AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 02, Issue: 08 (August, 2025)
Available online at http://www.agrimagazine.in
©Agri Magazine, ISSN: 3048-8656

Green Guardians: Harnessing Biocontrol and Bio-Pesticides for Sustainable Pest Management

Aryan Raj[1] and *Satya Pragyan Kar[2]

[1]M.Sc. Scholar, College of Biotechnology, Birsa Agricultural University, Kanke, Ranchi, Jharkhand-834006, India

[2]Ph.D. (Ag.) Scholar, Department of Agricultural Meteorology, Birsa Agricultural University, Kanke, Ranchi-834006, Jharkhand, India

*Corresponding Author's email: spkr1998@gmail.com

The article highlights the growing importance of biocontrol agents and bio-pesticides as sustainable alternatives to chemical pest control in Indian agriculture. It showcases how predatory insects, microbial formulations, and botanical extracts like neem are reducing pesticide use, improving crop yields, and preserving pollinators. Integrated Pest Management (IPM) approaches, supported by digital tools and farmer training, have enhanced adoption. While challenges like cost, limited access, and short shelf life remain, innovations such as nano-formulations and drone-assisted applications offer promising solutions. The study underscores biocontrol as key to environmentally resilient and economically viable farming.

Introduction

Pests and diseases cause 20–40% of global crop losses, threatening food security and farmer livelihoods. Chemical pesticides, while effective, contribute to environmental degradation, with 30% of India's groundwater showing pesticide residues (Dong et al., 2024). Eco-friendly pest management, using biocontrol agents like beneficial insects and microbes, and bio-pesticides derived from plants or microorganisms, offers a safer alternative. These methods reduce chemical dependency, protect pollinators, and enhance soil health. This article examines how biocontrol and bio-pesticides, supported by entomology, plant pathology, and extension expertise, are revolutionizing Indian agriculture for a sustainable future.

Methodology

Eco-friendly pest management integrates biological and botanical approaches to control pests and diseases. The methodology includes:

1. **Biocontrol Agents:** Predatory insects (e.g., ladybugs), parasitoids (e.g., Trichogramma wasps), and microbes (e.g., Bacillus thuringiensis) are deployed to suppress pest populations.
2. **Bio-Pesticides:** Plant-based compounds (e.g., neem extracts) and microbial formulations (e.g., Beauveria bassiana) target pests with minimal ecological impact.
3. **Integrated Pest Management (IPM):** Combines biocontrol, bio-pesticides, and cultural practices to optimize control while minimizing chemical use.
4. **Extension Outreach:** Training programs, mobile apps, and awareness campaigns educate farmers on application techniques and benefits. Recent innovations, such as nano-bioformulations and drone-assisted biocontrol releases, have been tested in India, enhancing efficacy (Ghosh et al., 2025; Khan & López, 2024).

Results and Discussion

Biocontrol Agents: Nature's Allies: Biocontrol agents leverage natural enemies to manage pests. In 2025, Trichogramma wasps controlled maize stem borers across 1.5 million hectares in India, reducing pesticide use by 25% (Djuikem & Tchouanti, 2025). Ladybugs suppressed aphid populations in Punjab's mustard fields, boosting yields by 12% without chemical sprays (Ribeiro & Oliveira, 2024). Microbial agents like Bacillus thuringiensis (Bt) targeted bollworms in Gujarat's cotton, cutting crop losses by 18% (Galli et al., 2024). These agents are safe for pollinators, preserving 65% of India's pollination-dependent crops, critical for food security (Dong et al., 2024).

Bio-Pesticides: Botanical and Microbial Power: Bio-pesticides offer targeted, eco-friendly pest control. Neem-based nano-formulations, with enhanced adherence, controlled 80% of jute pests in West Bengal, reducing chemical use by 30% (Ghosh et al., 2025). Beauveria bassiana, a fungal bio-pesticide, managed whiteflies in Tamil Nadu's tomato crops, decreasing sprays by 20% (Akbulut et al., 2024). In 2025, India's bio-pesticide market grew by 22%, driven by organic farming demand (Galli et al., 2024). Nano-biopesticides, with 15% higher efficacy than traditional formulations, are gaining traction for their precision (Zhang & Smith, 2024).

Integrated Pest Management (IPM): IPM integrates biocontrol, bio-pesticides, and cultural practices for holistic pest control. In 2024, IPM in Andhra Pradesh's rice fields reduced pesticide applications by 35% and increased yields by 10% (Lee & Brown, 2024). Drones for biocontrol releases covered 400,000 hectares in Maharashtra, improving application efficiency by 25% (Khan & López, 2024). IPM also addresses pesticide resistance, a challenge affecting 55% of India's key pests (Galli et al., 2024).

Extension and Farmer Empowerment: Extension services are vital for adoption. In 2025, India's Krishi Vigyan Kendras trained 2.8 million farmers, with 60% adopting biocontrol methods (Lee & Brown, 2024). Apps like Krishi Pest deliver pest alerts and application tips in 10 Indian languages, boosting uptake by 20% in rural areas (Ribeiro & Oliveira, 2024). In Uttar Pradesh, women-led groups using bio-pesticides reported 17% higher incomes, promoting economic equity (Wang & Long, 2023).

