**The role of predators in insect pest control**

**ABSTRACT**

Insect pests significantly restrict agricultural and horticultural productivity, which results in the widespread use of synthetic pesticides. The adverse effects of chemical management, such as insect resistance, environmental contamination, and harm to non-target species, emphasize the need for sustainable alternatives. Vertebrates and predatory arthropods are crucial to the biological control of pests in integrated pest management (IPM) systems. This review examines the ecological and functional significance of key predatory taxa, including coccinellid beetles (e.g., *Coccinella septempunctata, Cryptolaemus montrouzieri*), predatory mites (*Phytoseiulus persimilis, Amblyseius swirskii*),green lacewings (*Chrysoperla zastrowi sillemi*), predatory bugs (e.g., *Orius spp., Cyrtorhinus lividipennis*), spiders, and insectivorous birds. These predators effectively control populations of lepidopteran larvae, mealy bugs, thrips, mites, and aphids across a range of cropping regimes.

**Keywords:** Agriculture, Ecology, IPM, Pest control, Predators and sustainable management.

**INTRODUCTION**

Significant production losses in horticultural and agricultural crops are caused by insect pests, which results in financial losses and a greater reliance on pesticides. Overuse of chemical pesticides damages non-target organisms, such as beneficial insects, and causes environmental pollution and pest resistance. Because they consume harmful insect pests, predatory insects and arthropods are essential to natural pest control. They are essential elements of integrated pest management (IPM) and biological control techniques, which lower pest populations while fostering ecological balance. Insect predators are essential to the biological management of agricultural pests. Still, a lot of farmers rely mostly on synthetic pesticides to control pests, which creates problems including pesticide resistance, toxic residues, pest resurgence, and the extinction of beneficial species. Sustainable agriculture requires a shift from chemical-based pest management to biological control in order to address these problems. The use of the *Rodolia cardinalis*, for the control of *Icerya purchasi* the cottony cushion scale, is among the most noteworthy examples of traditional biological control. This accomplishment showed the possibilities of employing particular predators for efficient control of insect pests. Because they can live in a wide variety of agro-ecosystems, predatory insects are useful partners in managing pest populations.*Cryptolaemus montrouzieri, Scymnus coccivora, Chilocorus* *nigrita, Cheilomenes sexmaculata, Coccinella septempunctata, Curinus coeruleus, Chrysoperla zastrowi sillemi,* and *Blaptostethus pallescens* are a few of the most effective predators. Even while predatory insects are good at controlling pests, there are several drawbacks to their utilization which indicate the need for more study and responses from the scientific community (Furlong *et al*., 2010).

## ****TABLE 1: TYPES OF PREDATORS IN PEST MANAGEMENT****

|  |  |  |
| --- | --- | --- |
| Natural Enemy | Pest | Crop |
| The ladybird beetles *Menochilus sexmaculatus, Brumoides suturalis, Harmonia dimidiate* and *Coccinella septempunctata* and green lacewings, *Chrysoperla zastrowi sillemi* | Aphids*; Aphis craccivora, Myzus persicae, Lipaphis erysimi* (Hemiptera: Aphididae) and Leafhoppers; *Empoasca kerri, E. facialis, E. fabae* (Hemiptera: Cicadellidae) etc. | Vegetables, Fruits, Pulses, Oilseeds |
| Predatory mites such as *Phytoseilus persimilis* and several species of *Amblyseius spp.* | Spider mite; *Tetranychus spp.* (Acari: Tetranychidae) | Tomato, Brinjal, Sweet Peppers, Cucumber |
| Cryptolaemus montrouzieri, Scymnus spp. | Mealy bugs, *Paracoccus marginatus* and *Phenacoccus solenopsis,* green shield scale: *Pulvinaria psidii* (Hemiptera: Pseudococcidae) etc. | Brinjal, Okra, Tomato, Papaya, Guava, Sapota, Lemon |
| Coccinellids *Chilocorus nigrita* and *C. circumdatus* | Green scale, *Coccus viridis* (Hemiptera: Coccidae) on acid lime and white scale *Aulacaspis tubercularis* on mango (Hemiptera: Diaspididae) | Acid lime, Mango |
| Predatory mirid bugs, *Nesidiocoris tenuis* | Tomato pinworm, *Tuta absoluta* (Lepidoptera: Gelechiidae) etc. | Tomato, Potato, Pepper |

