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Harnessing weaver ants for sustainable pest management in agriculture: A systematic review

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Abstract

Weaver ants are increasingly recognised as effective biological control agents for sustainable pest management. They include the African weaver ant, Oecophylla longinoda Latreille, found in sub-Saharan Africa and the green tree ant, O. smaragdina Fabricius, which is common in Southeast Asia and Australia. Native to their regions, both species are arboreal, territorial and aggressive predators that support sustainable pest management in tropical and subtropical tree-based agroecosystems. They are traditionally used in perennial tree crops to provide a natural alternative to synthetic chemical pesticides, contributing to environmentally friendly farming practices. This review employed a systematic literature review (SLR) approach, guided by the preferred reporting items for systematic reviews and meta-analyses (PRISMA) framework to identify, screen and assess studies on weaver ants. It synthesises current scientific literature and field-based evidence on the use of weaver ants in integrated pest management (IPM) programmes. The review examines the ecological roles of weaver ants in pest management, biodiversity enhancement and overall ecosystem health. It also highlights economic benefits such as increased yields, improved crop quality and access to higher-value markets. However, the large-scale use of weaver ants faces challenges, including difficulties in colony propagation and a limited understanding of interspecific interactions. Key knowledge gaps remain in colony establishment, long-term ecological impacts and the scalability of ant-based biological control in commercial farming. This review also highlights future research priorities to optimise the use of weaver ants. As an underutilised biological resource, these ants offer strong potential to enhance the resilience, productivity and sustainability of tropical agriculture.

Introduction

Sustainable pest management is gaining importance in agriculture due to the harmful effects of synthetic chemical pesticides. Their overuse has contributed to biodiversity loss, pest resistance, disruption to non-target species and health risks to humans (Pimentel, 2005; Pretty and Bharucha, 2015). As a result, integrated pest management (IPM) strategies that emphasise ecological and biological methods are gradually promoted as sustainable strategies. A key component of IPM is biological control, which involves the use of natural enemies, such as predators, parasitoids, and pathogens, to manage insect pest populations (Shrewsbury and Leather, 2012; van Lenteren, 2012). Unlike synthetic chemical pesticides, biological control agents can establish themselves in the environment, reproduce and provide long-term pest suppression with minimal ecological disruption (Shrewsbury and Leather, 2012; Ratto et al., 2022). Furthermore, biological control can reduce the need for chemical interventions, thereby preserving beneficial insect populations, maintaining soil and water quality and enhancing overall ecosystem resilience (van Lenteren, 2012).

Weaver ants of the genus Oecophylla are among the most promising biological control agents. These ants are renowned due to their predatory behaviour and ability to suppress a wide range of insect pests (Peng and Christian, 2007; Olotu et al., 2013; Materu et al., 2014; Offenberg, 2015). The genus comprises two main species, which are the African weaver ant (AWA), Oecophylla longinoda Latreille, native to sub-Saharan Africa (SSA) (Wetterer, 2017) and the green tree ant (GTA), O. smaragdina Fabricius, found across Southeast Asia and Australia (Peng and Christian, 2007). In SSA, long before the advent of modern synthetic chemical pesticides, AWA were an integral part of agroforestry and fruit orchard management, providing effective pest control and supporting environmentally friendly farming systems (Van Mele, 2008; Wetterer, 2017). They have been particularly successful in perennial tree crops such as citrus, mango, cashew, and cocoa, contributing to higher yields and improved crop quality at reduced costs (Dwomoh et al., 2009; Olotu et al., 2013; Materu et al., 2014; Offenberg et al., 2013).

Similarly, in Southeast Asia and Australia, GTA plays a vital role in sustainable agriculture, particularly in citrus, mango, cashew, coconut and cacao orchards (Peng and Christian, 2005a; Offenberg et al., 2013). Field studies across the region have shown that GTA significantly reduces pest populations in these crops, while also enhancing fruit quality and reducing reliance on synthetic chemical pesticides (Peng and Christian, 2004; Exélis et al., 2023; Priya and Nalini, 2024). They suppress insect pests through both direct predation and the release of volatile kairomones that deter oviposition. Notably, 1-octanol, a compound produced by GTA, has been identified as a potent deterrent against fruit flies (Kempraj et al., 2022).

In addition to pest control, both weaver ant species provide valuable ecosystem services. They support biodiversity, enhance pollination, and improve smallholder livelihoods by reducing the use of synthetic chemical pesticides and enabling access to higher-value markets (Van Mele et al., 2007; Ratto et al., 2022).

