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AGGRESSION AND PREDATORY BEHAVIOUR OF WEAVER ANTS (*Oecophylla smaragdina*) TOWARDS DIFFERENT PREY

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ABSTRACT

Weaver ants (*Oecophylla smaragdina*) are naturally aggressive and highly territorial insects, renowned for their ability to defend colonies and prey upon a wide range of pest species. Their predatory and defensive behaviours make them valuable agents for biological control in oil palm plantations, where pests such as *Metisa plana* (bagworms) pose a major threat to crop productivity. However, the extensive use of chemical pesticides and the harvesting of these ants for human consumption have significantly reduced their populations in plantation ecosystems, thereby limiting their effectiveness as natural pest regulators. This study investigates the aggressive and predatory behaviours of *O. smaragdina* against *M. plana* in oil palm plantations to assess their potential role in biological control. Three different sites in northern Peninsular Malaysia, designated as Site A, Site B, and Site C, were used for the experiments. Aggression and predation assays were performed using *Metisa plana* (bagworms), *Tenebrio molitor* (mealworms), and *Acheta domesticus* (crickets) as prey. Ant behavioural responses were systematically observed and recorded at five-minute intervals throughout the 72-hour experimental period. Colonies of *O. smaragdina* exhibited the highest levels of aggression and predation towards bagworms compared with mealworms and crickets. Observed aggressive behaviours included biting and coordinated group attacks, with colonies from Site C exhibiting the most intense responses. These findings demonstrate that both food type and habitat influence the aggression and predatory performance of *O. smaragdina*. The results highlight the potential of this species as an effective biological control agent within integrated pest management (IPM) programmes, particularly in oil palm ecosystems.

Keywords: *Oecophylla smaragdina;* predatory insects; Aggressive behaviour; Biological control.

ABSTRAK

Kerengga *(Oecophylla smaragdina*) merupakan serangga bersifat agresif dan sangat teritorial, terkenal dengan keupayaannya mempertahankan koloni serta pemangsa pelbagai spesies perosak. Sifat pemangsa dan pertahanannya menjadikan kerengga amat berpotensi digunakan dalam kawalan biologi di ladang kelapa sawit, di mana perosak seperti *Metisa plana* (ulat bungkus) merupakan ancaman utama terhadap produktiviti tanaman. Namun begitu, penggunaan racun perosak kimia secara meluas serta aktiviti penuaian semut ini untuk kegunaan manusia telah mengurangkan populasi mereka di ekosistem ladang, sekali gus mengehadkan keberkesanannya sebagai pengawal perosak biologi. Kajian ini menilai tingkah laku agresif dan pemangsaan *O. smaragdina* terhadap *M. plana* di ladang kelapa sawit bagi menentukan potensinya sebagai agen kawalan biologi. Tiga tapak berbeza di utara Semenanjung Malaysia, yang dinamakan sebagai Tapak A, Tapak B dan Tapak C, telah digunakan untuk eksperimen ini. Ujian agresi dan pemangsaan dijalankan menggunakan M. plana (ulat bungkus), *Tenebrio molitor* (ulat roti) dan *Acheta domesticus* (cengkerik) sebagai mangsa, dengan tindak balas kerangga diperhatikan dan direkodkan pada sela masa lima minit selama 72 jam. Koloni *O. smaragdina* menunjukkan tahap agresi dan pemangsaan tertinggi terhadap ulat bungkus berbanding ulat roti dan kerangga. Tingkah laku agresif yang diperhatikan termasuk menggigit, dan serangan berkelompok yang berkoordinasi, dengan koloni dari Tapak C menunjukkan tindak balas paling kuat. Dapatan ini membuktikan bahawa jenis makanan dan habitat mempengaruhi tahap agresi serta keupayaan pemangsaan *O. smaragdina*. Hasil kajian ini menonjolkan potensi spesies ini sebagai agen kawalan biologi yang berkesan dalam program pengurusan perosak bersepadu (IPM), khususnya dalam ekosistem kelapa sawit.

