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

ISSN (E): 2583 – 1933

Curr. Agri.Tren.:e- Newsletter, (2026) *5*(5), 16-20

Current Agriculture Trends: *e-Newsletter*

Article ID: 630

Drones with a Sting: Releasing Predators to Win the Pest War

D. Prakash[1*], Swadhin Kumar Swain[2], Dhane Ankur Sudam[3], Devdare Sumit Navanath[4] and Saurav Dilip Adhagale[5]

[1]Assistant Professor, Department of Entomology, School of Agricultural Sciences, Sri Manakula Vinayagar Engineering College, Madagadipet, Puducherry

[2]Research Scholar, Department of Nematology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha

[3]Assistant Professor, Department of Entomology, Dr. B. S. Kokan Krishi Vidyapeeth, Dapoli, Maharashtra

[4]Highly Skilled ICAR Dogr Rajgurunagr, Department of Plant Pathology, Mahatma Phule Krishi Vidyapeeth, Rahuri

[5]M.Sc. Scholar, Department of Entomology, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra

Open Access

*Corresponding Author

D. Prakash*

Article History
Received: 1. 5.2026
Revised: 5. 5.2026
Accepted: 10. 5.2026

INTRODUCTION

Agricultural production systems worldwide are under constant pressure from insect pests that reduce crop yield and quality. The Food and Agriculture Organization estimates that pests and diseases account for significant annual losses in global food production. Historically, synthetic pesticides have served as the dominant solution for pest suppression due to their rapid action and ease of application. However, decades of intensive pesticide use have generated serious ecological and economic concerns. Many insect species have evolved resistance to commonly used insecticides, reducing treatment effectiveness and increasing production costs. Pesticide residues also contaminate soil, water and non-target organisms, including pollinators and natural enemies that contribute to ecosystem stability. Human exposure to pesticides further raises concerns regarding occupational safety and public health.

Biological control has gained renewed importance as a sustainable alternative to chemical-intensive pest management. Biological control involves the use of living organisms to suppress pest populations. Predators, parasitoids, entomopathogenic fungi and nematodes have been successfully used in many cropping systems to regulate insect pests naturally. At the same time, technological innovation is reshaping agriculture through automation and digitalization. Unmanned aerial vehicles, commonly known as drones, have become valuable tools in precision agriculture for crop monitoring, pesticide application and field mapping. More recently, drones have been adapted for the release of beneficial insects and biological control agents.

The concept of using drones to distribute natural enemies combines ecological pest management with advanced engineering. Drone-assisted predator release offers precise targeting, rapid deployment and reduced labour demands. This approach is especially valuable in large-scale farming systems where manual release of beneficial organisms may be time-consuming and inefficient.

The Growing Challenge of Agricultural Pests

Agricultural pests continue to threaten food security and economic stability across the world. Insect herbivores damage crops directly through feeding and indirectly by transmitting plant pathogens. Climate change, global trade and monoculture farming practices have intensified pest outbreaks and expanded the geographic distribution of many invasive species. Traditional pesticide-dependent management systems face several limitations. Repeated pesticide applications often disrupt ecological balance by eliminating beneficial insects along with target pests. Secondary pest outbreaks may occur when natural enemy populations are suppressed.

Pesticide resistance has become a major concern in agricultural entomology. Resistant insect populations require higher pesticide doses or alternative chemicals, increasing production costs and environmental risks. The need for environmentally sustainable and economically viable alternatives has accelerated interest in integrated pest management systems that combine biological, cultural and technological approaches.

Principles of Biological Control

- ❖ Biological control relies on ecological interactions between pests and their natural enemies. Natural enemies include predators, parasitoids and pathogens that suppress pest populations through predation, parasitism or infection.
- ❖ Predators consume multiple prey individuals during their lifetime. Common agricultural predators include ladybird beetles, lacewings, predatory mites and spiders.
- ❖ Parasitoids differ from predators because their immature stages develop within or on a single host insect, eventually killing it. Trichogramma wasps are widely used parasitoids that attack the eggs of lepidopteran pests.
- ❖ Entomopathogenic organisms such as fungi, bacteria and nematodes infect and kill insect pests through disease processes.