Despite growing recognition of weaver ants as effective biological control agents, their adoption in large-scale commercial farming remains limited. Colony management requires specialised knowledge and labour, making long-term maintenance challenging for many growers (Peng et al., 2013). Although some innovations, such as pupae transplantation, have shown promise by boosting colony size by up to tenfold within weeks (Ouagoussounon et al., 2013), their potential for large-scale application remains underexplored. Broader adoption is further limited by an incomplete understanding of the ecological interactions involving weaver ants. For instance, weaver ants may tend honeydew-producing pests such as aphids and scale insects, potentially exacerbating infestations (Styrsky and Eubanks, 2007). Moreover, their effects on non-target beneficial insects remain poorly understood, raising concerns about possible unintended trade-offs (Peng et al., 2013).

Variability in research contexts, methodologies and outcomes makes it difficult to draw generalisable conclusions. This review synthesises scientific and field-based evidence on the role of weaver ants in IPM for tropical and subtropical tree crops. It evaluates their effectiveness in pest control, contributions to biodiversity and ecosystem health and economic benefits such as higher yields and improved market access. The review also outlines key challenges, including colony management and scalability. It identifies knowledge gaps in areas such as colony propagation, long-term ecological effects and adaptability across crops and agroecological zones (Offenberg, 2015). Addressing these gaps is crucial to optimise the use of weaver ants in sustainable agriculture.

Search strategy

A systematic literature review (SLR) was conducted following the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines (Moher et al., 2009) to ensure a transparent, comprehensive and reproducible process. Relevant studies were identified through searches in five major databases: Web of Science, Scopus, CAB Abstracts, AGRICOLA and Google Scholar. Search terms included combinations of keywords such as Oecophylla longinoda, Oecophylla smaragdina, "weaver ants", "biological control", "integrated pest management", "IPM", "agroforestry", "tree crops" and "sustainable agriculture", using Boolean operators (AND, OR) to enhance sensitivity and specificity. Reference lists of key publications were also manually screened to capture additional relevant studies.

Inclusion and exclusion criteria

Studies published between 2004 and 2025 were included, with only English-language publications reviewed due to resource limitations. Eligible studies consisted of peer-reviewed articles, field experiments and observational studies focusing on Oecophylla longinoda or O. smaragdina as biological control agents in tropical and subtropical perennial tree-based agroecosystems across Africa, Southeast Asia and Australia. Excluded were studies unrelated to pest management or agriculture, reviews lacking original data, grey literature, dissertations, and conference abstracts without full texts.

Screening and selection process

The selection process followed the four standard PRISMA phases, such as identification, screening, inclusion and eligibility (Page et al., 2021). After removing duplicates, titles and abstracts were screened, followed by full-text assessments for relevance. Fifty-three studies met the inclusion criteria and were included in the final synthesis (Figure 1). These studies were analysed across five thematic areas: (i) biology and ecology of weaver ants, (ii) efficacy of weaver ants in insect pest control, (iii) ecological roles and ecosystem services, (iv) socio-economic factors affecting adoption and (v) research gaps and future directions. Thematic analysis followed Nowell et al. (2017).