Kata kunci: *Oecophylla smaragdina*; serangga pemangsa; tingkah laku agresif; kawalan biologi

INTRODUCTION

The genus *Oecophylla*, commonly known as weaver ants, is renowned for its highly aggressive and territorial behaviour, which underpins its ecological success in tropical environments (Offenberg 2021). These ants actively defend their colonies, nests, food resources, and broods through coordinated attacks mediated by chemical communication and powerful mandibles (Nouvian & Breed 2020).

Their aggression and predatory efficiency enable them to capture and subdue intruding insects, enhancing their role as natural biological control agents in agricultural ecosystems (Kumari et al. 2022). Weaver ants obtain energy from two primary sources: animal protein derived from hunting insect pests and carbohydrates obtained from honeydew secreted by sap-sucking insects or floral nectar (Offenberg 2021). This combination of aggressive defence and efficient foraging allows colonies to suppress herbivorous pests while maintaining growth and reproduction (Benelli 2015).

Notably, predatory activity does not compromise colony survival, as the primary reproductive individuals, such as queen larvae and pupae, are protected within the nest (Lindstedt et al. 2019). Kamaruddin et al. (2022) further examined the predatory behaviour of

Oecophylla smaragdina nesting on citrus plants (*Citrus microcarpa*). Hunting in coordinated groups, weaver ants capture a wide range of insects, including flies, beetles, caterpillars, and other herbivores, often secreting chemicals to aid in subduing prey (Miler 2022). Their dual diet of animal protein and carbohydrate-rich secretions supports colony growth and sustains foraging efficiency (Bouchebti et al. 2022).

Moreover, their overall aggressiveness enhances their effectiveness as predators (Royer et al. 2022). *Oecophylla smaragdina* is widely recognised for its aggressive behaviour, efficient predation, and ability to suppress diverse insect pests in agroecosystems (Exélis et al. 2022). Previous studies have demonstrated its effectiveness against caterpillar pests, including bagworms, in oil palm plantations (Wood & Kamarudin 2019). While both major and minor workers participate in foraging, they differ in morphology, strength, and task allocation, suggesting potential caste-specific contributions to colony-level pest suppression (Wills et al. 2018).

However, most research has focused on overall colony performance, with limited attention to how caste differentiation influences aggressiveness and predatory efficiency in pest control. This study aims to investigate the aggressive and predatory behaviours of major and minor workers of *O. smaragdina* towards different prey types. By linking caste-specific behaviour to pest suppression outcomes, this study provides theoretical insights into social organisation and practical applications for optimising weaver ant-mediated biological control. Such knowledge can reduce reliance on chemical insecticides and promote ecologically sustainable management practices in tropical agriculture.

MATERIALS AND METHODS

Study Area

The study was conducted in Bandar Baharu, Kedah, Malaysia (5.1312° N, 100.4955° E). Before the aggressive and predatory experiments, a four-week preliminary survey was conducted to identify stable *O. smaragdina* colonies that maintained their nests in the exact location without relocation. Nests were built on oil palm fronds.

Quantifying Weaver Ant Aggression Toward Prey

The aggressive responses of *O. smaragdina* were evaluated using three prey types: the 3rd instar larvae stage of Bagworms (*Metisa plana*), Mealworms (*Tenebrio molitor*), and Crickets (*Gryllus bimaculatus*). Mealworms (*Tenebrio molitor*) and crickets (*Acheta domesticus*) were used as standardised comparative prey due to their uniform size, availability, and ease of handling. This allowed reliable assessment of aggression and predation, providing a controlled baseline against which responses to the natural prey, *Metisa plana*, could be compared. All the prey used in the experiments were alive and intact, reflecting natural conditions, as *O. smaragdina* predominantly preys on living insects. Bagworms (3rd instar larvae) were presented with their bodies intact, while mealworms and crickets were also intact, ensuring that the ants' aggressive and predatory behaviours were observed under ecologically realistic conditions. The 3rd instar larvae stage of bagworms was collected from oil palm plantations in Slim River, Perak, while mealworms and crickets were purchased from a local pet shop near the insectary laboratory in Penang Island. Three active weaver ant foraging trails were selected for the experiment. Each prey item was placed individually on a small card and positioned 3 cm from the ant trail. Aggression was quantified using an aggression index, which integrates the number and intensity of attacks by workers toward the prey. Each trial lasted five minutes, during which observations were recorded at the end of the 5-minute period. A 10-minute interval was provided between trials to minimise disturbance and ensure that ant activity returned to baseline before the next observation. Each prey type was tested in three replicates, with fresh individuals introduced in each replicate.

