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Beneficial Insects in Pest Management: A Review of Their Role in Controlling Crop Infestation

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ABSTRACT: Pest infestation remains a major challenge in agricultural productivity worldwide, often leading to significant yield losses. Conventional chemical pest control methods, while effective, pose risks to human health and the environment, prompting a shift toward sustainable and eco-friendly alternatives. Beneficial insects play a vital role in integrated pest management (IPM) by naturally regulating pest populations through predation, parasitism, and competition. This review highlights the diversity and functional importance of beneficial insect species in various cropping systems, emphasizing their contribution to reducing pest outbreaks and supporting crop health.

KEYWORDS: Beneficial, Insects, Crop, Pest, Management.

I. INTRODUCTION

Agriculture is the fastest-growing industry and a crucial sector for sustenance. Over the years, advancements in technology and the introduction of equipment have enhanced efficiency and transformed crop cultivation and land management. India has seen significant enhancements in agricultural output in recent decades (Chand & Parappurathu, 2012; Pingali, 2012). Nonetheless, substantial production disparities persist for several crops across the rural landscape (Brahmanand et al., 2013; Sharma, 2016). Rajasthan, being an agricultural state with seventy percent of its population residing in rural areas and largely dependent on farming for their livelihood, also reflects this pattern. However, the agricultural industry in Rajasthan is currently facing a crisis due to multiple factors. The arid climate of western Rajasthan is the primary issue. The climatic conditions here are milder compared to some regions of this state, since the southern section of Rajasthan is around 400 km from the Arabian Sea. The state's economy is characterized by recurring droughts, famines and shortage circumstances. The monsoon in Rajasthan is unpredictable. The rainfall pattern is often variable and inconsistent. The issue of drought and hunger has been linked to the state. Economic deprivation among farmers hinders their adoption of advanced agricultural technology. The elevated illiteracy rate and insufficient education among farmers hinder the rapid advancement of the scientific and technical abilities essential for agricultural growth. The distribution of agricultural land is so flawed that a significant portion is owned by non-cultivators (Sharma and Basotia, 2018).

Amidst these broader state-level challenges, the Shekhawati region—comprising the districts of Sikar, Jhunjhunu, and Churu in northeastern Rajasthan—holds a distinctive place within the agricultural landscape of the state. Despite being situated in the semi-arid zone of Rajasthan, characterized by water shortages and severe weather conditions, agriculture remains the primary profession for most of its rural population. The Shekhawati area is characterized by sandy loam soils, undulating topography, low annual precipitation (between 300–500 mm) and high evapotranspiration rates. These variables result in a vulnerable agro-ecosystem that necessitates sustainable and adaptable agricultural techniques. Historically, agriculture in this region has mostly relied on rainfed methods, with limited access to canal irrigation (via the Indira Gandhi Canal in the western areas) and tube wells. The principal crops cultivated in the area are categorized into two seasons: Kharif and Rabi. The Rabi season, especially pertinent to this subject, involves the production of wheat, mustard, gram and barley. Mustard and gram are the predominant crops owing to their adaptation to arid environments and market demand. The use of drought-resistant and early-maturing crop types has enhanced agricultural output to a certain degree in recent years (Pal and Tripp, 1998; DoAFW, 2011). However, despite these advancements, agricultural productivity continues to face major threats from biotic stressors. Among these, crop pests remain a significant constraint on agricultural output, directly affecting both food security and farmers' livelihoods. Crop pests significantly hinder agricultural output in India including Rajasthan, risking food security and the lives of

farmers. A diverse array of pests, including weeds, diseases and insects, flourish under the country's heterogeneous agroclimatic conditions. Presently, pests include the Fall Armyworm, locust swarms and the Whitefly pose significant hazards to crops such as maize, rice and cotton, respectively. Climate change intensifies this problem, since elevated temperatures and unpredictable rainfall patterns promote the spread of pests, undermining conventional agricultural methods (Sarkar et al., 2024).

Diverse agricultural plants are significantly impacted by several insect varieties, leading to diminished production and financial misery for farmers owing to crop losses attributed to these pests. The combination of pest infestations and disease outbreaks may lead to dire circumstances, as seen in our nation. Consequently, stringent measures must be implemented immediately to terminate the pest infestation and diminish pest occurrences. The Food and Agriculture Organization of the United Nations (FAO) believes that East Asia, including China and South Asia together represent over fifty percent of pesticide use in emerging nations globally. Furthermore, producers often use substantial amounts of very dangerous pesticides or resort to prohibited or counterfeit products, rather than opting for less harmful options. To mitigate these adverse impacts, IPM provides a safer option for human and environmental health. IPM or Integrated Pest Control (IPC), is a comprehensive strategy that amalgamates methods for the economic regulation of pests. IPM is the optimal combination of cultural, biological and chemical strategies for the control of diseases, insects, weeds and other pests. As the global population increases, the need for food and fiber requires that farmers enhance crop production on current farmland (Bora et al., 2024).