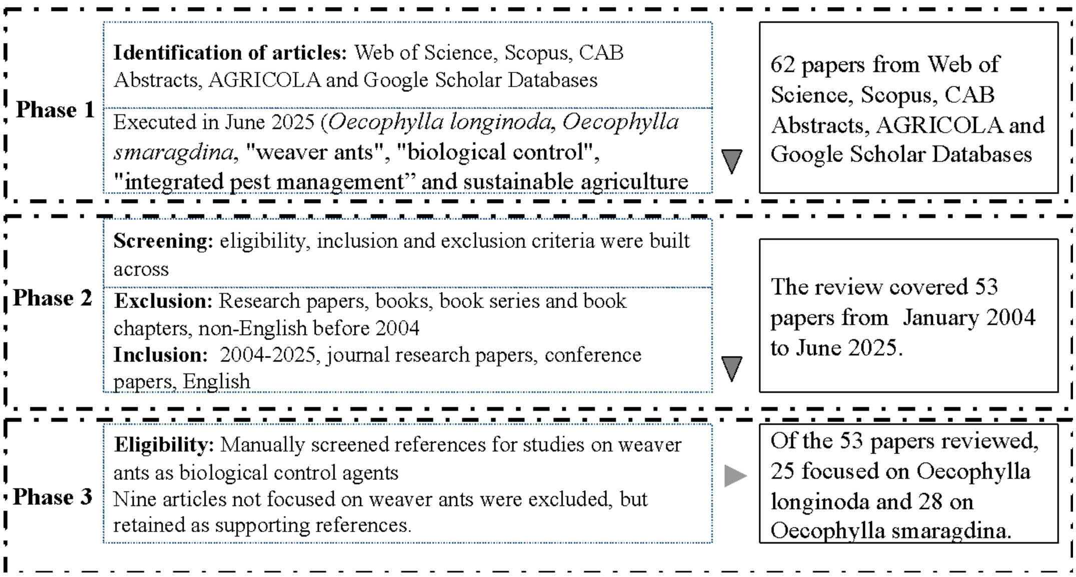

Figure 1. The flow chart of the PRISMA approach used in the SLR (Adopted from [Moher et al., 2009Page et al., 2021]

Biology and ecology of weaver ants

The two species of weaver ants are arboreal, highly territorial and aggressive predators that form large, organised colonies in tree canopies (Peng and Christian, 2007; Van Mele, 2008). Renowned for their sophisticated social structure and ecological importance in tropical agroecosystems, these ants thrive on perennial tree crops such as cashew, mango, coconut, citrus, and cocoa, where they serve as natural pest control agents within their native regions (Van Mele, 2008; Thurman et al., 2019). A defining characteristic of weaver ants is their remarkable nest-building behaviour. Workers use larval silk to bind living leaves together, creating large, polydomous nests that can span multiple trees (Van Mele and Cuc, 2007; Crozier et al., 2010). Colonies may contain over 100,000 individuals and are typically led by a single queen, although polygyny can occur under certain conditions (Offenberg et al., 2012). Their division of labour is highly structured, with major workers defending territory and capturing prey, while minor workers focus on brood care and nest maintenance (Offenberg et al., 2012; Nene et al., 2016).

Territoriality is central to the ecological role of weaver ants, whose success relies on arboreal nesting and foraging in dense, interconnected foliage with optimal humidity conditions characteristic of evergreen or semi-evergreen agroforestry systems (Peng and Christian, 2007; Van Mele et al., 2007). Weaver ants aggressively defend their foraging areas against intruding insects and rival ants, effectively limiting pest movement between trees (Offenberg and Wiwatwitaya, 2010; Peng and Christian, 2007). Their rapid recruitment and coordinated aggression make them formidable biocontrol agents in canopy-level tree crop systems (Van Mele, 2008; Thurman et al., 2019). As generalist predators, they consume a wide variety of herbivorous insects, including sap-sucking bugs, mealybugs, aphids, and scale insects (Dwomoh et al., 2009; Olotu et al., 2013). Their constant patrolling and collective attacks significantly reduce pest populations. Weaver ants also engage in mutualistic relationships with honeydew-producing insects such as aphids and mealybugs, feeding on their secretions in exchange for protection (Styrsky and Eubanks, 2007; Offenberg, 2013). While this relationship supports colony longevity, it can inadvertently lead to increases in minor pest populations, highlighting the need for balanced management strategies (Thurman et al., 2019).

Beyond pest control, they contribute to biodiversity conservation, enhance pollination by reducing herbivory pressure, and promote nutrient cycling (Perfecto and Vandermeer, 2010). This ecological multifunctionality supports agroecosystem resilience, positioning weaver ants as vital allies for sustainable agriculture amid growing environmental challenges.

Efficacy of weaver ants in pest control

Weaver ants are among the most effective natural enemies of agricultural pests in tropical and subtropical agroecosystems. Their role as biological control agents is well-documented in perennial crops such as cashew, mango, citrus, cocoa, coconut, guava, and papaya. Through direct predation, chemical deterrence and territorial exclusion, they offer a sustainable alternative to synthetic chemical pesticides (Peng and Christian, 2005b; Van Mele et al., 2007; Vayssières et al., 2016).