Biological control strategies are generally classified into three categories:

Table 1: Types of Biological Control Strategies

Strategy	Description	Example
Classical biological control	Introduction of exotic natural enemies	Release of parasitoids against invasive pests
Augmentative biological control	Periodic release of mass reared natural enemies	Trichogramma releases in maize
Conservation biological control	Protection of existing natural enemies	Habitat management for predators

Drone-based release systems primarily support augmentative biological control by enabling large-scale distribution of mass-reared beneficial organisms.

Drone Technology in Agriculture

Drones are remotely operated or autonomous aerial vehicles equipped with sensors, navigation systems and payload mechanisms. Agricultural drones have become increasingly important in precision farming applications. Modern agricultural drones are capable of performing multiple functions, including aerial imaging, crop health monitoring, irrigation

ISSN (E): 2583 – 1933

assessment and pesticide spraying. Advances in battery technology, GPS navigation and automation have improved drone efficiency and reliability.

Drone platforms used for biological control typically include release mechanisms designed to distribute beneficial insects evenly across agricultural fields. These systems may incorporate temperature control, vibration management and programmable release intervals to protect insect survival during flight. Multirotor drones are commonly used due to their manoeuvrability and precise hovering capabilities. Fixed-wing drones may cover larger areas but offer less precise release control.

Drone-Assisted Release of Predatory Insects

The use of drones for releasing predatory insects represents a major advancement in biological control technology. Traditional manual release methods often require extensive labour and may result in uneven distribution of beneficial organisms. Drone systems enable rapid and precise deployment across large agricultural areas. Beneficial insects can be released at predetermined locations and densities based on pest infestation levels and crop conditions. One of the most widely used examples involves the aerial release of Trichogramma parasitoids for controlling caterpillar pests in maize, rice and sugarcane systems. Drones carrying capsules containing parasitized host eggs distribute these biological agents efficiently across fields.

Ladybird beetles, green lacewings and predatory mites have also been released using drone platforms for suppression of aphids, whiteflies and other soft-bodied pests. Drone-based release systems are particularly useful in areas with difficult terrain, tall crops or limited accessibility, where manual release may be challenging.

Figure 1. Drone-assisted release of beneficial insects in agricultural fields for precision biological control and sustainable pest management.

Advantages of Drone-Based Predator Release

Drone-assisted biological control offers several important advantages over conventional methods.

Precision and Efficiency

Drones allow accurate targeting of pest hotspots identified through field monitoring and remote sensing technologies. This precision reduces waste and improves biological control effectiveness.

Reduced Labor Requirements

Manual distribution of beneficial insects across large fields is labour-intensive and time-consuming. Drones significantly reduce labour costs and operational time.

Environmental Sustainability

Unlike chemical pesticides, biological control agents generally pose minimal risks to non-target organisms and ecosystems. Drone-assisted release further reduces pesticide dependency and environmental contamination.

Improved Accessibility

Drones can operate in challenging environments, including flooded rice fields, steep terrain and densely planted crops.

Rapid Deployment

Outbreaks can be addressed quickly through automated release programs, reducing pest population growth before severe crop damage occurs.

Table 2: Comparison Between Conventional Pesticide Application and Drone-Assisted Biological Control

Parameter	Chemical Pesticides	Drone-Assisted Biological Control
Environmental impact	High	Low
Risk of resistance	High	Low
Target specificity	Moderate	High
Effect on beneficial insects	Often harmful	Generally safe
Labor requirement	Moderate	Low
Sustainability	Limited	High

Challenges and Limitations

Despite its promise, drone-based predator release faces several technical and ecological challenges.

Survival of Beneficial Insects

Mechanical vibration, temperature fluctuations and air turbulence during drone flight may affect insect survival and performance. Release systems must be carefully designed to minimize stress on biological agents.