## **(Seni** ***et al*., 2022)**

## ****ROLE OF PREDATORS IN PEST MANAGEMENT****

## Since they naturally control pest populations in agricultural ecosystems, predators are essential to sustainable pest management. By feeding on different pest species, these beneficial organisms lower their population and lessen the harm they do to crops. Unlike pesticides, which can kill both harmful as well as beneficial insects, predators target pest species specifically, making them an important aspect of integrated pest management (IPM) programs. Lady beetles (which eat aphids and scale insects), lacewings (whose larvae eat a variety of soft-bodied pests), and predatory mites (which eat spider mites) are some of the most common predators. Cutworms and root maggots are among the soil-dwelling pests that can be effectively managed by ground beetles and rove beetles. In some farming systems, even larger organisms like frogs, bats, and birds can function as natural predators. Predators help maintain pest populations below economic thresholds by feeding on pests at different phases of their life cycle, such as eggs, larvae, or adults. Reducing pesticide use, preserving habitat diversity, and planting food- and shelter-producing cover crops or flowering plants are all ways to support predator populations. These methods reduce the likelihood of insect outbreaks while promoting a sound ecological balance. Predators help agro ecosystems become more resilient over the long term by lowering the need for chemical treatments. All things considered, using predators to control pests is an economical, sustainable, and ecologically friendly strategy that fits in perfectly with contemporary agricultural objectives. By incorporating them into crop security plans, they improve biodiversity and encourage a natural equilibrium between pests and competitors, which results in more robust crops with more consistent yields. (Furlong *et al*., 2010; Luff, 1983)

### ****Ladybird Beetles****

Coccinellid beetles, also called ladybird beetles, are important biological control agents because they naturally prey on a variety of agricultural pests, especially scale insects, mealy bugs, aphids, and whiteflies. By controlling pest populations, they lessen the need for artificial pesticides and support environmentally friendly pest control. Ladybird beetles, its great eating capacity, quick reproduction, climate adaptation, and simplicity in mass rearing make them extremely useful. To guarantee long-term pest suppression, biological management programs employ coccinellids through introduction, augmentation, and conservation strategies. Because of their polyphagous nature, they may flourish in a variety of environments, and by offering them shelter and alternate food sources, their conservation efforts can be strengthened. Coccinellids support economically and environmentally sound pest management techniques by keeping pest populations below levels that cause economic harm (Johari *et al*., 2020).

