From Pests to Partners: Leveraging Insect Diversity and Entomopathogenic Fungi In Cashew Agroecosystems for Sustainable Pest Management

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Abstract

Cashew experiences significant yield reductions due to insect pest attacks. Although chemical insecticides have long been used for insect pest control, their continued use has increased concerns about chemical residues in cashew apples and nuts. This highlights the urgent need for safer and more sustainable pest management approaches. This study explores more sustainable solutions by examining insect diversity and entomopathogenic fungi (EPF) in cashew orchards across selected cashew growing locations in Ghana. Insects were sampled using visual hand-height and pyrethroid knockdown methods. Collected insect specimens were incubated for pathogen emergence. Insects in the order Hemiptera dominated the insect species sampled using the hand-height method, and these were mostly insect pests, such as *Helopeltis* spp., *Anoplocnemis curvipes* and *Pseudotheraptus devastans*. However, a natural predator, *Oecophylla longinoda*, a Hymenoptera, was the most abundant insect species using the pyrethroid knockdown method. EPF including species of *Metarhizium*, *Beauveria*, *Aspergillus*, *Fusarium*, and *Paecilomyces* were isolated, with some strains demonstrating high virulence under laboratory conditions. Notably, CRIG EPF3 achieved complete mortality of *P. devastans* and *Helopeltis* spp. within five days, while the other isolates achieved similar results within 15 days. These findings highlight the potential of native natural enemies including EPF isolates, as eco-friendly biocontrol agents for integration into Integrated Pest Management (IPM) programs.

Keywords: Insect species diversity, biocontrol, entomopathogenic fungi, cashew, Integrated Pest Management (IPM)

Introduction

Cashew, *Anacardium occidentale* L. is a crop of growing commercial importance in the tropics. It is valued for both its nuts and by-products. However, production is significantly constrained by insect pests that attack different plant parts, including stems and leaves as well as inflorescences, apples, and nuts causing significant losses at different growth stages (Dwomoh et al., 2008; Adeniyi & Asogwa, 2023). Among the most damaging are the coreid bugs, *Pseudotheraptus devastans* and *Anoplocnemis curvipes*, the tea mosquito bug, *Helopeltis* spp., the cashew stem girdler, *Analeptes trifasciata*, and fruit feeders such as *Pachnoda* spp., which contribute to premature fruit drop and shoot dieback (Dwomoh et al., 2008; Muntala et al., 2021).

Chemical insecticides remain the most widely used control measure, however, their heavy reliance poses long-term challenges, including residue risks, environmental hazards, pesticide resistance and regulatory restrictions (Dwomoh et al., 2007; Carvalho, 2017). At the same time, cashew orchards support a diverse community of organisms that play ecological roles ranging from pests to beneficial organisms such as predators, pollinators, and natural enemies, including the weaver ant, *Oecophylla longinoda* and entomopathogenic fungi (EPF) (Way & Khoo, 1992; Dwomoh et al. 2009; Vasanthi et al., 2014; Lacey et al., 2015).

Given these concerns, Integrated Pest Management (IPM) has gained prominence as a strategy that combines cultural, biological, and chemical tools to balance productivity with sustainability. Biological control in particular offers strong potential, with predators, parasitoids, and EPF receiving increasing attention as eco-friendly alternatives (Ballal & Verghese, 2015; Heraty, 2017; Bamisile et al., 2021; Sharma et al., 2023). EPF are naturally occurring fungi that infect and kill insects, with *Beauveria bassiana*, *Metarhizium anisopliae*, and *Isaria fumosorosea* among the best-studied agents (Zimmermann, 2007a; Mantzoukas & Eliopoulos, 2020). Previous studies have demonstrated their pathogenicity against cashew pests such as *Helopeltis* spp. and the cashew stem borer (Ambethgar & Mahalingam 2002; Sahayaraj & Namasivayam, 2008; Sahu & Sharma 2008).

Given the need to explore natural enemies for cashew insect pest management, the present study investigates insect diversity in Ghanaian cashew orchards. We document the presence of naturally occurring EPFs and evaluate their virulence under laboratory conditions. Recognising insects as both threats and ecological partners, the study underscores the importance of harnessing biodiversity for sustainable cashew pest management.

Materials and Methods

Insect sampling

Insect diversity was assessed using two approaches: the visual hand-height method and the pyrethroid knockdown technique. For the hand-height method, insects were counted and collected directly from trees in the field following the procedure described by Collingwood and Marchart (1971). The knockdown method was then used to complement visual observations and capture additional species. Four major cashew-growing regions of Ghana namely, Ashanti, Bono, Eastern, and Savannah, were selected and the data pooled. All collected insects were transferred to the insectary at the Cocoa Research Institute of Ghana (CRIG) for further study.

