Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 04 (JULY-AUG, 2026)
Available online at http://www.agriarticles.com

How Parasitoids Reduce Farmers' Reliance on Pesticides

*Rahul Nodal[1], Tejpal Tetarwal[1], Pavitra Choudhary[2] and Ravindra Kumar Meena[1]
[1]Dept. of Entomology, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan
[2]Dept. of Entomology, College of Agriculture, Agri. University, Jodhpur, Rajasthan
*Corresponding Author's email: nodalrahul@gmail.com

Chemical pesticides have long been the backbone of pest management in agriculture, but their overuse has triggered a cascade of problems including pest resistance, declining biodiversity, food chain contamination and the collapse of natural pest control systems. Parasitoids, a group of insects that complete their development by feeding on and ultimately killing a host pest, offer a promising biological alternative that can reduce farmer dependence on synthetic chemicals. This article brings together evidence from rice, maize, soybean, mango and stored grain systems to explain how parasitoids suppress pests, under what conditions they work best and what stands in the way of wider adoption. The findings consistently show that broad-spectrum insecticides harm parasitoids far more than most farmers realise, while simple changes such as planting flowering plants along field edges, switching to selective pesticides and releasing commercially reared parasitoids at the right time can substantially cut chemical use without sacrificing yield. Parasitoids are not a silver bullet but when integrated thoughtfully into farming systems, they represent one of the most ecologically sound and economically sensible tools available to modern agriculture.

Keywoeds: *Trichogramma*, Sustainable agriculture, Biological control, Conservation

Introduction

Across farming communities worldwide, a common story continues to unfold. Pests arrive, crops are threatened and the instinctive response is to reach for a chemical spray. This approach makes a certain kind of sense. Pesticides act quickly, they are widely available and their costs are familiar and predictable. For decades they have kept food production moving forward despite relentless pressure from insects, mites and other organisms that see a cultivated field as an open buffet. The trouble is that this convenience has come with a mounting set of consequences that are becoming harder to ignore. Pests evolve resistance to chemicals with remarkable speed, meaning that doses must increase and new formulations must constantly be developed just to maintain the same level of control. Insecticides designed to kill target pests routinely also kill the natural enemies that would otherwise keep pest populations in check, creating a vacuum that often makes outbreaks worse in the long run (Theenoor *et al*., 2024). Residues move through the food chain, turning up in water supplies, in the bodies of non-target animals and in the food that eventually reaches consumers. These are not theoretical concerns. They are well-documented patterns playing out across farming systems on every continent (Minkova *et al*., 2025). Against this backdrop, there is growing interest in working with nature rather than against it. One of the most compelling tools in this effort is a group of organisms that most people have never heard of: parasitoids. Unlike true parasites, which weaken their hosts but generally allow them to survive, parasitoids kill their hosts as part of their normal life cycle. A parasitoid wasp will lay its eggs in or on a pest insect and the developing larvae will consume the pest from within, eventually killing it. The pest dies while the parasitoid reproduces, helping farmers manage pests without relying on chemical sprays. (S *et al*., 2025).

How Parasitoids Naturally Control Crop Pests

Parasitoids belong mostly to the insect orders Hymenoptera. They are extraordinarily diverse. Estimates suggest there may be hundreds of thousands of parasitoids species worldwide and they attack virtually every major group of pest insects across every major crop (Kumaraswamy *et al*., 2024). Their basic biology is elegantly suited to pest control. A female parasitoids locates a host pest, often using chemical cues released by the pest itself or by damaged plant tissue and deposits one or more eggs. Depending on the species, eggs may be laid inside the host body, on its surface or within its eggs. The parasitoids larvae develop by consuming host tissues in a sequence that keeps the host alive just long enough for development to complete, at which point the host dies and adult parasitoids emerge (S *et al*., 2025). Because parasitoids are highly host specific in many cases, they pose minimal risk to non-target organisms compared to broad spectrum insecticides (Bueno *et al*., 2024).