Predatory Activity of *O. smaragdina* on Bagworms

The predatory behaviour of *O. smaragdina* major and minor workers was evaluated in an oil palm plantation in Bandar Baharu, Kedah, using. The 3rd instar larvae stage of bagworms (*Metisa plana*) as prey. The experiment was conducted over 72 hours on three active foraging trails. For each trial, ten bagworms (3rd instar larvae) were placed on an index card positioned along the trail, and each trial was replicated three times. Observations were conducted at 12-hour intervals, during which the number of ants interacting with the prey, the attack latency, and the number of bagworms removed by the colony were recorded.

Morphological Comparison of Worker Castes

Figure 1 provides a visual comparison of the two worker castes of *O. smaragdina*, illustrating their distinct morphological characteristics. Minor workers (Fig. 1a) are smaller and possess slender appendages, while major workers (Fig. 1b) are noticeably larger with more robust bodies and well-developed head and mandible structures. These morphological distinctions reflect the functional specialisation of each caste within the colony and help contextualise the caste-specific behavioural patterns examined in this study.

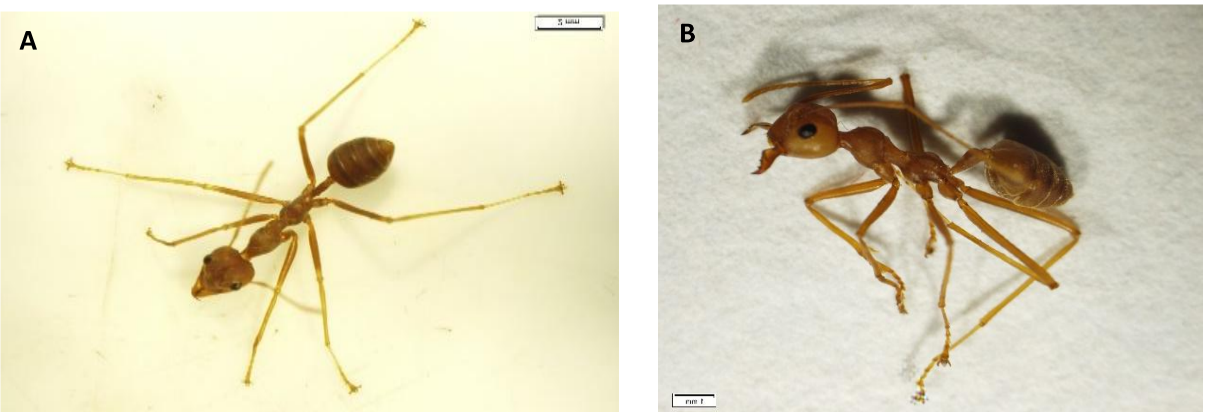

Figure 1. Workers of *O. smaragdina* ;(A) Minor worker (B) Major worker

Statistical Analysis

Aggressive behaviour in *O. smaragdina* was quantified using a composite Aggression Index (A). The formula is as following:

$A = (f\text{post}\times 1) + (f\text{purs}\times 2) + (f\text{bit}\times 3)$

A = aggression index

$f$post = frequency of aggressive posturing

$f$purs = frequency of pursuit

$f$bit = frequency of biting or grappling

Higher index values indicate greater intensity and frequency of aggressive responses toward the prey.

Predatory behaviour was assessed using the number of ants engaging with prey, attack latency (seconds from prey presentation to first contact), and number of prey items removed. Data were analysed in SPSS Version 28 (IBM Corp., Armonk, NY, USA). Data were first tested for normality using the Shapiro–Wilk test and for homogeneity of variance using Levene's test. When data met parametric assumptions, a one-way analysis of variance (ANOVA) was used to compare aggression indices, predatory responses, and foraging activity across prey types, trails, and seasons. Significant differences were further examined using Tukey's HSD post hoc test at a Significance level of $p<0.05$.

