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NUTRITIONAL ECOLOGY AND THERMAL REQUIREMENTS OF WEAVER ANTS (*Oecophylla smaragdina*): IMPLICATIONS FOR SUSTAINABLE LABORATORY REARING AND BIOLOGICAL CONTROL

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ABSTRACT

Weaver ants, *Oecophylla smaragdina* (Hymenoptera: Formicidae), are ecologically and economically important predators with strong potential as biological control agents in tropical agroecosystems. Despite their significance, little is known about their long-term rearing requirements under controlled laboratory conditions, particularly with respect to diet and temperature. This study investigated the dietary preferences and optimal rearing temperature of *O. smaragdina* through systematic choice and no-choice feeding trials combined with a one-year colony growth experiment. Nine diet types representing protein, carbohydrate, and lipid sources were tested in choice feeding trials, while four protein sources were assessed in non-choice trials. Colony growth and fecundity were simultaneously monitored across three constant temperature regimes (22°C, 25°C, and 29°C). Results showed a clear preference for carbohydrate-rich diets, such as sugar and glucose solutions, which supported high foraging activity. At the same time, protein-rich foods, particularly mealworms and crickets, were selectively transported to nests and were essential for brood development. Colonies reared at 29°C demonstrated significantly higher growth rates and larger final colony sizes compared with those at 25°C and 22°C, indicating that warmer conditions favor colony development. These findings highlight the combined influence of temperature and nutrition on the performance of *O. smaragdina*, providing practical guidelines for laboratory rearing. Improving dietary supplementation and rearing conditions enhances colony establishment and sustainability, supporting the use of weaver ants as effective biological control agents in oil palm plantations and other tropical cropping systems.

Keywords: Formicidae; diet preference; feeding trials; colony growth; thermal effect; tropical agroecosystems

ABSTRAK

Semut kerengga, *Oecophylla smaragdina* (Hymenoptera: Formicidae), merupakan pemangsa yang mempunyai kepentingan ekologi dan ekonomi serta berpotensi tinggi sebagai agen kawalan biologi dalam agroekosistem tropika. Walaupun spesies ini mempunyai nilai yang signifikan, maklumat mengenai keperluan pemeliharaan jangka panjang di bawah keadaan makmal terkawal, khususnya berkaitan diet dan suhu, masih terhad. Kajian ini bertujuan untuk menentukan keutamaan diet dan suhu pemeliharaan optimum bagi *O. smaragdina* melalui ujian pemakanan secara pilihan dan tanpa pilihan, di samping eksperimen pertumbuhan koloni selama satu tahun. Sebanyak sembilan jenis diet yang mewakili sumber protein, karbohidrat dan lipid diuji dalam ujian pemakanan secara pilihan, manakala empat sumber protein dinilai dalam ujian tanpa pilihan. Pertumbuhan koloni dan fekunditi turut dipantau secara serentak pada tiga rejim suhu malar, iaitu 22°C, 25°C dan 29°C. Hasil kajian menunjukkan bahawa semut kerengga lebih menggemari diet yang kaya dengan karbohidrat, seperti larutan sukrosa dan glukosa, yang menyokong aktiviti pencarian makanan yang tinggi. Pada masa yang sama, makanan yang kaya dengan protein, terutamanya *mealworm* dan cengkerik, dipilih untuk dibawa ke dalam sarang dan didapati penting bagi perkembangan peringkat perindukan. Koloni yang dipelihara pada suhu 29°C menunjukkan kadar pertumbuhan yang jauh lebih tinggi serta saiz koloni akhir yang lebih besar berbanding koloni pada suhu 25°C dan 22°C, menunjukkan bahawa suhu yang lebih tinggi menggalakkan perkembangan koloni. Dapatan kajian ini membuktikan bahawa suhu dan pemakanan memainkan peranan penting dalam menentukan prestasi *O. smaragdina* serta menyediakan panduan praktikal bagi pemeliharaan spesies ini di makmal. Penambahbaikan terhadap penyediaan diet dan keadaan pemeliharaan berupaya meningkatkan penubuhan serta kelestarian koloni, sekali gus menyokong penggunaan semut kerengga sebagai agen kawalan biologi yang berkesan di ladang kelapa sawit dan sistem tanaman tropika yang lain.