Their role in integrated pest management (IPM) has been widely recognized, with species like *Cryptolaemus montrouzieri* (coleoptera: coccinellidae), successfully introduced in different regions to control mealy bugs in crops such as citrus, grapes, coffee, and tea. Citrus mealy bug, *Planoccus* citri is managed by field release of *Cryptoleamus montrouizeri* the Australian lady bird beetle at a rate of 10 per tree. Grapes mealy bugPlanoccus citri And *Ferrisia virgata* is managed by the release of Cryptolaemus montrouzieri at the rate of 10 per vine. Coffee mealy bug and tea mealy bug, ,*Planococcus sp* is managed by releasing Cryptolaemus montrouzieri at the rate of **5–10 adults per coffee plant,** or about **2,000–5,000 beetles per hectare** depending on infestation level and repeat releases every **15–20 days** if necessary. *Chilocorus nigrita* (Coleoptera: coccinellidae), these was effective for the management of coconut scale (Aspidiotus destructor), red scale in citrus (*Aonidiella auranti.*),hemispherical scale (*Saissetia* *coffeae*) and green scale (Coccus viridis) in coffee.10–15 beetles/tree or 5,000–10,000/ha should be released depending on infestation. We should repeat the release every 15–20 days during peak infestation, also avoid chemical sprays before and after release; use selective insecticides if necessary. *Coccinella septempunctata* (coleoptera: coccinellidae) .They are productive in areas of northern parts of India with moderate temperature conditions . It repressess the population of aphid like *Myzus persicae* (green peach aphid),*Aphis gossypii* (cotton aphid), *Rhopalosiphum* *amides* (corn aphid),*Brevicoryne brassicae* (cabbage aphid) *and Macrosiphum rosae* (rose aphid). In Wheat / Mustard / Cabbage / Okra 2,000–5,000 beetles/ha should be released depending on aphid density. It should be released at 10–15 day intervals in peak aphid season. In Orchards like citrus, guava, rose) they are released at a rate of 10–20 beetles per tree or bush. In Polyhouse / Greenhouse Crops for smaller area 100–200 beetles per 100 m² is released. It should be regularly monitored and releases should be repeated every 2 weeks. (Kshitiz *et al*., 2021)

### ****Lacewings****

**As natural predators, green lacewings are essential to biological pest control. Particularly well-known for their voracious hunger, their larvae feed on a variety of soft-bodied insect pests, including moth eggs, mealy bugs, aphids, whiteflies, thrips, and tiny caterpillars. Because they lessen the need for chemical pesticides and encourage ecologically friendly methods of managing pests, these predators play a vital role in sustainable agriculture. They are a crucial part of integrated pest management (IPM) strategies because of their capacity to control a variety of insect species. Green lacewings work well in greenhouse settings as well as open-field crops, keeping pest populations under control. They enhance agricultural production and promote healthier crop growth by vigorously hunting and eating a lot of pests** **(Kothuri *et al*., 2025).**

**Green lacewings** (Chrysoperla spp.), especially Chrysoperla carnea, are highly valued biological control agents used as **generalist predators** in large numbers of crops. Depending on the goal and practicality, predators can be introduced at various times of their lives in biological pest control. Since eggs usually hatch in two to three days and are less expensive and quicker to transport, they are frequently used. Because of their rapid eating activity, larvae—especially those in their first or second instar stages—are aggressively predatory and are favored for locating pest hotspots. Because they are more expensive and more difficult to handle, adults are rarely utilized in bulk releases. Instead, they are varied crop types require varied predator release rates and techniques for biological control to be effective in various systems of cropping (Smith & Hagen, 1956). About 75,000–100,000 eggs or 10,000–20,000 larvae per hectare are advised for vegetables like tomato, chili, and cabbage. Early pest detection should be the main priority, especially for aphids and thrips. About 50,000–75,000 eggs per hectare or 10–15 larvae per vine or tree are employed in fruit crops including grapes, citrus, and mangos. These eggs and larvae primarily target mealy bugs, thrips, and mites at crucial stages like flowering and fruit set. Predator deployment for polyhouse crops, including cucumber and capsicum, involves the release of 10–20 larvae or 5,000–10,000 eggs per 100 square meters, with re-releases occurring every 10–15 days to ensure ongoing protection. Mostly used for colonization, which helps develop predator populations in the field. (Venzon *et al*., 2021)

### ****Predatory Bugs****

*Cyrtorhinus lividipennis* (Hemiptera: miridae), is one of the most efficient predator against leaf hoppers . For the purpose of managing important hopper pests in rice, the timing and density of predator release are critical. Predators are delivered at a rate of 100–200 adults per hectare for the Brown plant hopper (*Nilaparvata lugens*) during the early stages of hopper colonization, usually 20–25 days after sowing (DAS). With a slightly higher density of 150–250 adults per hectare, the White-backed plant hopper (*Sogatella furcifera*) is released during the early reproductive stage the crop. In order to control the Green leafhopper (*Nephotettix* *virescens*) population before it becomes out of control, predators are introduced at the beginning of the infestation, employing 100 to 150 adults per hectare. Hemiptera: anthocoridae, or *Orius spp*. These predatory anthocorids are deployed primarily to combat thrips in crops including pepper, onion, and cucurbits, but they also consume soft-bodied insects such as mites, aphids, whiteflies, lepidopteran eggs, pollen, and plant sap. Five to twenty thrips can be consumed daily by an adult predatory anthocorid bug. The species *Orius majusculus*, *Orius sauteri*,*Orius insidious*  and *Orius laevigatus,*are among most significant.

