

Short Communication

Biocontrol prospects of entomopathogenic fungi against mustard insect pests : An overview

Prabhu Prasanna Pradhan¹, Ashok Kumar Sharma² and Rudra Narayan Borkakati^{3*}

¹Dept. of Entomology, M.S. Swaminathan School of Agriculture, CUTM, Paralakhemundi-761211, Odisha, India

²ICAR-IIRMR, Sewar, Bharatpur-321 303, Rajasthan, India

³AAU-ZRS, Shillongani, Nagaon-782 002, Assam, India

*Corresponding author: rudra.n.borkakati@aau.ac.in

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Abstract

Mustard crops (*Brassica* spp.) face significant yield losses from insect pests like mustard aphid (*Lipaphis erysimi*) and sawfly (*Athalia lugens proxima*). Chemical insecticides are effective but their environmental and ecological risks drive the need for sustainable alternatives. Entomopathogenic fungi (EPF), including *Lecanicillium lecanii*, *Beauveria bassiana*, *Metarhizium anisopliae*, and *Nomuraea rileyi* have shown strong potential against these pests in laboratory, greenhouse, and field studies. *L. lecanii* and *B. bassiana* exhibit high virulence, achieving 70-90% mortality of *M. persicae* and *L. erysimi* under optimal conditions (22-28°C, 80-95% humidity). Combining EPF with neem-based biopesticides or reduced chemical insecticide doses effectively suppresses pest populations below economic thresholds. However, some EPF can affect natural enemies like coccinellids, chrysopids, and predatory beetles, necessitating careful application strategies. EPF, particularly *L. lecanii* and *B. bassiana*, offer a promising, eco-friendly component for integrated pest management (IPM) in mustard crops. Further research is needed to optimize formulations, improve field persistence, and ensure compatibility with beneficial insects for broader adoption.

Keywords: *Beauveria bassiana*, biological control, *Brassica* spp., entomopathogenic fungi, *Lecanicillium lecanii*, mustard aphid (*Lipaphis erysimi*), *Metarhizium anisopliae*, sawfly (*Athalia lugens proxima*), neem formulations

Introduction

Mustard (*Brassica* spp.) is one of the most important oilseed crops cultivated in India and many parts of the world. It plays a vital role in the edible oil economy and provides livelihood security to millions of farmers. However, its productivity is severely constrained by several insect pests, of which the mustard aphid, *Lipaphis erysimi* (Kalt.), and sawfly, *Athalia lugens proxima* Klug, are the most destructive. Aphid infestation alone may cause 35-96% yield loss depending on the severity and growth stage of the crop. The sawfly larvae feed voraciously on foliage, leading to substantial reductions in photosynthetic area and crop vigor. Traditionally, chemical insecticides have been the major tool for the management of these pests. Although effective, their indiscriminate use has led to several problems including development of resistance in insect populations, resurgence of secondary pests, residues in food and environment, and adverse effects on natural enemies and pollinators. With increasing emphasis on sustainable agriculture, there is an urgent need to explore eco-friendly and safer alternatives for mustard pest management.

Among the various biological control options, entomopathogenic fungi (EPF) such as *Lecanicillium lecanii*, *Beauveria bassiana*, *Metarhizium anisopliae*, and *Nomuraea rileyi* have gained importance due to their pathogenicity against a wide range of insect pests. These fungi infect and kill insects through contact, often under favorable temperature and humidity conditions, and thus offer potential as biocontrol agents in integrated pest management (IPM) programs. Several studies conducted under laboratory, greenhouse, and field conditions have demonstrated the effectiveness of EPF against mustard pests, particularly aphids, either alone or in combination with botanicals like neem-based formulations. However, the successful field application of entomopathogenic fungi depends on multiple factors such as environmental conditions, formulation technology, application methods, and compatibility with other IPM components. Moreover, their impact on non-target organisms, especially natural enemies such as coccinellid beetles and lacewings, needs careful evaluation to ensure ecological safety.

This review aims to synthesize the available information on the efficacy of entomopathogenic fungi against major

insect pests of mustard and their interaction with natural enemies. It also highlights the scope and limitations of these fungi in mustard pest management and discusses their role in sustainable IPM strategies.