Fungal isolation and identification

Dead insects from the field collections were incubated to encourage pathogen growth. Pathogens were isolated and cultured on selective media (Agyare et al., unpublished). Potential EPF were sub-cultured on Sabouraud Dextrose Agar (SDA) until pure isolates were obtained. Morphological identification was carried out using microscopic examination and taxonomic keys from the International Mycological Institute (IMI, 1993).

Laboratory evaluation of selected indigenous fungal isolates

Five fungal isolates (EPF1, EPF2, EPF3, EPF4, and EPF6) were selected for laboratory bioassays. To prepare the inoculum, spore suspensions were obtained by flooding culture plates with sterile distilled water (SDW). Spore concentration was adjusted to 4×10^4 spores/ml using a hemocytometer (CKSLAB CK-CB-30). For each isolate, 10 insects representing *Pseudotheraptus devastans*, *Anoplocnemis curvipes*, *Clavigralla tomentosicollis*, and *Helopeltis* spp. were sprayed with the suspension in glass vials using a 250 ml handheld sprayer. Controls received SDW. Mortality was recorded daily for 15 days, and results were expressed as percentages. Each treatment was replicated three times.

Results

Insect diversity

The composition of insect communities varied according to the sampling method used. The visual hand-height counts indicated that Hemiptera were the most abundant group, representing nearly half of all individuals recorded (Table 1). Within this order, *Helopeltis* spp. was the dominant insect species. Other important insect pests recorded were *Anoplocnemis curvipes* and *Pseudotheraptus devastans.* Insect orders such as Coleoptera, Hymenoptera, and Lepidoptera were present in lower proportions.

Table 1. Insect diversity in cashew orchards using visual hand-height method

Insect Order	**Abundance (%)**	**Dominant species**
Coleoptera	18	Unidentified leaf beetle
Dictyoptera	1	*Sphodromantis lineola*
Diptera	5	*Drosophila melanogaster*
Hemiptera	45	*Helopeltis* spp.
Hymenoptera	15	*Camponotus* spp.
Lepidoptera	10	*Acrocerops* sp.
Odonata	1	Unidentified sp.
Orthoptera	5	*Zonocerus variegata*

By contrast, the pyrethroid knockdown method revealed a different pattern in insect order abundance (Table 2). Here, Hymenoptera were the most dominant, largely due to high populations of the weaver ant *Oecophylla longinoda* (Table 2). Other prominent species in this order were the *Camponotus* spp. Orthoptera and Hemiptera were also well represented, while spiders (Araneae), Dipterans, and Coleopterans accounted for smaller fractions of the total catch (Table 2).

Table 2. Insect diversity in cashew orchards using the pyrethroid knockdown method

Insect Order	**Abundance (%)**	**Dominant species**
Araneae	5	Unidentified spider
Blattodea	1	*Arenivaga investigata*

Coleoptera	3	Unidentified leaf beetle
Diptera	2	*Musca domestica*
Hemiptera	19	*Helopeltis* spp.
Hymenoptera	52	*Oecophylla longinoda*
Orthoptera	18	*Phaneroptera sparsa* F.

Isolation of fungal isolates

A range of fungal taxa were recovered from dead insects incubated. Morphological features including mycelial growth and spore patterns, were consistent with those of species belonging to *Metarhizium*, *Fusarium*, *Beauveria*, *Aspergillus*, and *Paecilomyces*. Among these, *Metarhizium*- and *Fusarium*-like isolates were the most frequently encountered (Figure 1). This finding supports the hypothesis that cashew agroecosystems harbour naturally occurring entomopathogenic fungi with potential for pest suppression.