In Africa, AWA has demonstrated significant pest suppression. In Tanzania, AWA effectively controls sap-sucking cashew pests (Olotu et al., 2013; Abdalla et al., 2017), boosting yields similarly to insecticides and offering a viable option for organic pest management (Abdalla et al., 2017). In Ghana, AWA reduced populations of H. schoutedeni, P. devastans, and Anoplocnemis curvipes, with yields comparable to those from chemically treated trees (Dwomoh et al., 2009). In Benin, mango trees managed with weaver ants had fewer Rastrococcus invadens and produced better-quality fruit (Ouagoussounon et al., 2013). Weaver ants also suppress fruit flies by deterring oviposition (Kempraj et al., 2022; Van Mele et al., 2007). In Benin's cashew systems, weaver ants significantly increased nut size, yield, and marketable kernels, highlighting their value in sustainable pest management (Anato et al., 2015; Anato et al., 2017).

In Asia and Australia, GTA have shown comparable effectiveness to chemical pesticides in managing various insect pests. In mango orchards, they control Idioscopus species, thrips and weevils (Peng and Christian, 2004, 2005b, 2007; Offenberg et al., 2022). In Chinese citrus plantations, GTA reduces mealybugs and fruit flies, resulting in higher yields and reduced pesticide dependence (Niu et al., 2014). Similar benefits have been reported in coconut and guava farms in Vietnam and Malaysia (Samal and Kumar, 2024) and in Indonesian cashew farming (Beattie and Holford, 2022), where their presence also enhances access to organic markets. In Australia, GTA effectively controls beetles, leafrollers, and stink bugs in citrus and avocado systems (Offenberg et al., 2013). In India, they contribute significantly to the biological control of Helopeltis species in cashew orchards (Mahapatro and Mathew, 2014). Additionally, Peng et al. (2010, 2011) confirmed the efficacy of GTA in protecting African mahogany (Khaya senegalensis) in Australia by significantly reducing pest infestations, including Hypsipyla robusta.

Weaver ants integrate effectively into IPM systems; however, synthetic chemical pesticide use must be minimised to prevent disruption of their colonies (Van Mele et al., 2007). Although yields may be slightly reduced, the savings from lower input costs often lead to improved economic returns (Dwomoh et al., 2009; Offenberg et al., 2013). Additionally, the use of weaver ants supports organic certification and helps meet export quality standards, as demonstrated in countries such as Ghana, Tanzania, and Vietnam (Van Mele et al., 2007; Ouagoussounon et al., 2013).

Ecological roles and ecosystem services

Weaver ants play a crucial role in maintaining biodiversity and ecological balance in agroecosystems by reducing the need for broad-spectrum chemical pesticides, which often harm non-target species (Van Mele et al., 2007; Thurman et al., 2019). Their predation targets various herbivorous pests, such as aphids, mealybugs, caterpillars, beetles, and scale insects, selectively suppressing pests while sparing beneficial insects (Styrsky and Eubanks, 2007; Dwomoh et al., 2009). This helps support a balanced trophic structure in tree crops (Perfecto and Vandermeer, 2010). Through territorial exclusion, weaver ants limit pest colonisation and spread across trees, reducing pressure on local flora and fauna (Peng and Christian, 2007; Offenberg et al., 2012). By maintaining stable colonies with large foraging areas, they enhance ecosystem integrity in endemic geographical localities (Offenberg, 2015). Their nests increase habitat complexity, supporting diverse species of insects, which boosts ecosystem resilience (Falahudin and Alfarabi, 2023·).

Weaver ants also form mutualistic relationships with honeydew-producing insects such as aphids and mealybugs. Although this is sometimes considered a drawback, it can support colony survival and overall system stability if managed appropriately (Styrsky and Eubanks, 2007; Thurman et al., 2019). Their impact on pollinators is similarly mixed. While their aggressive behaviour near flowers may disrupt pollination (Styrsky and Eubanks, 2007), flowers also attract weaver ants that reduce effective pollinators (Gonzálvez et al., 2013). The reduction in herbivory they provide can enhance flowering and fruit set, potentially offsetting any negative effects (Perfecto and Vandermeer, 2010). The overall outcome depends on factors such as ant density, crop type, and landscape context.