Three broad strategies are used to harness parasitoids in agriculture. Classical biological control involves introducing a parasitoid species from the pest's native region to suppress an invasive pest that arrived without its natural enemies. Conservation biological control focuses on protecting and enhancing populations of parasitoids that are already present in or around fields, by reducing harmful pesticide use and managing the landscape to provide the food and shelter parasitoids need. Augmentative biological control involves mass rearing parasitoids in insectaries and releasing them into fields, either in large inundative releases designed to cause immediate pest knockdown, or in smaller inoculative releases designed to establish populations that will provide control across a season (Kumaraswamy *et al*., 2024). A farmer might reduce insecticide use to conserve resident parasitoids, plant flowering strips to provide adult parasitoids with nectar they need for energy and longevity and also make periodic releases of commercially reared parasitoids during peak pest pressure.

Evidence from Rice Systems

Rice feeds more than half the world's population and it is also one of the crops where evidence for parasitoid-based pest management is richest and most convincing.Fields with flowering bund plants supported larger parasitoids communities, parasitism rates on key rice pests were higher, pest damage was lower and crop yields were maintained at levels comparable to insecticide-treated fields. These finding matters because it suggests that a low-cost habitat modification, requiring no specialised equipment and no ongoing purchase of biological agents, can deliver pest control outcomes that rival chemical treatment while simultaneously reducing the chemical burden on the ecosystem.

The diversity of parasitoids present in rice landscapes is itself a resource that farmers are often unaware of. Surveys in Bangladeshi rice ecosystems have recorded more than 180 parasitoid species attacking rice pests across different growth stages (Ali *et al*., 2019). This community of natural enemies is present whether or not farmers acknowledge it and it is providing a level of pest suppression that is partly invisible precisely because it prevents many outbreaks from ever escalating to visible damage. In many cases, insecticide sprays interrupt a natural pest control service that beneficial insects were already providing at no cost. (Theenoor *et al*., 2024).

Research testing optimized releases of *Trichogramma japonicum*, a small egg parasitoid, into rice found that thoughtfully timed releases allowed insecticide use to be cut by sixty percent while simultaneously improving pest control outcomes, crop yield and net economic return to farmers (Ali *et al*., 2019). This is a striking result because it demonstrates not just that parasitoids can substitute for some pesticide use, but that making this substitution can actually improve performance on every metric that farmers care about.

Evidence from Maize and Soybean Systems

Maize and soybean are among the world's most economically important crops and both face severe pressure from lepidopteran caterpillars, particularly the fall armyworm, which has spread from the Americas across Africa and Asia with devastating effect. Parasitoids have been studied extensively in both crops and the evidence supports their value within integrated management programs (Bueno *et al*., 2024). In Indian maize fields, researchers comparing sprayed and unsprayed plots found that fall armyworm parasitism was actually higher in plots that received no insecticide treatment. Ten species of hymenopteran parasitoids were recorded across egg and larval stages, indicating that a diverse natural enemy community was present and actively attacking the pest (Pal *et al*., 2024). The decline in parasitism after spraying clearly shows that pesticides can interfere with nature's own pest control system, reducing the effectiveness of beneficial parasitoids.

This compatibility offers a practical solution for farmers who are not yet ready to completely replace chemical pesticides but want to reduce their dependence on the most harmful ones. Biopesticides, including microbial products based on the bacterium Bacillus thuringiensis (Bt), can effectively manage pests while causing little or no harm to beneficial insects. Unlike broad-spectrum chemical insecticides, they help preserve natural enemies such as parasitoids and predators, allowing biological control to continue alongside crop protection. In South American soybean and maize systems, parasitoid wasps in the genera *Cotesia* and *Campoletis* have been found consistently across fields and seasons, with larval parasitism averaging around ten percent in soybean and fourteen percent in maize (Bueno *et al*., 2024).