With release rates and frequencies tailored for the target pest, predatory insects are an effective way to control a variety of pest species in a variety of crop environments. The release strategy for thrips *(Frankliniella occidentalis, Thrips tabaci*) consists of 10–15 predators per square meter every week or every two weeks for greenhouse crops, 5,000–10,000 individuals per hectare every two–three weeks for open fields, and up to 20–30 predators per square meter every week in hotspot areas until control is reached. (Ahmed *et al*., 2018). Predators are released at a rate of 10–15 per square meter per week in greenhouses and 5,000–7,000 per hectare every 15–20 days in open fields to control aphids (*Aphis gossypii, Myzus persicae*). (Gesraha *et al*.,2022)

In polyhouses, 10–12 whiteflies per square meter per week are advised, however in open fields, 6,000–10,000 per hectare biweekly are appropriate (*Bemisia tabaci, Trialeurodes vaporariorum*). (Stansly *et al*., 2005). Every week, 10–15 predators per square meter in hotspots target spider mites (*Tetranychus urticae*), especially during the egg and larval phases, in protected crops. Finally, during the early phases of crop development, 10–12 predators per square meter, or 7,000–10,000 per hectare, are applied weekly in both polyhouse and open-field setups to combat lepidopteran eggs (e.g., *Helicoverpa spp*.), which are usually handled as an additional control strategy. (Karut *et al*., 2022)

### ****Spiders****

Spiders use both direct predation and non-consumptive methods to manage pest populations. Aphids, caterpillars, and other phytophagous insects are among the many insect pests that they aggressively hunt and eat. Furthermore, their very existence can change the behavior of pests by interfering with eating and reproduction. Spiders sometimes kill pests without consuming them, which further suppresses the population. Despite their advantages, a number of factors affect how well spiders work to control pests. Their importance in an ecosystem may be impacted by their relationships with other beneficial arthropods and their propensity for cannibalism. Furthermore, the type of crop, the type of pest, and the general variety of the spider community all affect how effective they are. (Daniel *et al*., 2021)

### ****Predatory Mites****

Predatory mites, such as *Phytoseiulus persimilis* (Acarina: Phytoseiidae), are vital in pest management, particularly in augmentative biological control, where they assist in regulating populations of detrimental agricultural pests. In recent decades, the market for biological control agents derived from arthropods has seen significant growth, with predatory mites, especially those belonging to the Phytoseiidae family, emerging as some of the most commonly utilized biocontrol agents. These mites effectively manage critical pests including whiteflies, thrips, spider mites, and aphids. A particularly successful species*, Amblyseius swirskii*, introduced in 2006, is highly regarded for its capability to simultaneously control both thrips and whiteflies. Predatory mites present numerous advantages in pest control; their generalist feeding behavior enables them to thrive on pollen and alternative prey, facilitating preventive introductions prior to the increase of pest populations. Their diminutive size and rapid reproduction rate render them easy to mass-produce and economically viable for commercial use. Furthermore, they can target various pest species, thereby enhancing their effectiveness within integrated pest management (IPM) strategies. Although soil-dwelling predatory mites are less frequently employed, they are utilized in greenhouses to manage pests such as sciarid larvae and thrips. Nonetheless, challenges persist in evaluating their population density and efficacy under field conditions. Despite these challenges, predatory mites continue to be crucial elements of sustainable pest management, decreasing reliance on chemical pesticides and fostering ecological equilibrium in agricultural systems. (Khajuria *et al*., 2009 ;Knapp *et al*., 2018)

