al*., 2017).

2. Lack of awareness and training: Many farmers require hands-on guidance to correctly release and conserve natural enemies.

3. Slow regulatory processes in some regions: Registration of microbial biopesticides and importation of natural enemies can be challenging where regulatory capacity is limited.

4. Supply chain gaps: Consistent and timely availability of biological agents is still a barrier in some developing regions.

Conclusion

Biological control is becoming a cornerstone of modern sustainable agriculture as farmers confront the rising costs and environmental impacts of chemical pesticides. The shift toward natural enemies is supported by ecological benefits, economic incentives, technological progress, and strong institutional backing. While challenges remain in ensuring consistent efficacy, improving supply chains, and expanding farmer training, the trajectory is clear: biological control is no longer an alternative approach but an essential component of resilient farming systems. As markets demand safer and more sustainable produce, and as global agriculture strives to balance productivity with ecosystem health, natural enemies will play an increasingly central role in crop protection strategies worldwide.

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