Evidence from Stored Grain and Other Systems

Pest problems do not end when crops leave the field. Stored grain is a major battleground where insects can destroy substantial proportions of harvests, particularly in regions where farmers must store grain on-farm for extended periods before sale. Here too, parasitoids offer tools that can complement or partially replace chemical fumigants. Species such as *Habrobracon hebetor* and *Pteromalus cerealellae* parasitize the larvae and pupae of common grain storage pests. Research has shown that these parasitoids can be used as components of post-harvest IPM programs, reducing grain losses while decreasing dependence on chemical treatments that raise concerns about residues in food (Mbata & Warsi, 2019). The confined environment of a grain store creates challenges for parasitoid deployment that are different from field conditions, but it also offers opportunities for more controlled management of parasitoid populations. Studies examining the parasitoid wasp community in stored grain facilities found that naturally occurring parasitoid communities have meaningful potential as biological control agents within integrated post-harvest management systems (Harush *et al*., 2021).

Why Pesticides Hurt Parasitoids So Much

Understanding the impact of pesticides on parasitoids is essential for designing farming systems that can benefit from both chemical and biological tools simultaneously.Research compiling a decade of data on the sensitivity of *Trichogramma pretiosum* to various pesticides found that adult parasitoids experienced approximately sixty-five percent reductions in parasitism when exposed to tested pesticide compounds (Rakes *et al*., 2020). This is a dramatic effect and it explains why fields that receive frequent insecticide applications often show poor parasitoid activity even when pest pressure might otherwise make them ideal habitat. Adult parasitoids are particularly vulnerable because they forage actively across the crop canopy, moving through the same spaces where pesticide residues are deposited.

The damage to parasitoids is not limited to direct mortality from contact with residues. Sublethal effects include reduced searching behaviour, impaired ability to locate hosts, reduced fecundity, and shortened adult lifespans (Theenoor *et al*., 2024). A parasitoid wasp that survives a pesticide exposure may lay far fewer eggs than it would have otherwise, meaning the impact on the next generation of parasitoids can be severe even when adult mortality appears modest. Different pesticide classes vary considerably in their toxicity to parasitoids and this variation creates opportunities for more selective management. Selective insecticides that are toxic to target pest species but relatively benign to natural enemies do exist and research has shown that choosing these compounds over broad spectrum alternatives can preserve much of the biological control that a diverse parasitoid community provides (Tomé *et al.*, 2024). The challenge is that selective options are not always cheaper than broad spectrum compounds and farmers operating under economic pressure may default to whatever product costs least per unit of pest killed without accounting for the hidden cost of losing natural enemy services.

The Role of Habitat and Landscape

One of the most consistent findings across the parasitoid research literature is that the physical structure of the farming environment matters enormously for parasitoid populations. Parasitoids are not simply passive responders to the crops and pests in a field. They have their own ecological needs that must be met if they are to thrive and provide reliable pest control (Minkova *et al.*, 2025). Adult parasitoid wasps and flies generally require carbohydrate sources such as nectar and honeydew to fuel their flight and extend their active life. A monoculture field lacking flowering plants offers very little food or shelter for parasitoids. As a result, these beneficial insects may leave in search of better resources or survive for a much shorter time. Research has repeatedly found that increasing floral diversity in and around crop fields, whether through maintaining wildflower strips at field edges, allowing weeds to flower in non-crop areas, or deliberately planting nectar-rich species on field margins, increases parasitoid abundance and often increases parasitism rates on crop pests (Ali *et al*., 2019).

The relationship between habitat diversity and biological control is not perfectly linear and it does not always translate into higher yields or greater farm profitability. Some parasitoid species are highly effective in simplified landscapes, suggesting that habitat management recommendations need to be tailored to specific crops, pest systems and regional contexts rather than applied uniformly. Nevertheless, the general principle that more complex and diverse agricultural landscapes support more robust populations of natural enemies, including parasitoids, is well supported across many studies and farming systems (Langer & Jensen, 2023).