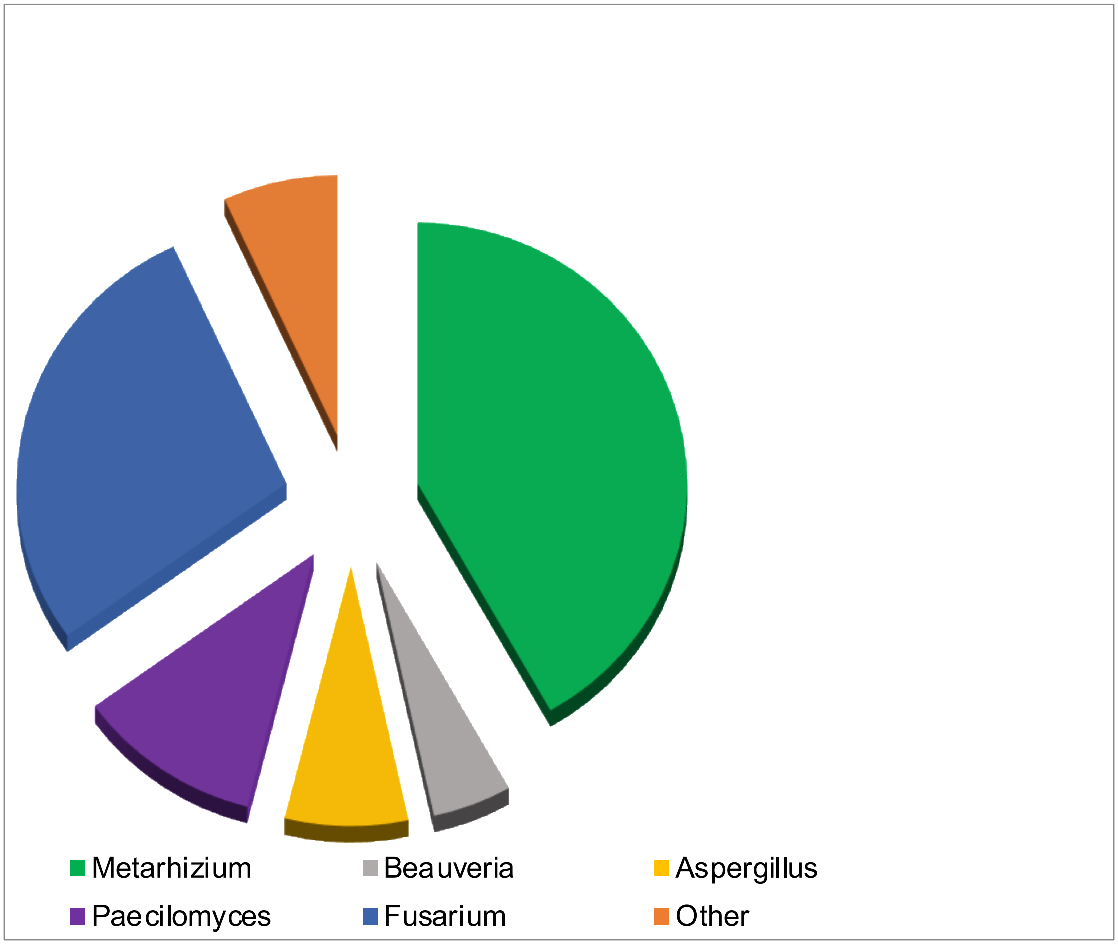

Figure 1. Pie chart showing the proportions of fungal isolates from insect cadavers

Pathogenicity of selected isolates

Laboratory bioassays demonstrated clear differences in virulence among the fungal isolates. CRIG EPF3 was the most virulent isolate, causing 100 % mortality in *P. devastans* and *Helopeltis* spp. within five days (Tables 3 and 5). Other isolates were slower, nevertheless, they achieved complete mortality of target pests within 15 days (Tables 3-6).

Table 3. Percentage mortality of *Pseudotheraptus devastans* over a 15-day period following application of different fungal isolates

Pathogen*	**5 DAI**	**10 DAI**	**15 DAI**
CRIG EPF1	85	100	0
CRIG EPF2	75	92	100
CRIG EPF3	100	0	0
CRIG EPF4	40	70	100
CRIG EPF6	38	100	0

*Pathogen with (-) was not evaluated. DAI – Day after inoculation

Table 4. Percentage mortality of *Anoplocnemis curvipes* over a 15-day period following application of different fungal isolates

Pathogen*	5 DAI	10 DAI	15 DAI
CRIG EPF1	-	-	-
CRIG EPF2	33	100	0
CRIG EPF3	85	100	0
CRIG EPF4	10	90	100
CRIG EPF6	83	100	0

*Pathogen with (-) was not evaluated. DAI – Day after inoculation

Table 5. Percentage mortality of *Helopeltis* sp. over a 15-day period following application of different fungal isolates