RESULTS

The aggressive behaviour of *O. smaragdina* workers varied across diet types and collection sites**.** At Site A, the highest aggression was observed toward crickets (75.33±42.15), followed by bagworms (70.67±24.54) and mealworms (60.33±40.67). At Site B, ants showed the strongest aggression toward bagworms (105.00±44.54), with slightly lower levels toward crickets (89.67±20.31) and mealworms (72.00±41.61). Similarly, at Site C, bagworms elicited the highest response (113.00±30.61), followed by mealworms (96.67±37.07) and crickets (73.00±25.53). Across all sites, bagworms consistently triggered higher aggression, while mealworms and crickets elicited more variable responses. The wide 95% confidence intervals indicate heterogeneity in aggressive behaviour depending on the diet type and location (Table 1).

Table 1. Mean aggressive index and 95% confidence intervals for different diet types from three sites in *O. smaragdina*

Location	**Diet**	**Mean**	**Std. Deviation**	**95% confidence interval**	
				Lower bound	**Upper Bound**
Site A	Bagworm	70.67	24.54	28.02	113.31
	Mealworm	60.33	40.67	17.69	102.98
	Cricket	75.33	42.15	32.69	147.64
Site B	Bagworm	105	44.54	62.36	147.64
	Mealworm	72	41.61	29.36	114.64
	Cricket	89.67	20.31	47.02	132.31
Site C	Bagworm	113	30.61	70.36	155.64
	Mealworm	96.67	37.07	54.02	139.31
	Cricket	73	25.53	30.36	115.64

The mean aggression indices of *O. smaragdina* across sites and diet types are summarised in Table 2. To test whether site, diet type, or their interaction significantly influenced these aggression responses, a statistical analysis was performed. The model accounted for 25.6% of the variation in aggression ($R^2 = 0.256$), although the adjusted R^2 value of –0.075 indicated limited predictive power. Mean aggression indices varied among sites, with Site C showing the highest values, followed by Site B and Site A. Differences were also observed among diet types; however, these variations were not statistically significant ($P>0.05$). The interaction between site and diet type showed no significant effect, indicating that the type of prey did not differentially influence aggression at the three locations.

Table 2. Tests that occur between subject effects

Parameters	**Mean Square**	**F-value**	**P-Value**	**Partial square**
Corrected model	957.2a	0.77	0.63	0.26
Intercept	957.2	154	0.001	0.89
Site	1620.48	1.31	0.29	0.13
Diet	1034.7	0.84	0.45	0.09
Site*Diet	586.82	0.48	0.75	0.095

a. R Squared=0.256 (Adjusted R Squared= -.075)

The aggressive index of *O. smaragdina* varied distinctly among prey types (Figure 2**).** For *f*post, aggression toward bagworms was highest (≈20%), followed by crickets (≈9%) and mealworms (≈7%). In *f*purs, bagworms again elicited the strongest response (≈30%), whereas mealworms (≈17%) and crickets (≈16%) induced moderate aggression. The most intense aggressive behaviour was recorded in *f*bit, with bagworms showing a marginal mean of ≈73%, compared with ≈44% for crickets and ≈40% for mealworms. The progressive increase from *f*post to *f*bit across all diets indicates an escalation pattern in aggressive behaviour, with bagworms consistently producing the highest aggression values.