Efficacy of entomopathogenic fungi against major insect pests of mustard

Several studies have highlighted the effectiveness of entomopathogenic fungi such as *Lecanicillium lecanii* (syn. *Verticillium lecanii*), *Beauveria bassiana*, and *Metarhizium anisopliae* against aphids and other insect pests of mustard. Early investigations by Easwaramoorthy and Jayaraj (1977) demonstrated the potential of *L. lecanii* against *Myzus persicae*, while Khalil *et al.* (1985) reported its high efficacy under greenhouse conditions with favorable humidity and temperature. Similarly, Sukhova (1987) and Harper and Huang (1987) confirmed that *L. lecanii* and *B. bassiana* could achieve up to 98% control of *M. persicae* when environmental conditions supported fungal growth. Pathogenicity assays revealed high mortality across aphid species. For instance, Hincapie *et al.* (1990) and Feng *et al.* (1990) showed that both *L. lecanii* and *B. bassiana* were pathogenic to multiple aphid species, with *B. bassiana* often acting more rapidly. Further bioassays confirmed dose-dependent mortality responses (Vehrs & Parrella, 1991; Karindah *et al.*, 1996; Safavi *et al.*, 2002), with LC50 values ranging between 10^4 and 10^5 conidia/ml depending on the host species.

Comparative virulence studies indicated that *L. lecanii* frequently outperformed *B. bassiana*. For example, Hayden *et al.* (1992) reported an LT50 of only 2.4 days for *L. lecanii* against *Sitobion avenae*, compared to 9.5 days for *B. bassiana*. Likewise, Miranpuri and Khachatourians (1995) found *L. lecanii* more pathogenic to aphids such as *S. avenae* and *Acyrtosiphon macrosiphum*. However, *B. bassiana* also proved effective in field conditions, as shown by Wang and Khudsen (1993), where it caused over 80% aphid mortality and significantly reduced fecundity. Neem-based formulations and extracts were also evaluated either alone or in combination with fungal pathogens. Patnaik *et al.* (1987), Bhathal and Singh (1994), and Gupta *et al.* (2001) found neem oil and commercial neem products (eg. Neemark, Neemazal, Nimbicidine) effective against *Lipaphis erysimi*, although their efficacy was often short-lived compared to synthetic insecticides. Field trials by Sontakke and Dash (1996) and Lal (1996) further supported the role of neem formulations in reducing aphid populations and improving mustard yield. More recent studies confirm the continuing relevance of entomopathogens. Ekesi *et al.* (2000, 2002) and Saranya

et al. (2010) demonstrated the pathogenicity of different isolates of *B. bassiana*, *L. lecanii*, and *M. anisopliae* against *Aphis craccivora* and *L. erysimi*, with mortality rates exceeding 90% at higher concentrations. Ujjan *et al.* (2012) and Alate (2012) further reported strain-specific variations in virulence, with *L. lecanii* and *M. anisopliae* performing best against lucerne and mustard aphids.

Field studies by Meena *et al.* (2013) highlighted the practical integration of entomopathogenic fungi with botanical and cultural practices. Treatments with *B. bassiana*, *L. lecanii*, and *M. anisopliae* not only reduced aphid populations significantly but also proved safe for natural enemies and pollinators. Sajid *et al.* (2017) and Deka *et al.* (2017) confirmed that *M. anisopliae* and *B. bassiana* remain promising biocontrol agents, while Vishvendra *et al.* (2018) noted that chemical insecticides like thiamethoxam and imidacloprid still outperformed fungal agents in certain cases. Overall, evidence suggests that entomopathogenic fungi, particularly *L. lecanii*, *B. bassiana*, and *M. anisopliae*, hold considerable potential as eco-friendly alternatives to chemical insecticides in the management of mustard aphids and related pests. Their efficacy, however, is strongly influenced by environmental factors (humidity, temperature), strain specificity, and application strategies. Integration with neem-based formulations and other eco-friendly measures may enhance their consistency under field conditions.

