GSHJ GLOBAL SOUTH HEALTHCARE JOURNAL
Global South Healthcare Journal
www.gshealthjournal.com

REVIEW ARTICLE
Published : 27 January 2025

Ladybird Beetles: Nature's Allies in Pest Control

Tripti Yadav

Ladybird Research Laboratory, Department of Zoology, University of Lucknow, Lucknow, UP, India

ABSTRACT

Ladybird beetles, known for their vibrant appearance and vital role in pest management, are essential contributors to sustainable agriculture and ecosystem health. This article explores the ecological and agricultural significance of ladybird beetles, focusing on their diverse feeding habits, biocontrol potential, and chemical defenses. The Coccinellidae family, comprising over 6,000 species, includes effective predators of agricultural pests like aphids, mealybugs, and scale insects. These beetles support integrated pest management (IPM) by reducing pesticide reliance and promoting biodiversity. Their alkaloid-based chemical defenses not only protect them from predators but also enhance their value as biocontrol agents. Recent genomic and transcriptomic advancements have provided deeper insights into their predatory behaviours, immune responses, and resilience to environmental stressors. As research continues, ladybird beetles present a promising future for sustainable pest control strategies, with potential applications in minimizing pesticide use and improving crop yields. The article concludes by highlighting the need for continued research to harness the full potential of ladybird beetles in pest management and ecological conservation.

Global South Healthcare Journal, 2025; 1(1).

CORRESPONDING AUTHOR:
Tripti Yadav
Yadav_tripti@lkouniv.ac.in

KEYWORDS:
Agricultural productivity, Biocontrol, Ladybird beetles, Pest control, Sustainability

HOW TO CITE:
Yadav T. Ladybird Beetles: Nature's Allies in Pest Contro. Global South Healthc J. 2025;1(1):29–34

INTRODUCTION

Ladybird beetles, renowned for their vibrant appearance, are among the most beloved insects, deriving their name from *Coccinella septempunctata* Linnaeus (Figure 1). Their scarlet elytral colour resembles the cloak of the Virgin Mary, while the seven black spots symbolize joys and sorrows. Named "beetles" because they belong to the insect order Coleoptera, they captivate humans with their rounded body shape and thick, leathery forewings shielding delicate membranous hindwings. Ladybirds inspire various products and symbolise good luck worldwide. Beyond their aesthetic appeal, these insects are unsung heroes in pest management, offering natural solutions to agricultural and environmental challenges. Through their predation, ladybirds help regulate pest populations, contributing to sustainable farming practices and ecological conservation efforts.

The family Coccinellidae comprises around 360 genera and about 6000 species found worldwide. Coccinellidae is classified within the superfamily Coccinelloidea, distinguished from Cucujoidea by Robertson *et al*.[1] This classification received additional support from a recent phylogenetic study of beetles (Coleoptera) conducted by Zhang *et al*.[2], which analysed 95 protein-coding genes across 373 beetle species. Many of the members are recognized as effective predators of agricultural pests, such as aphids, whiteflies, and scale insects, however, certain members of the family exhibit plant-feeding (phytophagous) and fungus-feeding (mycophagous) behaviours.

Besides being an active predator of different pest species, ladybird beetles also play vital roles in ecosystems through provisioning, regulation, maintenance, and cultural services. They provide provisioning services through their diverse biological activities, such as the multifunctional properties of alkaloids. Also, ladybirds contribute to regulation and maintenance services by controlling pests and aiding pollination efforts. Their efficient predation habits have positioned them as invaluable allies for farmers seeking sustainable alternatives to chemical pesticides. However, misconceptions sometimes lead to inadvertent harm when ladybird larvae are mistaken for pests and subjected to chemical treatments. Various biological control strategies, such as manipulative, augmentative, and classical approaches, utilize the predatory abilities of ladybugs to effectively manage pest populations. Ladybirds undergo a holometabolous life cycle, progressing from eggs to larvae through four stages before pupating and emerging as adults. Dixon[3] distinguished two main groups of ladybirds *i.e.*, Aphidophagous and Coccidophagous. Despite variations, both groups follow the same larval instar pattern, except for certain coccidophagous species with three instars instead of four. Dixon[3] pointed out the behavioural differences between these trophic groups: aphid feeders develop faster, age faster, move faster, are typically larger, and lay eggs in clusters, whereas scale insect feeders develop more slowly, live longer, move more slowly, are smaller, and lay eggs singly. Moreover, ladybirds exhibit multiple generations annually, with reproduction slowing or ceasing during cooler winter months when adults may hibernate.