Socio-economic factors affecting weaver ant adoption

Knowledge barriers to scaling and colony propagation

Studies from Africa and Southeast Asia have shown that the abundance of AWA and GTA fluctuates significantly between the production on-season and off-season, which has impeded their adoption (Olotu, 2016a; Salini and Ambika, 2019·). The use of weaver ants as biological control agents is further constrained by high labour requirements, associated costs, and the need for specialised ecological knowledge. Effective colony management demands precise nest handling, relocation, supplementary feeding and ongoing monitoring activities that are often beyond the capacity of smallholder farmers (Van Mele, 2008; Offenberg et al., 2012; Olotu et al., 2015). In Tanzania, the use of fish-based bait and sugar has proven to be both effective and affordable for maintaining colonies during the off-season, presenting a viable alternative to synthetic chemical pesticides (Olotu et al., 2015; Abdalla et al., 2016). Similarly, in Thailand, artificial nests have shown potential in supporting colony establishment during adverse weather conditions, thereby improving pest control and larval production (Offenberg, 2014). Nonetheless, limited access to extension services and training, particularly in areas such as colony establishment and pest-ant interactions, continues to be a major obstacle (Van Mele and Cuc, 2007·). These socio-technical barriers contribute to low uptake, especially in contexts where institutional support is lacking (Peng et al., 2013; Offenberg, 2015).

Scaling up weaver ant colony propagation remains challenging, limiting its adoption beyond smallholder, tree-based farms. Methods such as pupae transplantation offer potential but require technical skills and resources that many farmers lack (Ouagoussounon et al., 2013; Peng et al., 2013). Similarly, locating queen nests of weaver ants remains a key challenge for biocontrol adoption, as effective colony establishment relies on identifying the single reproductive nest, an otherwise accurate but time-and skill-dependent task (Nene et al.,2017). Dominant ant species such as Pheidole megacephala and Anoplolepis custodiens compete with weaver ants, reducing their populations and effectiveness in Tanzanian cashew plantations (Seguni et al., 2011; Olotu, 2016b). Managing these rival ants requires extra labour and ecological knowledge, creating challenges for resource-limited farmers. Vegetation management also influences ant competition, with P. megacephala hindering the stable establishment of weaver ants in IPM systems (Seguni et al., 2011). The adoption of weaver ants in IPM is also hindered by the difficulty of locating egg-laying queens, ensuring colony survival, and establishing robust populations essential for successful pest control (Ouagoussounon et al., 2013; Rwegasira et al., 2017).

Low financial incentives for adoption

Despite their potential to reduce reliance on expensive synthetic chemical pesticides and lower production costs, thereby increasing profit margins, the adoption of weaver ants as biological control agents faces several significant challenges. One major barrier is the limited financial incentives for smallholder farmers, who often require clear and immediate economic benefits such as higher yields, improved crop quality, and access to premium markets before adopting new practices (Van Mele et al., 2007; Offenberg, 2015; Ratto et al., 2022). Additionally, concerns persist about the ants' tendency to protect sap-sucking pests like aphids and mealybugs, which can undermine their overall effectiveness as pest controllers (Styrsky and Eubanks, 2007; Peng et al., 2013). Their aggressive behaviour can also harm beneficial insects and complicate harvesting activities, further discouraging adoption by farmers (Offenberg, 2015).

Economic uncertainties regarding the reliability of weaver ants as pest control agents across varying crops and environmental conditions contribute to limited adoption (Van Mele and Cuc, 2007·). The high initial costs of colony establishment pose a major barrier, particularly for farmers without access to subsidies or financial assistance (Peng et al., 2013; Offenberg, 2015). Although economic analyses by Williams et al. (2015)· and George and Rwegasira (2017) show favourable outcomes, such as positive net present value (NPV), benefit-cost ratio (BCR), and internal rate of return (IRR), these returns are generally not compelling enough to drive widespread use of weaver ants in cashew and mango production systems.

Seasonal fluctuations in AWA populations between cashew on-seasons and off-seasons pose challenges to their consistent use, often necessitating dietary supplements such as fish waste or bait to sustain colony health (Olotu, 2016a; Olotu et al., 2015). Although research suggests that weaver ants can be used economically without additional feeding (Williams et al., 2015·), these seasonal variations present practical difficulties for farmers. Further obstacles to adoption include the ants' aggressive behaviour, their tendency to promote scale insects and the formation of dense nests. However, sugar feeding has been shown to alleviate these issues and improve farmer acceptance (Correa et al., 2023). Overcoming these barriers requires integrated approaches, including farmer training to manage ant-related risks, financial support, and market-based incentives aimed at reducing pesticide use and promoting sustainable agriculture (Coulibaly et al., 2014). Moreover, the growing consumer demand for organic or low-pesticide produce offers a valuable opportunity to enhance profitability and market access, particularly in export-oriented horticultural industries (Ratto et al., 2022).