Furthermore, numerous insects inhabit agricultural land that do not pose a danger to crop production but are advantageous to farmers in various capacities, such as natural enemies, pollinators, productive insects, scavengers, weed suppressors and soil enhancers. Insects may be advantageous to humans in several ways, both directly and indirectly. The most significant beneficial species are those whose products possess substantial economic worth. The insects responsible for agricultural pollination are of great importance. Additional advantageous insects serve as food, contribute to the biological control of insect pests and plants, act as soil scavengers, are used in medicine and research and possess aesthetic value (Getanjaly et al., 2015).

II. PEST INFESTATION IN CROPS AND THEIR MANAGEMENT STRATEGIES

Since the inception of agriculture approximately 10,000 years ago, farmers have encountered challenges from various organisms, primarily animal pests (insects, mites, nematodes, rodents, slugs, snails and birds), plant pathogens (viruses, bacteria, fungi) and weeds (i.e., competitive flora), collectively referred to as pests. Two primary variables that impede efficient crop production are abiotic and biotic factors. Abiotic variables include the deficiency or surplus of water throughout the growing season, harsh temperatures, excessive or insufficient irradiance and nutrient supply imbalances. These abiotic elements can only be regulated within certain constraints. Biotic variables, such as pests, may significantly diminish agricultural yields. These organisms may be managed using physical (cultivation, mechanical weeding, etc.), biological (appropriate cultivar, crop rotation, antagonists, predators, etc.) and chemical methods (pesticides).

Crop losses may be classified as either qualitative or quantitative. Decreased productivity results in quantitative losses, diminishing the output per unit area. Pests can induce qualitative losses by diminishing the quantity of valuable constituents in the product, impairing its market quality (e.g., due to pigmentation), compromising its storage properties or contaminating the harvested product with pests, pest remnants or toxic byproducts (such as mycotoxins) (Sarkar et al., 2024). Certain insect pests, such as aphids, leafhoppers, moths, weevils, beetles, termites and scale insects, are primary causes of biotic stress on crops, causing significant damage and leading to substantial agricultural productivity losses. Agriculture serves as the economic backbone of every nation, significantly enhancing national development and improving the level of living and financial prosperity of its populace. Insect pests play a key part in Earth's ecology, exerting both beneficial and negative impacts. Pest infestations in the agricultural industry pose a significant problem, leading to a decline in crop quality. The prevalent pests, pathogens and weeds inflict significant harm on crops, leading to diminished market value of agricultural goods. The identification and categorization of insects are crucial for informed decision-making regarding crop recovery and possible profitability in the agricultural industry (Zabi et al., 2025).

Table 1: List of Insect Pests

S. No.	Insect Pests	Crop
1	Gram pod borer	Cotton pigeon pea, sunflower. tomato
2	Whitefly	Cotton tobacco
3	Brown planthopper	Rice
4	Green leafhopper	Rice
5	Serpentine leaf miner	Cotton tomato. cucurbits
6	Fruit fly	Fruits and vegetables
7	Wheat aphid	Wheat Barley, oats
8	Pink stem borer	Wheat
9	Gall midge	Rice
10	Diamondback moth	Cabbage cauliflower
11	Pyrrilla	Rice Sugarcane
12	Mealy bugs, Phenacoccus solenopsis	Field and horticultural crops
13	Scirtothrips dorsalis (Hood), Frankliniella schultzei (Trybom), Thrips tabaci (Lindeman), Scirtothrips citri (Moulton)	Groundnut cotton, citrus

Source: Sarkar et al. (2024)

Over time, pests and insects that adversely affect agriculture will adapt to environmental changes. Therefore, it is important to monitor them closely, routinely inspect plants for signs of infestation and implement targeted management methods. The appropriate and safe use of authorized pesticides may assist a farmer in producing healthy food throughout the year. A significant advantage of pesticides is their ability to inhibit the proliferation of certain detrimental pests that adversely affect agricultural output. Pesticides, when used properly and effectively, may combat plant diseases and weeds, consequently promoting plant vitality and enhancing agricultural yield (Osei et al., 2021). However, despite their benefits, the excessive or improper use of chemical pesticides can lead to serious environmental degradation, pest resistance and potential health risks to humans and animals. To mitigate these adverse impacts while still ensuring effective pest control, IPM has emerged as a more sustainable and eco-friendly approach. IPM or IPC, is a comprehensive strategy that amalgamates approaches for the economic regulation of pests.