Kata kunci: Formicidae; keutamaan diet; ujian pemakanan; pertumbuhan koloni; kesan suhu; agroekosistem tropika

INTRODUCTION

Oecophylla smaragdina (Hymenoptera: Formicidae) are obligate arboreal ants that construct elaborate leaf nests bound with larval silk, a distinctive behaviour that has long attracted ecological interest (Pierre & Ramli 2022). The species exhibits pronounced aggressive and predatory behaviour, which underpins its ecological dominance in tropical ecosystems (Patrick et al. 2025). They are widely distributed across the Oriental and Australasian regions, extending from India and Sri Lanka to northern Australia and the Solomon Islands (Wetterer 2014). In Malaysia and Thailand, where they are locally known as "kerengga," these ants dominate the lowland forests and plantation canopies, representing one of the most ecologically significant ant species of the humid tropics (Pimid et al. 2019). Their ecological importance lies in both predatory and mutualistic roles, as large colonies with multiple nests and reproductive queens suppress insect herbivores while maintaining mutualistic associations with honeydew-producing insects (Nelson & Mooney 2022).

The foraging success and colony development of *O. smaragdina* depend heavily on a dual diet: Carbohydrates, obtained from floral nectar and honeydew, which sustain worker

activity, and proteins, derived from insect prey, which are essential for brood development and queen fecundity (Gathalkar & Sen 2018). This nutritional flexibility underpins their role as natural biological control agents in tropical agroecosystems (Lutinski et al. 2024). Farmers in Southeast Asia have long recognized the importance of these resources and, during periods of food scarcity, often supplement their diets with protein-rich items such as fish or chicken entrails (Tella 2023). However, such supplementation does not fully reflect the ants' dietary preferences. Laboratory studies indicate that *O. smaragdina* consistently prefer mealworms over other protein sources such as fish, honey, or artificial diets (Advento et al. 2022). Similarly, controlled rearing trials highlight the importance of supplementing colonies with insects such as mealworms, crickets, or bagworms, alongside carbohydrate sources like sugar solutions, to sustain queen fecundity and worker activity (Morales-Ramos et al. 2024).

Despite these insights, most research has focused on field ecology, supplementation practices, or general dietary observations. Much less is known about precise nutritional preferences under controlled laboratory conditions, particularly when tested through systematic choice and no-choice feeding assays. Temperature has been shown to influence colony growth and queen fecundity in ants (Nakamura et al. 2017). Nutritional factors are also crucial, as diet affects brood development, worker survival, and overall colony performance in social insects (Lihoreau et al. 2018).

This study investigated the dietary preferences of *O. smaragdina* under choice and no-choice feeding conditions, while concurrently monitoring colony growth and fecundity across three constant temperature regimes during a one-year laboratory trial. The research identifies conditions promoting sustained colony development by integrating nutritional and environmental factors. The findings enhance our understanding of the nutritional ecology of *O. smaragdina* and provide practical insights for establishing robust, self-sustaining colonies that can be used as biological control agents in tropical agroecosystems, particularly against leaf-feeding pests in oil palm plantations.

MATERIALS AND METHODS

Field Collection and Insectary Setup of *Oecophylla smaragdina*

Nine colonies of *Oecophylla smaragdina* were collected from three study sites in Kedah, a northern Peninsular Malaysian state, specifically from an oil palm plantation in Bandar Baharu (5°06′ N, 100°32′ E; 5°06′ N, 100°32′ E, and 5°06′ N, 100°32′ E; Figure 1). The sites were readily accessible for regular sampling during the study duration, and no chemical pesticides were reported to have been applied in the study areas for at least three years prior to the commencement of this study, based on information provided by plantation management. This condition likely reduced potential external influences on ant populations and nest attributes, particularly given the documented susceptibility of *O. smaragdina* to insecticides (Duru et al. 2026). Due to the aggressive nature of the species, a grease-based barrier was applied along the upper inner rim of the rearing containers to prevent escape. The colonies were housed in transparent plastic containers measuring 26.5 cm (L) × 30 cm (W) × 10 cm (H). Prior to use, all containers were thoroughly cleaned to eliminate potential contaminants. Colonies were carefully removed from their natural nests and transferred into these containers, which served as artificial habitats. Fresh oil palm fronds were placed inside each container to simulate natural nesting conditions and minimise stress. The colonies were then transported to the insectary laboratory at the School of Biological Sciences, Universiti Sains Malaysia, located in Gelugor, Penang Island (5°21′ N, 100°18′ E), where they were maintained under controlled conditions for subsequent experiments. To facilitate safe collection, nests were lightly sprinkled with water

to reduce defensive behaviour and minimise the release of formic acid. Following collection, the ants were transferred into prepared containers and allowed to acclimate for one week before experimentation. The colonies were subsequently maintained under laboratory