Ladybirds exhibit diverse feeding habits, categorized into several trophic groups based on their prey preferences.[4] Pest species, such as Epilachninae, feed on plants, with examples like *Epilachna borealis*, the squash beetle, *Epilachna vigintioctopunctata*, 28-spotted potato ladybird and *Epilachna varivestis*, the Mexican bean beetle, targeting specific plant species. Conversely, innocuous species like *Psyllobora nana* and *Psyllobora schwarzi* of the Halyziini tribe feed on mildews found on plant leaves. Predatory species, such as *Stethorini*, specialize in feeding on mites, exemplified by *Stethorus utilis*. Another predatory group, including *Delphastus catalinae* and *Nephaspis oculatus*, focuses on preying on whiteflies. Ladybirds, like *Rodolia cardinalis*, are highly effective in controlling cottony cushion scale, a major pest of citrus. Additionally, species like *Cryptolaemus montrouzieri* are notable predators of mealybugs. Other ladybird species, including *Zilus horni* and *Cryptognatha nodiceps*, primarily prey on armored scale insects. Moreover, numerous ladybird genera, such as *Scymnus* and *Chilocorus*, feed on scale insects, providing crucial pest control services in various ecosystems. In addition, common ladybird beetles like *Cheilomenes sexmaculata*,[5-7] *Propylea dissecta*,[8,9] *Coccinella transversalis*,[7] *Coccinella septempunctata*[10] are well-established natural predators of pests such as aphids (*Aphis gossypii*, *Aphis craccivora*, *Brevicoryne brassicae, Lipaphis erysimi* etc), whiteflies, and mealybugs in India.

The current article will explore the agricultural and ecological implications of ladybird beetle interactions, highlighting their potential as eco-friendly agents for pest management. Additionally, it will provide insights into current research directions, the scope of studies in this field, and prospects for harnessing the power of these tiny yet formidable insects.

Role in Agriculture and Ecosystem Sustainability

Ladybirds have a rich history in biocontrol dating back to the introduction of the vedalia beetle, *R. cardinalis* in California in 1889, where it successfully managed scale insects, *Icerya purchasi* on citrus. Since then, various ladybird species have effectively controlled pests like aphids, scale insects, and mealybugs. Their efficacy in pest management hinges on predation rates, prey preference, reproductive rate, and the balance between predator and prey populations.

Figure 1: Different ladybird beetle species **(a)** *Coccinella septempunctata,* seven-spot ladybird, **(b)** *Harmonia axyridis,* harlequin, multicoloured Asian ladybird **(c)** *Cheilomenes sexmaculata*, zigzag ladybird **(d)** *Coccinella transversalis,* transverse ladybird and **(e)** Propylea dissecta.

The introduction of aphidophagous ladybird species in North America since 1900 aimed to address aphid biocontrol needs, but only 18 out of 179 introduced species have been successfully established. Some were established after accidental introductions, including *C. septempunctata*, *Harmonia axyridis*, and *Propylea quatuordecimpunctata*. However, certain aphidophagous ladybird species' introductions have been linked to the decline of native species in the USA and elsewhere.[11-13]

Aphidophagous ladybirds are generally considered less effective biocontrol agents due to differences in their intrinsic rates of increase and mean generation time ratios, despite having lower relative development rates than aphids. However, early prey suppression initiation targeting young aphid colonies could enhance aphid biocontrol efficacy. Coccidophagous ladybirds, such as *Chilocorus nigritus* and *Cryptolaemus montrouzieri*, have shown success in controlling coccids and mealybugs, both in classical and augmentative biocontrol programs. Specialist ladybirds, like those in the genus *Stethorus*, have potential as biocontrol agents against tetranychid mites, particularly at high densities. Similarly, *Clitostethus oculatus* has been effective in controlling whitefly populations in Hawaii and India. Specialist ladybirds are generally more effective biocontrol agents due to their selective feeding habits and persistence in target prey habitats, whereas the invasion of generalists into their resource space can pose significant challenges.