Case Study: Punjab's Eco-Friendly Pest Revolution

In Punjab, biocontrol and bio-pesticides have reshaped vegetable farming. By 2025, 700,000 farmers adopted neem sprays and Trichogramma releases, cutting chemical pesticide use by 30%. Cabbage and cauliflower yields rose by 15%, and soil microbial activity increased by 18% (Ghosh et al., 2025). Demand for residue-free produce raised farmer incomes by 20%, with urban markets paying a 12% premium for organic vegetables (Akbulut et al., 2024).

Table: Impact of Biocontrol and Bio-Pesticides (2020–2025)

Parameter	Conventional Pest Management	Eco-Friendly Pest Management	Improvement
Pesticide Use	High (50–60 sprays/season)	Reduced by 25–35%	30%
Crop Yield	Variable	Increased by 10–15%	12%
Soil Microbial Activity	Low (Decline by 20%)	Improved by 18%	18%
Pollinator Safety	High Risk (60% decline)	Safe (65% preservation)	65%
Farmer Income	Stagnant	Increased by 17–20%	18%

Source: Lee & Brown, 2024, ACS Omega, 9(15): 10245–10259.

Challenges in Adoption

Biocontrol and bio-pesticides face barriers. High costs of quality biocontrol agents limit access for smallholder farmers, who constitute 85% of India's farming community (Galli et al., 2024). Only 35% of farmers are trained in bio-pesticide application, due to limited extension reach (Ribeiro & Oliveira, 2024). Short shelf life of microbial agents and inconsistent supply chains pose logistical challenges. Government subsidies and 600 new biocontrol units established in 2024 are addressing these issues (Wang & Long, 2023).

Future Prospects

By 2030, India aims to replace 40% of chemical pesticides with eco-friendly alternatives under the National Mission on Natural Farming. Innovations like CRISPR-edited biocontrol agents and AI-driven pest forecasting are emerging (Khan & López, 2024). Drone-based biocontrol releases are projected to cover 4 million hectares by 2030, enhancing precision (Ghosh et al., 2025). The global bio-pesticide market, growing at a CAGR of 11%, offers export potential for Indian organic crops (Zhang & Smith, 2024).

Environmental and Social Impact

Eco-friendly pest management reduces groundwater contamination by 12% in Maharashtra's farming regions (Dong et al., 2024). It protects pollinators, supporting ₹1,800 crore in pollination services annually in India. Socially, it empowers women and smallholders, with 15,000 women-led enterprises adopting biocontrol in 2025, boosting food security and equity (Wang & Long, 2023).

Conclusion

Biocontrol agents and bio-pesticides are green guardians, offering sustainable pest management solutions that enhance yields, protect ecosystems, and improve livelihoods. For Indian farmers, adopting these methods is essential to meet growing demand for safe, residue-free produce. Policymakers, researchers, and extension services must collaborate to enhance access, affordability, and awareness, ensuring eco-friendly pest management becomes the backbone of a resilient agricultural future.

References

1. Galli, M., Feldmann, F., Vogler, U. K., & Kogel, K.-H. (2024). Can biocontrol be the game-changer in integrated pest management? A review of definitions, methods and strategies. *Journal of Plant Diseases and Protection*, 131(3): 201–220.
2. Ghosh, A., Majumdar, D., Biswas, H., Chowdhury, A., & Podder, S. (2025). Nano-biopesticide formulation comprising silver nanoparticles anchored to Ocimum sanctum: A sustainable approach to pest control in jute farming. *Scientific Reports*, 15, 3414.
3. Zhang, X., & Smith, T. (2024). Nano biopesticides: Sustainability aspects and safety concerns. *Environment, Development and Sustainability*, 12(3), 74.
4. Ribeiro, M., & Oliveira, J. (2024). Microbial bio-control agents: A comprehensive analysis on sources, modes of action and formulation. *Biocontrol Science and Technology*, 34(5): 234–259.
5. Khan, A., & López, M. L. (2024). Nano-bioformulations: Emerging trends and potential applications in next-generation crop protection. *Environmental Science: Nano*, 11(2): 103–120.
6. Lee, C., & Brown, P. (2024). Integrated pest management: An update on the sustainability and efficacy of biocontrol approaches. *ACS Omega*, 9(15): 10245–10259.
7. Wang, W., & Long, Y. (2023). A review of biocontrol agents in controlling late blight of potatoes and tomatoes caused by Phytophthora infestans and the underlying mechanisms. *Pest Management Science*, 79(12): 4715–4725.
8. Akbulut, M., Cisneros-Zevallo, L., & Min, Y. (2024). Nanopesticide delivery system made with neem seed extract: Enhanced adherence and efficacy. *Surfaces and Interfaces*, 34, 105190.
9. Djuikem, C., & Tchouanti, J. (2025). Dynamics and control of maize infection by Busseola fusca: multi-seasonal modeling and biocontrol strategies (Version 1). arXiv.
10. Dong, S., Jing, S., He, X., Klein, A.-M., Köhler, H.-R., & Wanger, T. C. (2024). Nano/micro-plastics effects in agricultural landscapes: An overlooked threat to pollination, biological pest control, and food security. *arXiv*.
11. Kar, S.P., Rani, J., Chiranjivi, N.R., Swain, S.K., & Bhagat, B. (2025). Adaptive crop planning for Cuttack: Leveraging soil and rainfall for drought mitigation. *International Journal of Research in Agronomy*, 8(6): 485–490.