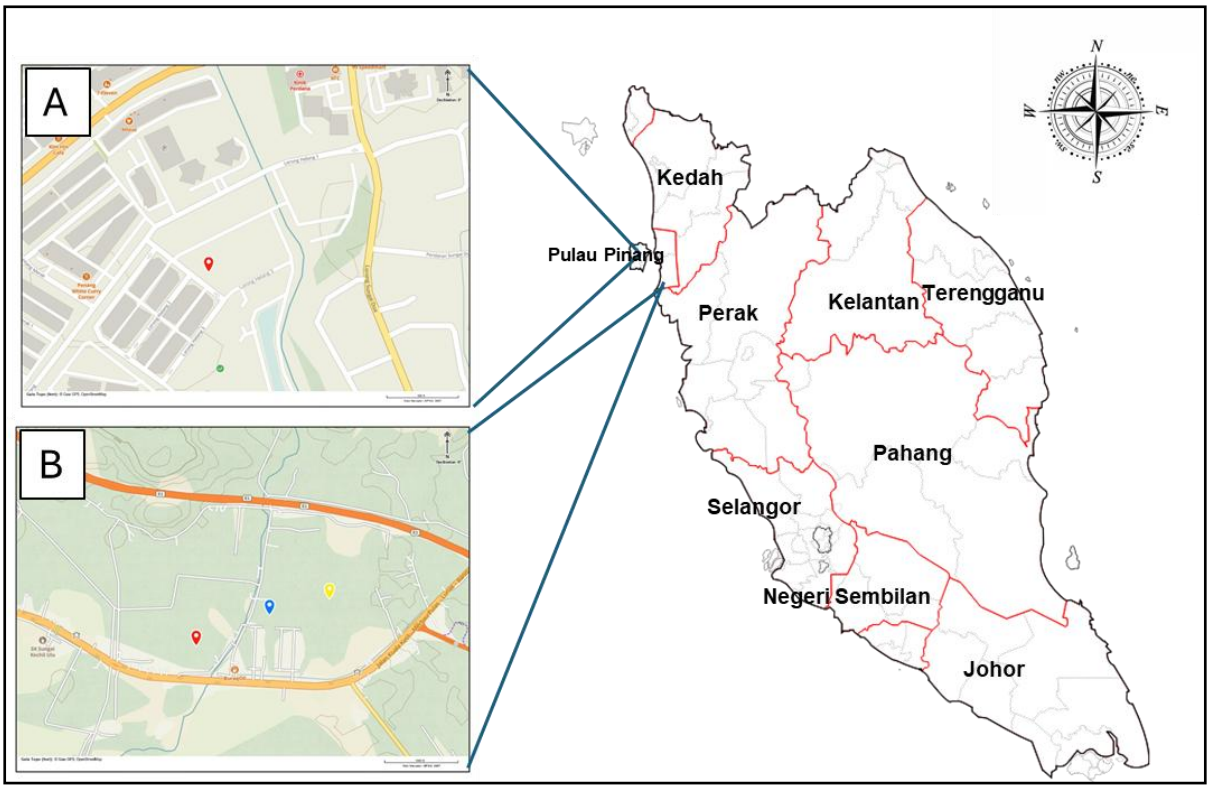

Figure 1. Map showing the study locations and laboratory site in Peninsular Malaysia. (a) Location of the School of Biological Sciences, Universiti Sains Malaysia, Gelugor, Penang Island, where morphometric analyses were conducted. (b) Sampling sites in Kedah, a northern state of Peninsular Malaysia, specifically within an oil palm plantation in Bandar Baharu, where three *O. smaragdina* colonies were collected

Diet Preparation

Nine food types, representing different nutrient categories of proteins, carbohydrates, and lipids were selected to investigate diet preferences and foraging behaviour. Protein-rich diets included canned mackerel (*Rastrelliger kanagurta*) (Marushin Canneries [M] Sdn. Bhd.), mealworms (*Tenebrio molitor*), and crickets (*Gryllus bimaculatus*) were obtained from a local commercial pet supplier situated in the vicinity of Universiti Sains Malaysia. Carbohydrate-rich diets consisted of 30% sugar solution (Malayan Sugar Manufacturing Co. Bhd.), 30% glucose solution (LFD Manufacturing Sdn. Bhd.), and 30% honey (The Nielsen Company [M] Sdn. Bhd.). Lipid-rich diets included olive oil, canola oil (Yee Lee Edible Oils Sdn. Bhd.), and coconut oil (Visesha Manufacturing Sdn. Bhd.). All food items were sourced from local suppliers in Penang Island, Malaysia.