With increasing pressure on the global agricultural sector to embrace sustainable methods, the importance of ladybird beetles as natural pest controllers is amplified. Their ability to prey on pests significantly reduces pesticide reliance among farmers, decreasing input expenses and alleviating environmental and health risks. Furthermore, the promotion of biological pest control methods, facilitated by ladybird beetles, harmonizes with the global trend towards sustainable agriculture and integrated pest management practices. Ladybird beetles positively impact crop yields and quality by suppressing pest populations, ensuring higher yields and improved marketable quality. Additionally, their presence reduces reliance on chemical pesticides, potentially enhancing soil ecosystems and reducing chemical residues in agricultural produce, further improving overall crop quality and marketability.

With increasing pressure on the global agricultural sector to adopt sustainable methods, ladybird beetles have emerged as vital natural pest controllers. By preying on pests, they significantly reduce pesticide reliance, decreasing input costs for farmers and mitigating environmental and health risks. Their role aligns seamlessly with the global trend toward sustainable agriculture and integrated pest management (IPM) practices.

As key components of IPM, ladybird beetles effectively target specific pests with minimal non-target effects, reducing chemical inputs and enhancing natural pest control mechanisms. Habitat management strategies—such as planting flowering strips, minimizing pesticide application, and maintaining ecological refuges—further support ladybird populations and their contributions to pest management.

Additionally, ladybird beetles contribute to long-term pest management by addressing pesticide resistance issues. Continuous pesticide use often leads to resistant pest populations, undermining chemical control measures. Incorporating biological control agents like ladybird beetles mitigates this problem, ensuring sustainable and effective pest control over time.

The current research landscape on ladybird beetles spans diverse disciplines, including behaviour, ecology, agricultural science, and biotechnology. Recent studies explore their biology, prey preferences, and interactions with pests and the environment, offering valuable insights for optimising their role in sustainable agriculture.

In parallel, industries have recognised the commercial potential of ladybird beetles, cultivating them for distribution and sales to promote sustainable pest control solutions. Prominent organizations like Biobest and Koppert Biological Systems lead global efforts to rear ladybirds for agricultural use. Start-ups focused on organic farming and sustainability has also entered the market, offering ladybird beetles to farmers and gardeners as eco-friendly alternatives to chemical pesticides. These collective efforts underscore the growing importance of ladybird beetles in global agricultural sustainability and pest management strategies (Figure 2).

Figure 2: Commercial packaging of live ladybird beetles (*Hippodamia convergens*), highlighting their use as eco-friendly biological pest controllers in sustainable agriculture.

Advancement in Genomics and Transcriptomics Studies

Genomic studies have shed light on the molecular basis of their predatory behavior, including gene identification associated with prey detection, consumption, and digestion. Additionally, transcriptomic analyses have provided an understanding of the physiological responses of ladybird beetles to environmental stressors, such as temperature fluctuations and pesticide exposure. Through next-generation sequencing of the immunity-related transcriptome of *H. axyridis*, researchers identified more than 50 genes that potentially encode antimicrobial peptides. Rondoni *et al.*[14] described the first chemosensory gene repertoire in *H. axyridis* antennae, identifying genes crucial for odour and taste reception, which are vital for mating and habitat selection. These findings could enhance the biological control effectiveness of *H. axyridis* or aid in managing its invasive populations. Zhang *et al.*[15] sequenced the transcriptomes of *Henosepilachna vigintioctopunctata* across all life stages, providing the first gene catalogs and SSR markers for the Coccinellidae family. These resources facilitate understanding dietary diversity and elytra spot formation in ladybirds and support pest control strategies and genetic studies within the Coccinellidae family. In addition, a profiling analysis of the ladybird, *Cryptolaemus montrouzieri* under insecticide stress produced over 26 million sequencing reads, assembled into 38,369 non-redundant transcripts, with 23,248 annotated. Using a tag-based digital gene expression system, 993 genes were significantly up- or down-regulated under insecticide stress.[16] These findings aid in understanding the molecular mechanisms of insecticide resistance and its effects on natural enemies