Efficacy of entomopathogenic fungi against natural enemies

The use of entomopathogenic fungi (EPF) for pest management raises concerns regarding their potential non-target effects on beneficial insects, particularly coccinellid predators. Several studies have reported varying levels of susceptibility of ladybird beetles and other natural enemies to fungal pathogens, depending on species, developmental stage, fungal isolate, and environmental conditions. Fuxa and Tanada (1987) observed that insects under stress were more vulnerable to *Beauveria bassiana* infections. They suggested that *B. bassiana* could act as an important mortality factor for coccinellids such as *Coccinella septempunctata*, while its impact on other species with limited contact with soil or pathogen-rich habitats would be relatively less significant. The relationship, however, was found to vary both spatially and temporally. Similarly, Magalhaes *et al.* (1988) reported that adults of *Coleomegilla maculata* and *Eriopis connexa* were susceptible to direct exposure of *B. bassiana*. Further, James and Lighthart (1994) demonstrated that *B. bassiana*, *Metarhizium anisopliae*, and *Paecilomyces fumosoroseus* were pathogenic to first-

Table 1: Efficacy of entomopathogenic fungi and neem formulations against mustard aphid and related pests

Target pest(s)	Entomopathogen / Biopesticide	Key Findings	Reference
<i>Myzus persicae</i> pathogenicity against aphids.	<i>Lecanicillium lecanii</i> (syn. <i>Verticillium lecanii</i>)	Easwaramoorthy & Jayaraj (1977)	Demonstrated strong
Aphids	<i>L. lecanii</i>	High efficacy under greenhouse conditions with favorable humidity and temperature.	Khalil <i>et al.</i> (1985)
<i>M. persicae</i>	<i>L. lecanii</i> , <i>Beauveria bassiana</i>	Up to 98% control under conducive environment.	Sukhova (1987)
<i>M. persicae</i>	<i>B. bassiana</i>	Achieved high mortality when humidity supported fungal growth.	Harper & Huang (1987)
Aphids	<i>L. lecanii</i>	High pathogenicity across aphid species.	Hincapie <i>et al.</i> (1990)
Cereal aphids	<i>L. lecanii</i> , <i>B. bassiana</i>	Both fungi pathogenic; <i>B. bassiana</i> acted more rapidly.	Feng <i>et al.</i> (1990)
Ornamentals aphids	<i>L. lecanii</i> , <i>B. bassiana</i>	Dose-dependent mortality, $LC_{50} = 10^4 - 10^5$ conidia/ml.	Vehrs & Parrella (1991)
<i>Aphis gossypii</i>	<i>L. lecanii</i>	High virulence in laboratory assays.	Karindah <i>et al.</i> (1996)
<i>Acyrtosiphon pisum</i>	<i>L. lecanii</i>	High mortality, LC_{50} in range of $10^4 - 10^5$ conidia/ml.	Safavi <i>et al.</i> (2002)
<i>Sitobion avenae</i>	<i>L. lecanii</i> vs. <i>B. bassiana</i>	LT_{50} of 2.4 days for <i>L. lecanii</i> vs. 9.5 days for <i>B. bassiana</i> .	Hayden <i>et al.</i> (1992)
<i>S. avenae</i> ,	<i>L. lecanii</i> , <i>B. bassiana</i>	<i>L. lecanii</i> more pathogenic than <i>B. bassiana</i> .	Miranpuri & Khachatourians (1995)
<i>Acyrtosiphon macrosiphum</i>			
Russian wheat aphid	<i>B. bassiana</i>	>80% mortality; fecundity significantly reduced.	Wang & Knudsen (1993)
Mustard sawfly (<i>Athalia proxima</i>)	Neem oil	Caused developmental abnormalities and mortality.	Patnaik <i>et al.</i> (1987)
<i>L. erysimi</i>	Neem formulations	Effective but short-lived compared to synthetic insecticides.	Bhathal & Singh (1994)
<i>L. erysimi</i>	Neemak, Neemazal, Nimbicidine	Effective in reducing aphid populations.	Gupta <i>et al.</i> (2001)
Mustard aphids	Neem formulations	Reduced aphid populations and improved yield.	Sontakke & Dash (1996)
<i>L. erysimi</i>	Neem formulations	Bio-efficacy confirmed in field trials.	Lal (1996)
<i>Aphis craccivora</i> ,	<i>B. bassiana</i> , <i>L. lecanii</i> ,	Mortality >90% at higher concentrations.	Ekesi <i>et al.</i> (2000, 2002)
<i>L. erysimi</i>	<i>Metarhizium anisopliae</i>		
<i>A. craccivora</i>	<i>B. bassiana</i> , <i>L. lecanii</i> , <i>M. anisopliae</i>	All isolates pathogenic; mortality rates >90%.	Saranya <i>et al.</i> (2010)
<i>L. erysimi</i>	<i>L. lecanii</i> , <i>M. anisopliae</i>	Strain-specific variations in virulence.	Ujjan & Shahzad (2012)
Lucerne aphids	<i>L. lecanii</i> , <i>M. anisopliae</i>	High pathogenicity against aphids.	Alate (2012)
Mustard aphids	<i>B. bassiana</i> , <i>L. lecanii</i> , <i>M. anisopliae</i>	Reduced aphid populations; safe for natural enemies.	Meena <i>et al.</i> (2013)
<i>L. erysimi</i>	<i>B. bassiana</i> , <i>M. anisopliae</i> , <i>Bacillus thuringiensis</i>	Confirmed high mortality in lab assays.	Sajid <i>et al.</i> (2017)
<i>L. erysimi</i>	<i>B. bassiana</i> , <i>M. anisopliae</i>	Promising biocontrol agents under Assam conditions.	Deka <i>et al.</i> (2017)
<i>L. erysimi</i>	Insecticides vs. entomopathogens	Chemical insecticides (<i>thiamethoxam</i> , <i>imidacloprid</i>) outperformed fungal agents in some cases.	Vishwendra <i>et al.</i> (2018)