Diet Composition and Feeding Trials

According to the product label, the canned mackerel (*R. kanagurta*) contained 14% protein. In contrast, fresh *T. molitor* larvae (mealworms; Coleoptera: Tenebrionidae) contain 47–60% protein (Makkar et al. 2014), while *G. bimaculatus* (crickets) contain 61–69% protein. For

lipid-rich diets, olive oil and coconut oil each contained 15% lipid, while canola oil contained 14% lipid, as indicated on their respective labels. For each feeding trial, 10 g of protein- and lipid-rich diets were placed in bowls measuring 1 cm (d) × 10cm (h). Carbohydrate-rich diets were prepared as 20% solutions and presented on feeding platforms. The diet bowls were positioned at one end in each colony container, while water-soaked cotton wool was provided ad libitum. Colonies of *O. smaragdina* reared in the laboratory were used for the feeding preference experiments. Two experimental designs were employed: choice feeding and non-choice feeding (Bockoven et al. 2015).

Choice Feeding Trials

In the choice feeding trials, nine diet types, namely canned mackerel, mealworms (*T. molitor*), crickets (*G. bimaculatus*), sugar solution, glucose solution, honey, olive oil, canola oil, and coconut oil, were simultaneously introduced into transparent acrylic containers (26.5 × 30.5 × 10 cm). Each diet (5 g) was arranged side by side, allowing the ants to freely select among the available options. Data collection included (i) the amount of food consumed, determined by measuring the remaining mass of each diet at the end of each observation period; (ii) the number of foraging ants transporting food to the nest; and (iii) the number of ants visiting each diet. Observations were recorded at 24-h intervals over a 72-h period (three consecutive days) under controlled room temperature conditions (27°C).

Non-Choice Feeding Trials

In the non-choice feeding trials, four diet types, namely mackerel, bagworms, mealworms (*T. molitor*), and crickets (*G. bimaculatus*), were tested separately. Each diet (5 g) was placed individually in a container, and ants were restricted to a single food source during each trial. Data collection included (i) the amount of food consumed, determined by measuring the remaining mass of each diet at the end of each observation period, and (ii) the number of ants visiting the food source. Observations were recorded at 24-h intervals over a 72-h period (three consecutive days) under controlled room temperature conditions (27°C).

Effects of Temperature on Colony Development of *Oecophylla smaragdina*

Nine colonies of *O. smaragdina* were used in this study. Each colony consisted of queens, female alates, male alates, and both major and minor workers. Colony development and life cycle progression were monitored in an insectary laboratory on Penang Island from January 2024 to January 2025. Environmental conditions were maintained at three temperature regimes of 22°C, 25°C, and 29°C. Colonies were fed with mealworms (*Tenebrio molitor*) and crickets (*Gryllus bimaculatus*). Additional dietary components included chicken skin as a source of protein and lipids, and a 20% sugar solution as a carbohydrate source. Water was provided *ad libitum* using cotton wool soaked in distilled water and placed within the artificial plastic nest. Colony establishment, brood development, and population growth were continuously observed. Particular attention was given to egg production by the queen as an indicator of colony expansion under laboratory conditions. The suitability of different temperature regimes for rearing *O. smaragdina* was evaluated, and colony population size was assessed to determine its potential for reintroduction into the field as a biological control agent against bagworms in oil palm plantations. Each treatment was replicated three times. Colony establishment and brood development of *O. smaragdina* were successfully achieved in laboratory rearing containers (Figure 2). The established colonies exhibited active brood care behaviour and normal feeding activity under controlled conditions. Colonies provided with different food sources, including chicken skin, sugar solution, and apple, showed consistent growth and brood development.