Weather Dependence

Wind speed, rainfall and temperature influence both drone operation and insect activity. Unfavourable weather conditions may reduce release efficiency and biological control success.

Regulatory Constraints

Drone operation is subject to aviation regulations that vary between countries. Licensing, flight restrictions and operational approvals may limit agricultural deployment.

Economic Considerations

Initial investment costs for drone systems and mass rearing facilities may be substantial, particularly for small-scale farmers.

Ecological Risks

Although biological control is generally environmentally friendly, improper release of exotic species may disrupt native ecosystems. Careful risk assessment and ecological monitoring remain essential.

Future Prospects and Innovations

- Emerging technologies are expected to enhance the effectiveness and scalability of drone-assisted biological control.
- Artificial intelligence may improve pest identification and release optimization. Swarm drone technologies could coordinate large-scale operations across extensive agricultural landscapes.
- Advances in insect mass rearing, genetic improvement and formulation technologies may further improve biological control efficiency.
- Nanotechnology and smart sensors may allow real-time monitoring of beneficial insect performance and pest suppression outcomes.
- Policy support, farmer training and interdisciplinary collaboration will be essential for widespread adoption.

CONCLUSION

Drone-assisted release of predators and parasitoids represents a transformative development in sustainable pest management. By combining biological control principles with precision agriculture technologies, drones offer environmentally responsible alternatives to pesticide-intensive farming systems. The integration of unmanned aerial vehicles into pest management programs improves efficiency, reduces labour requirements and enhances ecological sustainability. Although technical, regulatory and economic challenges remain, ongoing advances in robotics, artificial intelligence and biological control science are rapidly expanding the potential of this approach. As agriculture seeks resilient solutions to climate change, pesticide resistance and environmental degradation, drone-based biological control may become a central component of future integrated pest management systems. The convergence of ecology and technology has opened a new frontier in crop protection where drones equipped not with chemicals but with beneficial organisms may help secure sustainable food production for future generations.

REFERENCES

Bale, J. S., Van Lenteren, J. C., & Bigler, F. (2008). Biological control and sustainable food production. *Philosophical Transactions of the Royal Society B: Biological Sciences, 363*(1492), 761–776. https://doi.org/10.1098/rstb.2007.2182

Barratt, B. I. P., Moran, V. C., Bigler, F., & Van Lenteren, J. C. (2018). The status of biological control and recommendations for improving uptake for the future. *BioControl, 63*, 155–167. https://doi.org/10.1007/s10526-017-9831-y

Bhutia, K. L., Bhattacharyya, B., & Dutta, P. (2023). Applications of drones in precision agriculture and pest management. *Journal of Agricultural Engineering, 60*(2), 87–102.

Heimpel, G. E., & Mills, N. J. (2017). *Biological Control Ecology and Applications*. Cambridge University Press.

Huang, Y., Hoffmann, W. C., Lan, Y., Wu, W., & Fritz, B. K. (2009). Development of a spray system for an unmanned aerial vehicle platform. *Applied Engineering in Agriculture, 25*(6), 803–809. https://doi.org/10.13031/2013.29229

Parra, J. R. P. (2010). Egg parasitoids commercialization in the New World. *International Organization for Biological Control Bulletin, 58*, 59–66.

Pilkington, L. J., Messelink, G., Van Lenteren, J. C., & Le Mottee, K. (2010). Protected biological control of biological pest management in the greenhouse industry. *Biological Control, 52*(3), 216–220. https://doi.org/10.1016/j.biocontrol.2009.05.022

Van Lenteren, J. C. (2012). The state of commercial augmentative biological control plenty of natural enemies but a frustrating lack of uptake. *BioControl, 57*, 1–20. https://doi.org/10.1007/s10526-011-9395-1

Zhang, C., & Kovacs, J. M. (2012). The application of small unmanned aerial systems for precision agriculture a review. *Precision Agriculture, 13*(6), 693–712. https://doi.org/10.1007/s11119-012-9274-5