Pathogen*	5 DAI	10 DAI	15 DAI
CRIG EPF1	-	-	-
CRIG EPF2	100	0	0
CRIG EPF3	100	0	0
CRIG EPF4	50	100	0
CRIG EPF6	-	-	-

*Pathogen with (-) was not evaluated. DAI – Day after inoculation

Table 6. Percentage mortality of *Clavigralla tomentosicollis* over a 15-day period following application of different fungal isolates

Pathogen*	5 DAI	10 DAI	15 DAI
CRIG EPF1	-	-	-
CRIG EPF2	77	100	0
CRIG EPF3	-	-	-
CRIG EPF4	30	90	100
CRIG EPF6	8	45	100

*Pathogen with (-) was not evaluated. DAI – Day after inoculation

Discussion

The present study provides new insights into the diversity of insect communities and their associated entomopathogenic fungi (EPF) in Ghanaian cashew orchards. The dominance of Hemiptera observed in visual counts aligns with previous findings that coreid bugs are among the most abundant and destructive pests of cashew (Dwomoh et al., 2008; Muntala et al., 2021). However, the prominence of Hymenoptera in the knockdown samples highlights the ecological importance of beneficial insects such as *Oecophylla longinoda*, which are known to contribute to pest suppression and pollination (Way & Khoo, 1992, Dwomoh et al., 2009). Their high representation here underscores their potential role as “partners” in pest suppression (Thurman et al., 2019). The contrasting results emphasize that while direct observation methods are more effective for capturing conspicuous, mobile pests, knockdown techniques may better reflect the abundance of insects such as ants, which nest within tree canopies and above hand-height. These findings suggest that a combination of methods provides a more comprehensive assessment of insect diversity and ecological interactions in cashew agroecosystems.

The isolation of *Metarhizium*, *Fusarium*, *Beauveria*, and other fungi from field-collected insects confirms that cashew agroecosystems harbour a natural reservoir of entomopathogenic fungi. *Beauveria bassiana* and *Metarhizium anisopliae* are well documented as biocontrol agents (Zimmermann, 2007a; Bamisile et al., 2021). The high prevalence of *Metarhizium* is consistent with its well-documented role as a common entomopathogen infecting a wide range of insect pests (Roberts & St. Leger, 2004; Zimmermann 2007b; Thube et al. 2022). The presence of *Beauveria* and *Paecilomyces* spp. further highlights the diversity of naturally occurring fungi capable of regulating insect populations, supporting earlier reports of their pathogenic activity against hemipteran pests (Meyling & Eilenberg, 2007; Zimmermann 2008). However, *Fusarium* species, though traditionally known as plant pathogens, have increasingly been reported as opportunistic EPF in agricultural ecosystems, potentially contributing to insect mortality (Tosi et al. 2015; Sharma and Marques 2018; da Silva Santos et al. 2020). These findings suggest that EPFs are important components of the cashew landscape and could be harnessed in integrated pest management (IPM) strategies to reduce reliance on synthetic insecticides.

Laboratory assays demonstrated that isolates CRIG EPF3 had particularly high virulence against multiple cashew pests. The virulence of CRIG EPF3 against *P. devastans* and *Helopeltis* spp. suggests that certain indigenous strains may be as effective as commercial biocontrol products. Such rapid action is consistent with previous studies where *Metarhizium anisopliae* and *Beauveria bassiana* isolates demonstrated fast-acting infection processes leading to significant pest mortality (Ekesi et al. 2002; Bugeme et al., 2008). The remaining isolates, though slower than CRIG EPF 3, still achieved total mortality within 15 days, which aligns with the typical infection timeline of entomopathogenic fungi under laboratory conditions (Meyling & Eilenberg, 2007; Lacey et al., 2015). This observed duration of activity between isolates may be attributed to factors such as variation in spore adhesion, cuticle penetration, and/or toxin production (Mantzoukas & Eliopoulos, 2020). These findings highlight the variability in virulence among EPF isolates and suggest that rapid-acting strains such as CRIG EPF 3 could be prioritized for field application.

Conclusion and recommendation

This study demonstrates that sampling methods influence insect diversity assessments. It also confirms the presence of diverse insect communities in cashew orchards and highlights the potential of indigenous fungal pathogens, particularly CRIG EPF3 as a promising candidate for biocontrol applications. Beyond their direct pathogenic effects, these fungi contribute to ecological balance by interacting with other natural enemies. Their integration into pest management strategies could reduce reliance on synthetic insecticides, thus mitigating the risks of chemical residues in cashew produce and preserving environmental and human health. Future research would focus on molecular identification of isolates, formulation development, and large-scale field trials to evaluate persistence, efficacy, and farmer adoption potential.

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