Table 2: Efficacy of entomopathogenic fungi (epf) against natural enemies

Natural enemy tested	Entomopathogenic Fungus (EPF)	Key Findings	Reference
<i>Coccinella septempunctata</i>	<i>Beauveria bassiana</i>	Stressed insects more vulnerable; <i>B. bassiana</i> an important mortality factor for coccinellids; impact varied spatially & temporally.	Fuxa & Tanada (1987)
<i>Coleomegilla maculata</i> , <i>Eriopis connexa</i>	<i>B. bassiana</i>	Adults susceptible to direct exposure.	Magalhaes <i>et al.</i> (1988)
<i>Hippodamia convergens</i> (1 st instar larvae)	<i>B. bassiana</i> , <i>Metarhizium anisopliae</i> , <i>Paecilomyces fumosoroseus</i> , <i>Nomuraea rileyi</i>	First three fungi pathogenic; <i>N. rileyi</i> non-pathogenic.	James & Lighthart (1994)
<i>C. septempunctata</i>	<i>B. bassiana</i> (1×10^8 conidia/ml)	Moderately susceptible.	Delete <i>et al.</i> (1995)
<i>C. septempunctata</i>	<i>B. bassiana</i>	Reported susceptibility.	Manjula & Padmavathamma (1996)
<i>C. septempunctata</i>	6 isolates of <i>B. bassiana</i>	All isolates highly pathogenic under lab conditions.	Masarrat & Humayun (1996)
<i>Serangium parcesetosum</i> (2 nd instar larvae)	<i>B. bassiana</i> , <i>P. fumosoroseus</i>	More susceptible to <i>B. bassiana</i> than <i>P. fumosoroseus</i> .	Poprawski <i>et al.</i> (1998)
<i>C. septempunctata</i>	<i>Verticillium lecanii</i> (HRI 1.72), <i>P. fumosoroseus</i>	Very little effect; few infections observed.	Yeo (2000)
Coccinellids (general)	<i>B. bassiana</i>	Most fungal diseases attributed to <i>B. bassiana</i> .	Ghazavi <i>et al.</i> (2005)
<i>C. septempunctata</i> , <i>Chrysoperla carnea</i> , <i>Dicyphus tamaninii</i>	<i>B. bassiana</i> , <i>M. anisopliae</i>	<i>B. bassiana</i> non-pathogenic; <i>M. anisopliae</i> pathogenic only to <i>C. carnea</i> and <i>D. tamaninii</i> .	Thungrabeab & Tongma (2007)
<i>C. septempunctata</i>	<i>B. bassiana</i> (alone/ combined with EPF)	Found unsafe for coccinellids.	Gauns (2012)
Coccinellids in okra ecosystem	<i>B. bassiana</i> 1.15% WP (alone/combined)	Detrimental effects; reduced ladybird beetle survival.	Palthiya (2014)

instar larvae of *Hippodamia convergens*, while *Nomuraea rileyi* did not cause infections. Likewise, Delete *et al.* (1995) considered *C. septempunctata* to be moderately susceptible to *B. bassiana* at a concentration of 1×10^8 conidia/ml. Manjula and Padmavathamma (1996) also reported susceptibility of *C. septempunctata* to *B. bassiana*. Supporting this, Masarrat and Humayun (1996) found that six isolates of *B. bassiana* were highly pathogenic to the same predator under laboratory conditions.