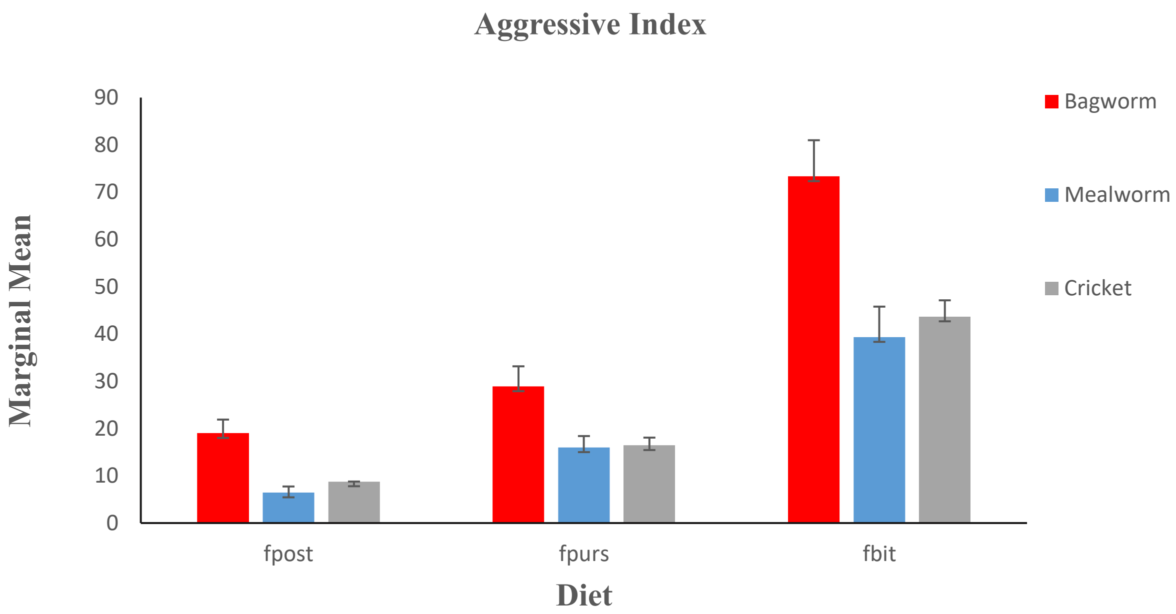

Figure 2. Aggressive Index of *O. smaragdina* across different diet type

The aggressive index of *O. smaragdina* exhibited clear variation across the three study sites (Fig. 3). For *f*post, aggression levels were relatively low, with marginal means of approximately 12% at Site A, 11% at Site B, and 10% at Site C. In *f*purs, Site B recorded the highest aggression (≈26%), followed closely by Site C (≈24%) and Site A (≈13%). A pronounced increase was observed in *f*bit, where Site C showed the highest mean aggression (≈60%), followed by Site B (≈55%) and Site A (≈45%). The increasing pattern from *f*post to *f*bit across all sites indicates a sequential escalation in aggressive behaviour, reflecting the transition from initial detection to direct attack.