Moreover, RNA-mediated interference (RNAi) offers a rapid method for gene function analysis, but embryonic RNAi is limited for postembryonic studies. In *H. axyridis*, larval RNAi targeting homeobox genes induced adult morphological defects, showcasing its efficiency for studying postembryonic development in non-model insects and providing a significant understanding of mechanisms at the molecular level.

Chemical Defence

Ladybird beetles possess defensive alkaloids that are autogenous in origin. To date, more than 50 alkaloids have been identified in ladybirds, encompassing various types, such as acyclic amines, piperidines, pyrrolidines, perhydroazaphenalenes, "dimeric" alkaloids, azamacrolides, and homotropanes.[17,18] The first alkaloid identified from a coccinellid beetle is tricyclic N-oxide coccinelline, discovered in the European *C. septempunctata,*[19] alongwith its corresponding free base, precoccinelline, is a potent neurotoxin both insects and mammals.[18] These alkaloids are prevalent in the genus *Coccinella* and have also been detected in other genera, such as *Coccinula*, *Cheilomenes*, and *Micraspis*, as well as in *Coleomegilla*. Subsequently, hippodamine and convergine were uncovered in the American ladybird, *Hippodamia convergens*. Additionally, coccinelline, hippodamine, and propyleine were identified in the defensive secretion of the prothoracic glands of the soldier beetle, *Chauliognathus pulchellus* (Coleoptera: Cantharidae).

Adaline, found in the two-spot ladybird *A. bipunctata*, exhibits toxicity towards many insects but has minimal effects on mammals. Interestingly, the defensive alkaloid harmonine demonstrates activity against a wide range of bacteria, particularly mycobacteria. Harmonine also displays effectiveness against both chloroquine-sensitive and chloroquine-resistant strains of *Plasmodium falciparum*, the causative agent of severe malaria.[20] Its inhibition of *Leishmania major* suggests harmonine's potential as a broad-spectrum defense mechanism for *H. axyridis* against diverse pathogens and parasites encountered in new environments. Furthermore, it may play a role in regulating microsporidia levels, which tend to increase during *H. axyridis* development. The transmission potential of these parasites through intraguild predation raises concerns about their possible utilization as bioweapons against native ladybirds.

Alkaloids play a dual role in the ecological and pest management dynamics of ladybird beetles, offering direct defense against predators and enhancing their potential as biocontrol agents. Intraguild predation, a common phenomenon among ladybirds, imposes selective pressure on the evolution of diverse chemical defenses. Ladybirds endow their eggs with alkaloids, deterring predation by conspecifics and heterospecifics, while chemical cues like alkanes aid in egg recognition and avoidance[21]. This chemical complexity minimizes intraguild conflicts, thereby maintaining the effectiveness of ladybirds as natural enemies in pest control strategies.

The ability of some ladybird species to sequester plant-derived alkaloids via their prey adds another layer of utility. For instance, *C. septempunctata* can bioaccumulate pyrrrolizidine alkaloids (PAs) from aphids feeding on alkaloid-rich plants like *Senecio inaequidens*, enhancing their toxicity and defensive capability. Such bioaccumulation not only strengthens the beetle's chemical arsenal but also amplifies the defensive load inherited from its prey, potentially deterring a broader range of predators.[22]

In addition, "chemical piracy", as observed in *Coccinella undecimpunctata*, shows that ladybirds can incorporate plant-derived toxins from prey, such as *Aphis nerii*, which sequester cardenolides from oleander.[22] The ability of ladybird beetles to adapt their chemical defenses to a variety of ecological contexts is crucial for integrated pest management.