Implications for Farmers and Policy

The evidence shows that farmers can benefit from parasitoids by adopting more sustainable pest management practices. Reducing unnecessary insecticide applications and spraying only when pests exceed the economic threshold level (ETL) helps conserve beneficial parasitoids while lowering production costs. When chemical control is necessary, selective insecticides and biopesticides should be preferred because they are less harmful to natural enemies. Maintaining flowering field margins, hedgerows, and other non-crop vegetation provides food and shelter for parasitoids, strengthening natural pest control. Governments and extension agencies can further support farmers through training, improved pesticide labeling, incentives for habitat conservation, and greater availability of mass-reared parasitoids for biological control. Promoting these practices in terms of both economic savings and environmental benefits will encourage wider adoption of sustainable pest management strategies.

Conclusion

Parasitoids are among nature's most effective allies in the fight against crop pests. By naturally suppressing pest populations, they help farmers reduce pesticide use, lower production costs, and protect the environment without compromising crop productivity. Research from a wide range of cropping systems shows that simple practices such as avoiding unnecessary insecticide sprays, using selective or biological pesticides, and conserving flowering habitats can greatly enhance the activity of these beneficial insects. While parasitoids are not a complete replacement for pesticides, they are an essential component of integrated pest management (IPM). By working with nature rather than against it, farmers can build more resilient, profitable, and sustainable farming systems for the future.

References

1. Ali, M. P., Bari, M., Haque, S., Kabir, M. M. M., Afrin, S., Nowrin, F., Islam, M. S., & Landis, D. (2019). Establishing next-generation pest control services in rice fields: eco-agriculture. *Scientific Reports, 9*.
2. Bueno, A., Sutil, W. P., Cingolani, M. F., & Colmenárez, Y. (2024). Using egg parasitoids to manage caterpillars in soybean and maize: Benefits, challenges, and major recommendations. *Insects, 15*.
3. Harush, A., Quinn, E., Trostanetsky, A., Rapaport, A., Kostyukovsky, M., & Gottlieb, D. (2021). Integrated pest management for stored grain: Potential natural biological control by a parasitoid wasp community. *Insects, 12*.
4. Kumaraswamy, S., Sindhura, K., Radhika, D. H., & Damodaram, K. (2024). Parasitoids as biocontrol agents in India. *Current Opinion in Insect Science, 101282*.
5. Langer, V., & Jensen, S. M. (2023). Parasitoids of the cabbage seed weevil deliver high and consistent parasitism in variable landscapes: A showcase of conservation biocontrol. *Pest Management Science*.
6. Mbata, G., & Warsi, S. (2019). *Habrobracon hebetor* and *Pteromalus cerealellae* as tools in post-harvest integrated pest management. *Insects, 10*.
7. Minkova, I., Karova, A., & Ilieva-Pencheva, T. (2025). Role of regulating ecosystem services in reducing the use of chemical pesticides. *Agricultural Sciences*.
8. Pal, S., Bhattacharya, S., Dhar, T., Gupta, A., Ghosh, A., Debnath, S., Gangavarapu, N., Pati, P., Chaudhuri, N., Chatterjee, H., Senapati, S., Bhattacharya, P. M., Gathala, M., & Laing, A. (2024). Hymenopteran parasitoid complex and fall armyworm: A case study in eastern India. *Scientific Reports, 14*.
9. Rakes, M., Pasini, R., Morais, M. C., Araújo, M. B., De Bastos Pazini, J., Seidel, E., Bernardi, D., & Grützmacher, A. D. (2020). Pesticide selectivity to the parasitoid *Trichogramma pretiosum*: A pattern 10-year database and its implications for integrated pest management. *Ecotoxicology and Environmental Safety, 208*, 111504.
10. S, M., P., G., V., & R, M. (2025). Egg parasitoids: A promising biocontrol agent in insect pest management. *International Journal of Engineering Science and Advanced Technology*.
11. Theenoor, R., Ghosh, A., & Venkatesan, R. (2024). Harmonizing control: Understanding the complex impact of pesticides on parasitoid wasps for enhanced pest management. *Current Opinion in Insect Science, 101236*.
12. Tomé, M. P., Weber, I. D., Garcia, A., & Godoy, W. A. (2024). Integrating management tactics to mitigate *Spodoptera frugiperda* resistance in Bt corn: Refuge proportions, natural parasitoids, and selective insecticide application. *Pest Management Science*.