### ****TABLE 2: Common Predatory Mite Species and Their Targets****

|  |  |  |  |
| --- | --- | --- | --- |
| **Predatory Mite** | **Scientific Name** | **Target Pests** | **Crops** |
| **Phytoseiid mite** | Phytoseiulus persimilis | Two-spotted spider mite (Tetranychus urticae) | Tomato, cucumber, capsicum |
|  | Neoseiulus californicus | Spider mites, broad mites, thrips (partially) | Strawberry, capsicum, flowers |
|  | Amblyseius swirskii | Thrips, whiteflies, broad mites | Cucurbits, tomato, pepper |
|  | Amblyseius cucumeris | Thrips, some mites | Sweet pepper, eggplant |
|  | Neoseiulus longispinosus | Spider mites, thrips (partially) | Ornamentals, vegetables |

### **(van Lenteren *et al*., 2018; Arthurs *et al*., 2009)**

The suggested release rates for predatory mites differ based on the target pests and the specific species of mite. *Phytoseiulus persimilis* is known to be effective against spider mites, with a recommended release rate of 5–10 mites per plant or 2,000–5,000 per hectare, typically applied once or twice at the onset of the infestation. For *Neoseiulus californicus*, which addresses both spider and broad mites, the advised release rate is 10–25 mites per square meter, applied weekly or biweekly depending on the level of pest pressure. *Amblyseius swirskii*, which targets thrips, whiteflies, and broad mites, should be released at a rate of 50–100 mites per square meter or 50,000–100,000 per hectare, with preventive applications recommended during flowering. *Amblyseius cucumeris,* primarily utilized for thrips control in flowers, is suggested to be released at 25–50 mites per square meter, with reapplications every two weeks in greenhouse environments. Lastly, *Neoseiulus longispinosus*, effective against both mites and thrips, should be released at 25–50 mites per square meter, with application rates adjusted according to pest population assessments. Regular monitoring is advised to ensure effective pest management.(van Lenteren *et al*., 2018).

1. **Birds**

Birds, including swallows, sparrows, and insectivorous bats, play a crucial role in managing flying insect pests. They serve as natural predators, effectively reducing pest populations and minimizing damage to crops. Various bird species, such as insectivorous songbirds and raptors, consume agricultural pests like caterpillars, beetles, aphids, and rodents, thereby aiding in the balance of ecosystems. Research indicates that birds are instrumental in controlling insect populations, which decreases the need for chemical pesticides and fosters sustainable agricultural practices. Nonetheless, their effectiveness is contingent upon the availability of suitable habitats, the diversity of landscapes, and the composition of bird species. To bolster avian pest control, farmers and land managers should focus on preserving diverse habitats, planting native flora, and providing nesting opportunities, thereby ensuring a stable bird population that supports natural pest management. (Muley *et al*., 2012).

### ****Key Insectivorous Birds Beneficial to Agriculture****

Several insectivorous bird species play a vital role in agricultural pest control by preying on a wide range of harmful insects. The Black Drongo (*Dicrurus macrocercus*) is particularly effective in managing caterpillar populations such as *Helicoverpa,* as well as moths and grasshoppers, by actively foraging in open fields (Ali and Ripley, 1987). The Cattle Egret (*Bubulcus ibis*) is commonly seen in ploughed or recently tilled fields where it feeds on grasshoppers, crickets, beetles, and caterpillars (Dhindsa and Saini, 1994). Similarly, the Common Myna (*Acridotheres tristis*) contributes to pest regulation by feeding on caterpillars, grubs, and locusts, while Swallows (*Hirundo rustica*) specialize in catching flying insects like leafhoppers, moths, and flies during flight

. The Bulbul (*Pycnonotus spp*.), though also known to feed on fruits, consumes a significant number of insects and fruit flies, aiding in pest suppression (Ali and Ripley, 1987). Lastly, the Hoopoe (*Upupa epops*) is recognized for probing soil in search of insect larvae and pupae, thus targeting pests at an early life stage (Dhindsa and Saini, 1994). The regular presence of these birds in agroecosystems enhances natural pest regulation, contributing to sustainable and eco-friendly farming practices.