Agricultural pest control now uses both old and new methods to protect crops. This combined approach helps keep farming sustainable and improves crop production. Traditional methods rely on eco-friendly cultural, mechanical, and physical techniques, such as adjusting farming practices, manually removing pests and modifying environmental conditions to deter infestations. These practices focus on prevention and maintaining ecological balance without the use of chemicals. Modern pest control incorporates biological, chemical and genetic methods for more precise and sustainable management. Biological control uses natural predators and parasites to reduce pest populations, while chemical control involves regulated use of pesticides, which, although effective, carry environmental and health risks. Genetic control, including the development of pest-resistant crops through genetic engineering, represents a cutting-edge solution to minimize pesticide dependence and enhance crop resilience. Together, these methods form the foundation of IPM, which aims to minimize economic losses, protect health and the environment, and support long-term agricultural sustainability. Beneficial insects play a critical role within this system by naturally controlling pests and aiding pollination, emphasizing the need for their conservation and further study (Bhat et al., 2024).

III. BENEFICIAL INSECTS AND THEIR ROLE IN PEST CONTROL AND POLLINATION

Insects provide numerous benefits to humans, both directly and indirectly, playing vital roles in various ecological and economic contexts. Among the most important are species that produce products of considerable economic value. Additionally, insects that facilitate agricultural pollination hold significant importance, as they directly support crop production. Beyond pollination, many beneficial insects contribute to the biological control of pest insects and plants, helping to maintain ecological balance. They also act as soil scavengers, aiding in nutrient recycling, and have applications in medicine and scientific research. Furthermore, some insects possess aesthetic value, enriching biodiversity and cultural appreciation. However, the widespread expansion of agriculture combined with the heavy use

of broad-spectrum insecticides has led to a decline in populations of natural enemies of pests, increasing the likelihood of pest outbreaks. Studies have shown that pesticide use is closely linked with a significant reduction in natural pest control services. Consequently, improving agroecosystems by fostering beneficial insect populations emerges as one of the most effective strategies to reduce dependence on chemical pesticides, thereby promoting sustainable crop production (Reddy et al., 2022).

An ecologically sustainable pest management technique involves the introduction of predators and parasitoids into fields or greenhouses, notably in the growth of vegetable crops, soft fruits and decorative plants. In an IPM strategy, natural enemies may be used with other approaches, including chemical, cultural and genetic treatments, for optimal control. Selective insecticides may be used in chemical control approaches with little impact on natural enemies. Landscape alteration may also improve biological control in agricultural areas (Gurr and Kvedaras, 2010). Natural enemies include a varied collection of creatures, including carnivores, parasitic insects, nematodes and microorganisms (Lee and Landis, 2001; Cork et al., 2009). Insect parasites (parasitoids) are mostly tiny wasps or flies and the majority are host-specific (Irtwange, 2006). Parasitic insects are parasitic just during their immature (larval) stage. Although the juvenile parasitoid eliminates a single host throughout its growth, each individual predator dispatches several victims. Predatory beetles are the most diverse insect group globally, including around 40% of all known insect species. The order Coleoptera encompasses several families, with the Carabidae (ground beetles) and Coccinellidae (lady beetles) being significant for crop protection. Lady bugs are a significant category of natural enemies (Mahr et al., 2008). Praying mantises (Mantodea) prey on a wide range of pests and natural enemies. Both nymphs and adults exhibit predatory behavior. Green insects consume vegetation, whereas brown insects prey on other insects (Brun, 2014). Lacewings of the order Neuroptera exhibit several advantageous characteristics, including a broad prey spectrum and significant voracity (McEwen et al., 2001). The Green tree ant (*Oecophylla smaragdina*) and the meat ant (*Iridomyrmex sanguineus*) prey on a wide variety of slow-moving invertebrates, including caterpillars and beetles (Chin and Brown, 2010).