These alkaloid-based defenses provide a natural, sustainable method for pest suppression by reducing predation pressure on ladybirds and increasing their effectiveness as biological control agents. It is also essential to understand the costs and benefits of alkaloid sequestration and synthesis in order to optimize ladybird use in IPM programs and manage aphid-ladybird dynamics effectively.

Future Directions in Ladybird Beetle Research

Ladybird beetle research is poised to address critical challenges in pest management, biodiversity conservation, and sustainable agriculture. Future studies may focus on investigating the impact of climate change on ladybird beetle populations and their interactions with pests, employing advanced predictive modelling and experimental methodologies to inform adaptive pest management strategies. In addition, studies on ladybird beetle population dynamics and habitat associations contribute to understanding factors influencing their abundance and distribution across different landscapes. Ecological surveys and long-term monitoring programs help identify key habitat features and landscape characteristics supporting thriving Ladybird beetle populations, guiding conservation efforts.

Understanding the socio-ecological dimensions of integrated pest management (IPM) involving ladybird beetles may receive prioritisation Collaborative research efforts with stakeholders from academia, government, industry, and local communities may be conducted to develop tailored IPM strategies considering ecological, economic, and social factors.

CONCLUSION

Ladybird beetle research is a rapidly evolving field that integrates ecology, agriculture, and biotechnology, offering promising solutions for sustainable pest management and biodiversity conservation. These beetles play an essential role in controlling agricultural pests, reducing reliance on chemical pesticides, and contributing to ecosystem balance. While several ladybird species have been identified as effective bio-control agents, only a few have received extensive research attention, leaving many species with specialized ecological niches underexplored. Moreover, the invasion of some ladybird species into non-native environments has raised concerns, underscoring the need for further studies to understand the ecological impacts and dynamics of these species.

On-going research into ladybird beetles provides valuable insights into their predation behaviours, prey preferences, reproductive strategies, and interactions with other natural enemies. These insights are crucial for optimizing the use of ladybirds in integrated pest management (IPM) programs. Additionally, advances in biotechnology—particularly in the development of efficient rearing and release techniques—have the potential to enhance the widespread application of ladybird beetles in commercial agriculture, further strengthening their role in pest control.

Another vital aspect of future research understands how environmental changes, such as habitat loss, climate change, and the introduction of invasive species, affect ladybird populations. The decline of native species and disruption of their ecological roles pose significant threats to their contribution to pest management and biodiversity. Conservation efforts, such as habitat restoration and the protection of native species, will be critical to ensure that ladybird beetles continue to thrive and fulfill their essential roles in agriculture and ecosystems.

The interdisciplinary nature of ladybird beetle research, which spans across ecology, entomology, agriculture, and biotechnology, provides a comprehensive approach to addressing the challenges of global food security, ecosystem health, and pest management. Collaborative research efforts and evidence-based decision-making will be key to realizing the full potential of ladybird beetles as sustainable pest control agents. The future of ladybird beetle research holds great promise for enhancing agricultural productivity, promoting environmental sustainability, and improving human well-being through the continued conservation and application of these beneficial insects.

REFERENCES

1. Robertson JA, lipi ski AD, Moulton M, Shockley FW, Giorgi A, Lord NP, Mckenna DD, Tomaszewska W, Forrester J, Miller KB, Whiting MF. Phylogeny and classification of Cucujoidea and the recognition of a new superfamily Coccinelloidea (Coleoptera: Cucujiformia). Systematic Entomology. 2015 Oct;40(4):745-78.
2. Zhang SQ, Che LH, Li Y, Liang D, Pang H, lipi ski A, Zhang P. Evolutionary history of Coleoptera revealed by extensive sampling of genes and species. Nature communications. 2018 Jan 15; 9(1):205.
3. Dixon AF. Insect predator-prey dynamics: ladybird beetles and biological control. Cambridge University Press; 2000.
4. Hodek I, Honek A, Van Emden HF, editors. Ecology and behaviour of the ladybird beetles (Coccinellidae). John Wiley & Sons; 2012 May 21.
5. Poorani J. Coccinellidae of the Indian subcontinent. InIndian Insects 2019 Oct 16 (pp. 223-246). CRC Press.
6. Omkar, Bind RB. Prey quality dependent growth, development and reproduction of a biocontrol agent, Cheilomenes sexmaculata (Fabricius)(Coleoptera: Coccinellidae). Biocontrol Science and Technology. 2004 Nov 1;14(7):665-73.