Poprawski *et al.* (1998) revealed that second-instar larvae of *Serangium parcesetosum* were more susceptible to *B. bassiana* compared to *P. fumosoroseus* when exposed directly to conidia. In contrast, Yeo (2000) found that isolates of *Verticillium lecanii* (HRI 1.72) and *P. fumosoroseus* had very little effect on *C. septempunctata*, with only a few individuals succumbing to infection. Ghazavi *et al.* (2005) noted that fungal diseases in coccinellids were mostly attributed to *B. bassiana*. Research from Thailand by Thungrabeab and Tongma (2007) showed that *B. bassiana* was non-pathogenic to *C. septempunctata*, *Chrysoperla carnea*, and *Dicyphus tamaninii*, whereas *M. anisopliae* was pathogenic only to *C. carnea* and *D. tamaninii*. However, Gauns (2012) concluded that *B. bassiana*, alone or in combination with other EPF, was unsafe for coccinellid predators including *C. septempunctata*. Similarly, Palthiya (2014), while testing different EPF formulations in okra, reported that *B. bassiana* 1.15% WP, both alone and in combination, had detrimental effects on coccinellid survival, as reflected by reduced numbers of surviving ladybird beetles. Collectively, these findings highlight the variability in EPF pathogenicity toward natural enemies. While some isolates appear relatively safe, others can negatively affect predator survival. Therefore, careful evaluation of fungal isolates for their selectivity is crucial before recommending their inclusion in integrated pest management (IPM) programs.

Entomopathogenic fungi, natural enemies, and weather interactions in the management of mustard pests

Research on mustard and other vegetable ecosystems has highlighted the critical role of habitat manipulation and entomopathogenic fungi in regulating pest populations while conserving natural enemies. Borkakati *et al.* (2019a) demonstrated that crop habitat manipulation significantly enhanced the activity of natural enemies against key pests of the cabbage ecosystem, while similar approaches were also found effective in brinjal (Borkakati *et al.*, 2019b). Studies on rapeseed–mustard further

emphasized the potential of entomopathogenic fungi as biocontrol agents, where *Lecanicillium lecanii* and *Beauveria bassiana* showed considerable pathogenicity against aphids and other pests of *Brassica campestris* var. toria (Pradhan *et al.*, 2020a). Detailed surveys conducted in Assam documented the diversity of insect pests of mustard and their associated natural enemies (Pradhan *et al.*, 2020b), while subsequent investigations revealed the seasonal incidence patterns of these insect–natural enemy complexes in relation to meteorological parameters (Pradhan *et al.*, 2020c). The influence of abiotic factors such as temperature and relative humidity on insect population dynamics has also been well established in other cropping systems, including the seasonal abundance of water hyacinth weevils (Borkakati *et al.*, 2007) and brinjal shoot and fruit borer (*Leucinodes orbonalis*) (Borkakati *et al.*, 2021). Parallel findings from cabbage (Ahmed *et al.*, 2016) and Bhut Jolokia (Begam *et al.*, 2016) ecosystems further strengthen the evidence that pest incidence and natural enemy activity are strongly governed by climatic parameters. Collectively, these studies underscore the importance of integrating habitat manipulation, microbial biocontrol agents, and weather-based pest forecasting into sustainable pest management strategies for mustard and related crops in Assam and adjoining regions.

Conclusion

Entomopathogenic fungi (EPF), including *Lecanicillium lecanii*, *Beauveria bassiana*, and *Metarhizium anisopliae*, are highly effective, eco-friendly biocontrol agents for managing mustard aphids and other insect pests. Studies confirm their strong pathogenicity, achieving 80–90% pest mortality under optimal conditions, with *L. lecanii* often outperforming others in speed and efficacy against aphids. Field performance depends on factors like humidity, temperature, strain selection, and application techniques. Combining EPF with neem-based formulations or cultural practices enhances their reliability, providing a sustainable alternative to chemical insecticides. However, their impact on natural enemies, such as coccinellid beetles, varies by species, developmental stage, and fungal strain, with some isolates showing significant pathogenicity in lab settings while others have minimal effects. This variability highlights the need for careful strain selection to ensure compatibility with beneficial insects in integrated pest management (IPM) frameworks. In conclusion, EPF offer a promising solution for sustainable mustard pest control, but their effective use requires strain-specific optimization, improved formulations, and field validation to balance efficacy with ecological safety.

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