Natural enemies serve as biological control agents that govern pest populations in various situations (Belmain et al., 2013). They may directly induce insect death and indirectly disrupt the feeding behaviors of pest species, hence mitigating crop damage (Macfadyen et al., 2015). The majority of natural enemies provide a supplementary function in the pollination of food crops and blooming plants. Principal pollinators include bees (including honey bees and wild bees), butterflies, moths and flies (Rondon et al., 2008). Beneficial insects play an essential part in sustainable agriculture. These insects facilitate natural pest control, pollination and the equilibrium of agroecosystems. Given the escalating risks that chemical pest management technologies provide to biodiversity, environmental health and human safety, the significance of eco-friendly alternatives has become more apparent. Parasitoids, predators and pollinators are among the most useful insect partners in agriculture. These groups not only regulate detrimental insect populations but also significantly enhance agricultural yield and preserve ecological equilibrium.

- **Parasitoids:** Parasitoids are tiny insects or their larvae that develop by living either inside or on the bodies of harmful insect hosts, ultimately causing the host's death. Unlike typical parasites that generally do not kill their hosts, parasitoids are lethal by nature. Various species of wasps and flies are the most common examples of parasitoids and they function in this role during stages such as the egg, larva, or pupa. These organisms are essential in naturally controlling pest populations in agricultural systems. As reported by Souza et al. (2019), parasitoids are found across a broad taxonomic range—occurring in at least one family of Neuroptera, two families of Lepidoptera, eleven families of Coleoptera, twenty-one of Diptera and sixty-three of Hymenoptera. Their broad distribution and ecological significance make them key agents in environmentally sustainable pest control.
- **Predators:** Insect predators are organisms that actively hunt and feed on multiple pest species throughout their lives. Unlike parasitoids, predators are not dependent on a single host to complete their development; instead, they consume several prey individuals, often daily. These beneficial insects are usually very active and are commonly observed on plant surfaces, in the soil and within nearby vegetation such as shrubs and trees. Their presence helps in maintaining pest populations at manageable levels without relying on chemical control. Common predatory insects include beetles (which prey on aphids), green lacewing larvae, praying mantises and various ground beetles. These natural enemies are a vital component of IPM systems due to their role in preserving ecological balance (Getanjaly et al., 2015).
- **Pollinators:** Pollinators are indispensable to both ecological systems and agricultural production because they enable the pollination process—essential for the reproduction of flowering plants. Insects like bees, butterflies,

flies, moths and certain beetles facilitate the transfer of pollen from the male parts (anthers) to the female parts (stigmas) of flowers. This process leads to fertilization and the formation of seeds and fruits. Crops such as sunflower, cucurbitaceous vegetables (e.g., cucumber, melon), alfalfa, coriander, cardamom, sesame and apples are highly dependent on insect pollination, especially for cross-pollination. Honey bees, in particular, are critical pollinators. They collect and transport pollen in specialized structures called pollen baskets on their hind legs and inadvertently carry pollen from flower to flower during foraging. In the case of sunflowers, studies indicate that insect pollination can enhance crop yield by up to 35%. This demonstrates the considerable contribution of pollinators to global food security and agricultural sustainability (Hill, 1997).

Given the significant ecological and agricultural roles of parasitoids, predators and pollinators, it becomes crucial to document and analyze their diversity, abundance and functional importance in different regions.

IV. CONCLUSION

Beneficial insects are indispensable allies in the sustainable management of crop pests, offering an environmentally safe and cost-effective alternative to chemical pesticides. Their roles as natural predators, parasitoids and pollinators are crucial for maintaining pest populations below damaging thresholds and enhancing overall crop productivity. This review has demonstrated that conserving and promoting beneficial insect diversity through IPM practices can significantly reduce reliance on harmful pesticides, thereby mitigating negative environmental impacts and fostering ecological resilience. This is especially important in places like Rajasthan, where farming is greatly affected by bad weather, low incomes and a higher risk of pest outbreaks, especially in the Shekhawati region. The dry weather, lack of money and low use of technology make it hard for farming to be sustainable. In these situations, the ecological benefits of helpful insects become even more important. IPM is a broad and flexible method that combines cultural, biological, chemical and genetic strategies. The biological part, which focuses on beneficial insects, is essential for keeping the environment in balance and making farming sustainable. But using broad-spectrum insecticides without thinking about it has caused these helpful insect populations to drop, making pest problems worse and putting biodiversity at risk. For farmers in Rajasthan, especially those in fragile agro-ecosystems, using eco-friendly pest control methods and protecting helpful insect species can make a big difference. In the end, use of beneficial insects not only makes farming more resilient and secure, but it also protects the ecological integrity that is necessary for farming to continue in Rajasthan and other similar areas around the world.

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