**FUTURE THRUST**

Predators' capacity to adapt to changing weather conditions and the challenges of mass rearing are the main barriers to their use in pest management. Research has to focus on creating methods for their easy mass production on artificial diet or looking for other readily available insect species that can multiply quickly in laboratory conditions. Predator taxonomy and bioecology, the impact of the environment on predators, the method or methods of release, interactions between prey, predators, and crop plants, efficacy studies, and appropriate documentation are all essential for this. In addition to their function in controlling the population of insect pests, additional research is needed to show how these predators affect the environment as part of an integrated pest management approach. (Seni *et al*., 2022).

## ****CONCLUSION****

Predators are crucial for effective pest management as they naturally control pest populations, decrease reliance on pesticides, and enhance ecosystem health. By implementing strategies that foster predator populations, farmers can boost crop yields, minimize pest damage, and promote biodiversity. Future studies should aim to refine predator conservation methods to better incorporate biological control into contemporary agriculture and horticulture. A comparative analysis of various predators in biological pest management reveals that no single predator can effectively manage all pest species across different cropping systems. Nonetheless, certain predators demonstrate exceptional efficacy in specific situations. Among generalist predators, green lacewings (*Chrysoperla carnea*) are recognized for their versatility and effectiveness, as they can target a wide array of sucking pests, including aphids, thrips, whiteflies and mealybugs. Their larvae are particularly aggressive and are extensively utilized in vegetable, fruit, and protected crop cultivation, establishing them as a important aspect of integrated pest management (IPM) programs. Assessing mealybug outbreaks, especially in crops like citrus, grapes, coffee, and tea, the Australian ladybird beetle (*Cryptolaemus montrouzieri*) has shown remarkable effectiveness due to its specialization in mealybug predation and its adaptability to various agro-climatic conditions. Likewise*, Chilocorus nigrita* serves as a significant predator for controlling scale insects in perennial crops such as coconut, citrus, and coffee. In rice ecosystems, *Cyrtorhinus lividipennis* stands out as the most dependable predator for managing planthoppers and leafhoppers when introduced during the initial stages of pest colonization.

In the realm of protected cultivation, predatory mites including *Phytoseiulus persimilis, Amblyseius swirskii,* and *Neoseiulus californicus* provide exceptional management of spider mites, thrips, and whiteflies. Their diminutive size, swift reproduction rates, and adaptability to greenhouse conditions render them suitable for both preventive and remedial measures. Additionally, *Orius spp*., a category of predatory insects, significantly contribute to the control of thrips, aphids, whiteflies, and lepidopteran eggs, particularly in high-value greenhouse crops. Furthermore, ecological predators such as spiders and birds aid in pest suppression through direct predation and by disrupting pest behavior. Although their populations are not easily manipulated via mass release, they are vital to a balanced agroecosystem and can be preserved through habitat diversification and reduced pesticide application. In summary, while green lacewings are recognized as the most effective generalist predators across various cropping systems, optimal outcomes are achieved by integrating multiple predators that are specifically suited to the pest complex and crop environment, thereby improving the effectiveness and sustainability of biological control within integrated pest management (IPM) strategies. The development of economical artificial rearing methods utilizing substitute prey or artificial diets for important predators such as ladybird beetles, lacewings, and predatory bugs must be the top priority of future study. In order to improve predator selection and deployment tactics, more attention should be paid to researching predator-prey-plant interactions under various agroclimatic circumstances. Furthermore, further research on underutilized ecological predators like spiders and birds is necessary, with an emphasis on how they might be included into long-term habitat management initiatives.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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