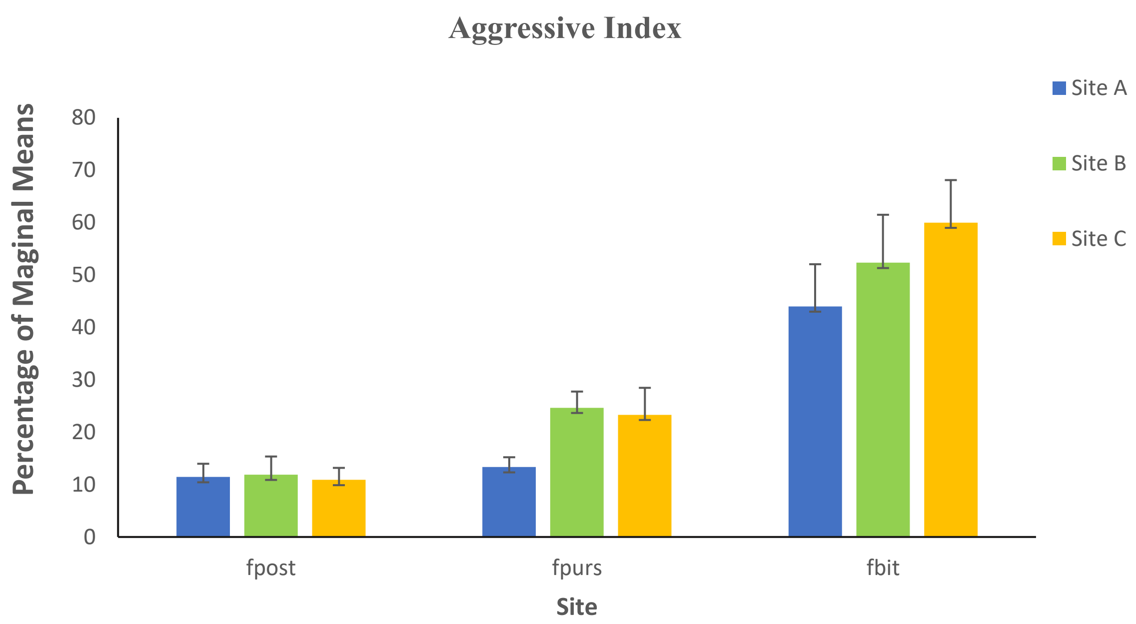

Figure 3. Variation in aggressive index of *O. smaragdina* across different sites

Figure 4 illustrates the temporal dynamics of predatory behaviour in major and minor workers of *O. smaragdina* when preying on bagworms. The y-axis represents the number of ants engaging with the prey, and the x-axis represents time (in seconds, ranging from 1 to 72 s). Pink squares, and minor workers by olive-green triangles indicate major workers. Initially, a few ants from either caste engage with the prey, reflecting minimal predatory activity. Over time, the number of predatory ants increases in both groups, indicating an initial latency period before active hunting. Minor workers respond first, suggesting a scouting or investigative role, while major workers are recruited later, showing a sharp increase in predatory numbers around 72 seconds. This recruitment pattern may reflect coordinated task allocation, with major workers mobilised when prey handling exceeds a certain threshold. The temporal distinction between minor and major worker activity highlights a division of labour in prey detection and capture, contributing to efficient prey removal in *O. smaragdina* colonies.

Figure 4. Temporal dynamics of predatory activities in major and minor *O. smaragdina* workers

DISCUSSION

The results indicate that the aggressive behaviour of *O. smaragdina* workers is influenced both by diet type and collection site. Bagworms consistently elicited the highest aggression across all sites, while responses to mealworms and crickets were more variable. This suggests that certain prey items, particularly live or active insects, may trigger stronger defensive or territorial responses due to their perceived threat or competition potential (Kannan et al. 2022). Site-specific variation in aggression, reflected by wide 95% confidence intervals, may be attributed to local colony experience, resource availability or environmental factors. For instance, Site B and C colonies displayed higher aggression toward bagworms than Site A, possibly due to higher resource competition or previous exposure shaping defensive behaviours (Afzal et al. 2025). Such heterogeneity highlights the plasticity of behavioural responses in *O. smaragdina*, which can modulate aggression according to ecological context and prey characteristics. These findings align with previous studies demonstrating that aggression in weaver ants is not uniform but influenced by diet type, prey mobility and local colony conditions, reflecting adaptive strategies to maximise resource defence and colony survival (Exélis et al. 2024). The pronounced response to bagworms suggests this prey type may be both highly preferred and competitive, eliciting substantial behavioural investment from workers.

The aggressive index of *O. smaragdina* varied significantly among prey types, reflecting clear differences in the ants' behavioural responses to diet composition. Aggression was highest toward bagworms, moderate toward crickets, and lowest toward mealworms, with a consistent escalation from *f*post to *f*bit. This pattern suggests that the perceived value or desirability of prey strongly influences colony-level aggression. Such behavioural modulation likely arises from a combination of nutritional preference, prey mobility, and chemical cues, which collectively signal resource importance to the colony (Han et al. 2023). The heightened aggression toward bagworms may be associated with their higher protein content or natural association with the ants' ecological niche, resulting in increased recruitment and defensive intensity. Similar trends have been reported in other ant species, where high-value or nutritionally rich prey elicit more vigorous predatory and territorial behaviours (Sahayaraj & Hassan 2023). In contrast, the lower aggression toward mealworms suggests that easily subdued or less rewarding prey do not warrant strong collective responses, which is consistent with optimal foraging and energy allocation principles in eusocial insects (Vasconcelos et al. 2017).