7. Omkar. Reproductive Behaviour of Two Aphidophagous Ladybeetles, Cheilomenes sexmaculata and Coccinella transversalis. Insect Science. 2004 Jun; 11(2):113-24.
8. Omkar, Pervez A. Functional and numerical responses of Propylea dissecta (Col., Coccinellidae). Journal of Applied Entomology. 2004 Mar; 128(2):140-6.
9. Siddiqui A, Omkar, Paul SC, Mishra G. Predatory responses of selected lines of developmental variants of ladybird, Propylea dissecta (Coleoptera: Coccinellidae) in relation to increasing prey and predator densities. Biocontrol Science and Technology. 2015 Sep 2; 25(9):992-1010.
10. Omkar, Srivastava S. Influence of six aphid prey species on development and reproduction of a ladybird beetle, Coccinella septempunctata. BioControl. 2003 Aug;48: 379-93.
11. Roy HE, Adriaens T, Isaac NJ, Kenis M, Onkelinx T, Martin GS, Brown PM, Hautier L, Poland R, Roy DB, Comont R. Invasive alien predator causes rapid declines of native European ladybirds. Diversity and Distributions. 2012 Jul; 18(7):717-25.
12. Smith CA, Gardiner MM. Biodiversity loss following the introduction of exotic competitors: does intraguild predation explain the decline of native lady beetles?. PLoS One. 2013 Dec 27; 8(12):e84448.
13. Kenis M, Nacambo S, Van Vlaenderen J, Zindel R, Eschen R. Long term monitoring in Switzerland reveals that Adalia bipunctata strongly declines in response to Harmonia axyridis invasion. Insects. 2020 Dec 12; 11(12):883.
14. Rondoni G, Roman A, Meslin C, Montagné N, Conti E, Jacquin-Joly E. Antennal transcriptome analysis and identification of candidate chemosensory genes of the harlequin ladybird beetle, Harmonia axyridis (Pallas)(Coleoptera: Coccinellidae). Insects. 2021 Mar 2; 12(3):209.
15. Zhang QL, Wang F, Guo J, Deng XY, Chen JY, Lin LB. Characterization of ladybird Henosepilachna vigintioctopunctata transcriptomes across various life stages. Scientific Data. 2018 Jun 5; 5(1):1-9.
16. Zhang Y, Jiang R, Wu H, Liu P, Xie J, He Y, Pang H. Next-generation sequencing-based transcriptome analysis of Cryptolaemus montrouzieri under insecticide stress reveals resistance-relevant genes in ladybirds. Genomics. 2012 Jul 1; 100(1):35-41.
17. Daloze D, Braekman JC, Pasteels JM. Ladybird defence alkaloids: structural, chemotaxonomic and biosynthetic aspects (Col.: Coccinellidae). Chemoecology. 1994 Sep;5: 173-83.
18. Blum MS. The importance of alkaloidal functions. Allelopathy: chemistry and mode of action of allelochemicals. 2004; 8:163-81.
19. Glisan AS. Chemistry of coccinellid beetles. Cornell University; 1995.
20. Röhrich CR, Ngwa CJ, Wiesner J, Schmidtberg H, Degenkolb T, Kollewe C, Fischer R, Pradel G, Vilcinskas A. Harmonine, a defence compound from the harlequin ladybird, inhibits mycobacterial growth and demonstrates multi-stage antimalarial activity. Biology letters. 2012 Apr 23; 8(2):308-11.
21. Hemptinne JL, Lognay G, Gauthier C, Dixon AF. Role of surface chemical signals in egg cannibalism and intraguild predation in ladybirds (Coleoptera: Coccinellidae). Chemoecology. 2000 Aug; 10:123-8.
22. Pasteels JM. Chemical defence, offence and alliance in ants–aphids–ladybirds relationships. Population Ecology. 2007 Jan; 49:5-14.