Human-ant conflict and nuisance behaviour

The adoption of weaver ants as natural pest-control agents is also limited by their aggressive nature and their risk of becoming pests in newly introduced areas. While these ants are effective at controlling agricultural pests, their territorial aggression and potential ecological impact raise significant concerns (Peng & Christian, 2007; Offenberg, 2015). A key factor influencing their adoption is their territorial aggression, especially in the GTA, where larger worker ants are more aggressive than smaller ones. These ants quickly attack intruders to defend their colonies, posing a risk to humans who may inadvertently disturb them during activities like crop harvesting. The resulting painful stings or bites could deter farmers from using them, particularly in densely populated rural or urban areas where ant territories overlap with human activities (Kamhi et al., 2015).

Additionally, the introduction of weaver ants into new regions can lead to unintended ecological consequences. Their predatory nature makes them highly effective at controlling pests, but they may also target beneficial species, such as pollinators or natural pest controllers. This could disrupt local ecosystems and complicate integrated pest management (IPM) strategies. Research shows that Oecophylla smaragdina can reduce populations of beneficial insects, undermining the long-term sustainability of pest control efforts (Newe et al., 2010; Offenberg, 2015). The presence of weaver ants in human habitats may also require costly control measures. If these ants become a persistent nuisance, particularly in areas where they interact with people, communities may be less willing to adopt them as part of their pest-control strategies. The balance between the benefits of pest control and the risks of human–ant conflicts could ultimately determine their acceptance (Kamhi et al., 2015; Peng & Christian, 2007).

Research gaps and future directions

Despite increasing recognition of weaver ants as effective biological control agents, several challenges continue to limit their broader and sustained use in IPM systems. A significant gap lies in the limited understanding of their long-term ecological impacts. While short-term studies report positive outcomes such as pest suppression and yield improvement, few have examined their effects on native ant populations, pollinators (Gonzálvez et al., 2013), or honeydew-producing pests like scale insects, which may lead to secondary outbreaks (Styrsky and Eubanks, 2007). There is a clear need for long-term, site-specific research to assess these trade-offs across various agricultural systems.

Improvements in colony management are also necessary. Techniques such as pupae transplantation, multiple-queen colony founding, and the provision of fish waste during cashew off-seasons have been shown to enhance colony survival and growth (Ouagoussounon et al., 2015; Peng et al., 2013; Olotu et al., 2015). However, these practices are labour-intensive, expensive, and may result in conflicts between queens. There is a pressing need for practical, cost-effective methods and clearer guidelines on aspects such as optimal colony size, establishment timing, and orchard layout. Additionally, stronger policy support is required, as synthetic pesticides continue to dominate many IPM strategies. Policies should formally acknowledge weaver ant husbandry, encourage pesticide reduction and facilitate organic certification schemes. Incorporating weaver ant management into agricultural education and extension services would further support the widespread adoption of this approach.

Farmer training and the use of digital tools are also vital. Successful approaches, including field schools and peer-to-peer learning networks in Benin and Vietnam (Ouagoussounon et al., 2013; Van Mele and Cuc, 2007), could be scaled up through mobile applications, video content, and agroecology platforms to help overcome limitations in traditional extension services. Finally, strengthening market development through certification, branding and improved value chains for pesticide-free, ant-managed produce can incentivise adoption. Farmer cooperatives could play a key role in enabling smallholders to access premium markets and share the costs of capacity building and training.

Conclusion

This review finds that weaver ants hold significant promise as sustainable biological control agents in tropical and subtropical perennial tree cropping systems. They are effective in suppressing pest populations and reducing dependence on synthetic chemical pesticides. In addition to pest control, their use contributes to biodiversity conservation, strengthens ecosystem resilience and can enhance the livelihoods of smallholder farmers. Nonetheless, several constraints, including the complexity of colony management, high labour requirements, and a lack of financial incentives, continue to limit their broader adoption, particularly in large-scale agricultural operations. Addressing these socio-economic and ecological challenges is crucial for the successful integration of weaver ants into IPM strategies and the advancement of sustainable agriculture. Future research should focus on developing cost-effective and scalable methods for colony propagation and management, such as pupae transplantation and supplementary feeding, that are accessible and practical for smallholders and ensure colony viability throughout seasonal cycles.

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Conflict of interest declaration

The author has no conflicts of interest to declare.

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