These findings indicate that *O. smaragdina* exhibits adaptive behavioural flexibility, adjusting aggression based on prey quality and ecological context. From an applied perspective, this adaptive response has important implications for biological control programmes. Identifying prey or pest species that elicit stronger aggressive reactions, such as bagworms, can help optimise management strategies to enhance ant-mediated pest suppression in agroecosystems (Dejean et al. 2024). Understanding diet-driven aggression provides valuable insight into how *O. smaragdina* maximises ecological efficiency and reinforces its potential as an effective biocontrol agent in tropical agricultural systems.

The results demonstrate that the aggressive index of *O. smaragdina* varied notably among the study sites, with aggression progressively intensifying from *ƒ*post to *ƒ*bit. The highest aggression observed at Site C, followed by Sites B and A, indicates that environmental and colony-related factors may strongly influence worker responsiveness. Such variation likely reflects the influence of local resource availability, colony density, and interspecific competition, which are known to modulate the behavioural dynamics of social insects (Neumann & Pinter 2022). Elevated aggression at Site C could be attributed to greater competition for food resources or the presence of larger colonies, both of which enhance defensive motivation and cooperative attack behaviour. Conversely, the lower aggression recorded at Site A may indicate reduced ecological pressure or lower energetic demand, highlighting behavioural plasticity in response to local environmental cues (Manfredini et al. 2019). Comparable spatial differences in aggression have been documented in other *Oecophylla* populations, where variations in habitat structure and prey abundance alter colony vigilance and recruitment intensity (Bockoven et al. 2015). This site-specific modulation underscores the adaptive flexibility of *O. smaragdina* in balancing energy investment between foraging and defence. The ability to adjust aggression according to ecological context ensures efficient resource protection while minimising unnecessary expenditure of worker effort. These findings support the view that aggression in *O. smaragdina* is a context-dependent trait shaped by both intrinsic colony conditions and extrinsic environmental pressures, reinforcing its role as a key behavioural mechanism for maintaining colony fitness and survival.

The temporal pattern of predatory behaviour in *O. smaragdina* indicates a clear division of labour between minor and major workers. Minor workers were the first to engage with prey, likely performing scouting or investigative roles. In contrast, major workers were recruited later, contributing significantly to prey handling once the task exceeded a threshold (Lucon-Xiccato et al. 2024). This sequential recruitment enhances foraging efficiency, allowing colonies to allocate labour according to task demands and body size (Kamaruddin et al.2022). The latency period observed at the start of predation reflects typical cautious exploration behaviour, reducing risk to the colony while assessing prey (Palmer 2018). The rapid increase in major worker participation at later time points suggests that larger ants are mobilised when physical strength or handling ability is required, consistent with task partitioning observed in other ant species (Gordon 2024). Overall, the temporal distinction between castes underscores the adaptive organisation of *O. smaragdina* colonies. By coordinating scouting, recruitment and prey handling, colonies optimise predatory efficiency, reduce individual risk and ensure effective resource acquisition. Such division of labour is a hallmark of eusocial insects and contributes to the ecological success of weaver ants in complex tropical environments.

CONCLUSION

Oecophylla smaragdina workers exhibited site- and prey-specific variation in aggressive and predatory behaviour, with bagworms eliciting the highest responses and Site C showing the greatest overall aggression. Minor workers-initiated prey engagement, while major workers were recruited later, reflecting a clear division of labour and coordinated colony-level responses. These findings highlight the ecological flexibility and efficiency of *O. smaragdina* in natural field settings. While their potential as a biological control agent is significant, their aggressive behaviour may pose challenges for field workers and could affect non-target organisms, such as pollinating insects. Careful management strategies, including timing of ant release and monitoring of non-target impacts, are therefore essential for the safe and effective integration of weaver ants into agroecosystems. Future research should investigate how ecological and environmental variables across different habitats influence aggression, prey preference, and overall colony performance to optimise their application in integrated pest management.

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AUTHORS DECLARATIONS

Conflict of Interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Ethics Declarations
No ethical issue is required for this research.

Data Availability Statement
This manuscript has no associated data.

Authors' Contributions
Patrick Tobechukwu Duru (PTD) and Lukman Idowu Gambari (LIG) conceptualised this research and designed the experiments; Kumara Thevan (KT) performed the data analysis; Hasber Salim (HS) participated in the interpretation of the data. All authors read and approved the final manuscript after review.

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