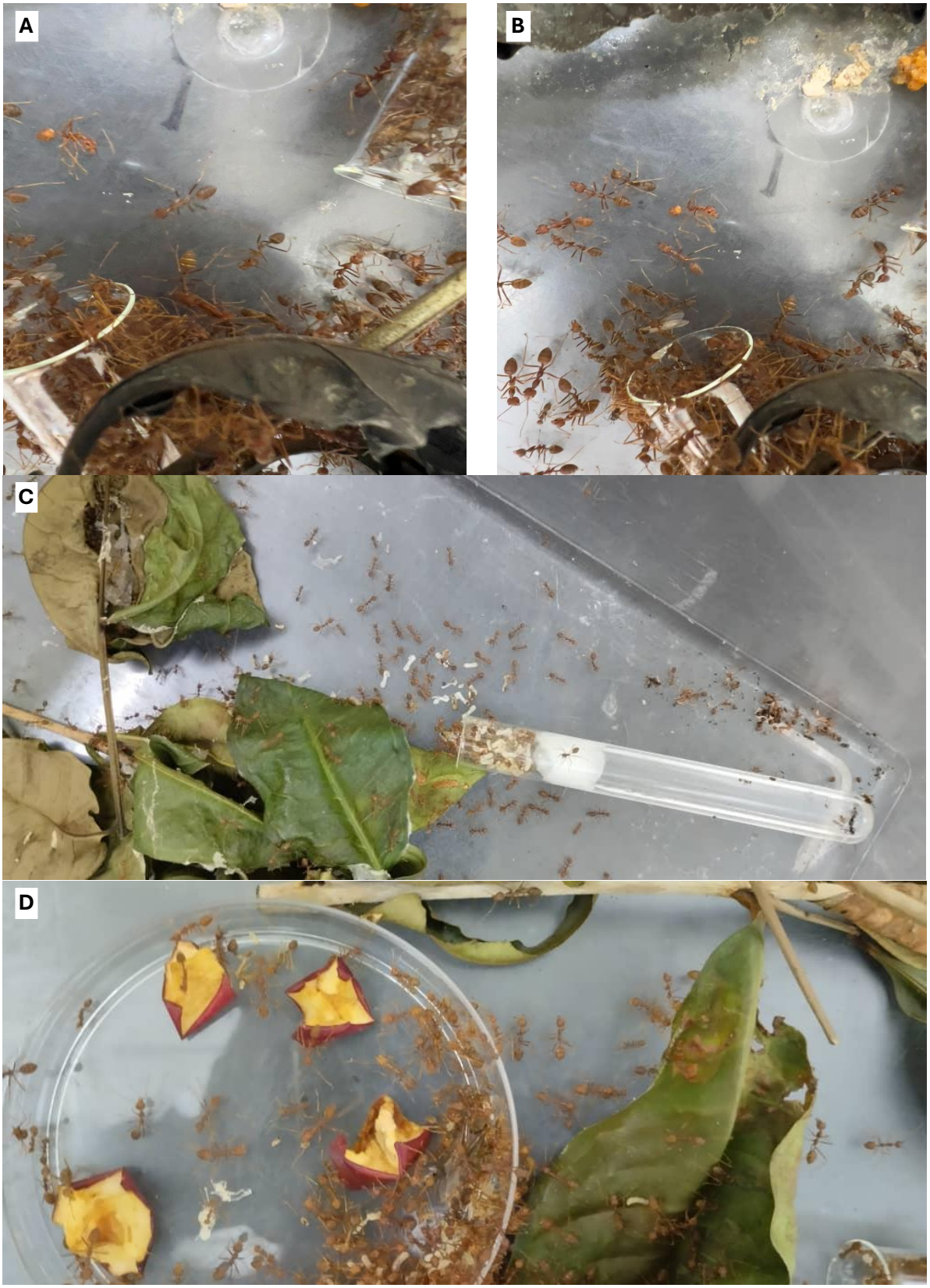

Figure 2. Colony establishment and brood development of weaver ants (*O. smaragdina*) in a laboratory rearing container. Figure (a) represents a colony of the weaver ants, Figure (b) represents a colony fed with chicken skin, Figure (c) represents a colony fed with sugar solution, and Figure (d) represents a colony fed with apple

Data Analysis

All experimental data were subjected to statistical analysis to evaluate treatment effects on colony growth and other measured parameters. One-way Analysis of Variance (ANOVA) was conducted using IBM SPSS Statistics, Version 28, to determine whether significant differences existed among the treatments. The assumptions of normality and homogeneity of variance were verified prior to ANOVA to ensure the validity of the test. Post-hoc comparisons of treatment means were performed using Tukey's Honest Significant Difference (HSD) test at a Significance level of $P = 0.05$. This allowed for the identification of specific pairs of treatments that differed significantly while controlling for Type I error. All analyses accounted for replicates within each treatment to improve statistical reliability and reduce variability.

The growth rate of *O. smaragdina* colonies was calculated as a percentage change in colony size over the experimental period using the following formula:

$$\text{Growth Rate} = \frac{Final\ Colony\ size - Initial\ Colony\ size}{Initial\ Colony\ size} \times 100$$

RESULTS

Choice Diet of Feeding Preferences of *Oecophylla smaragdina*

Table 1 shows significant differences in the amount of food consumed, the number of ants visiting the food, and the quantity of food returned to the nest across different diet types (P=0.001). Sugar was the most consumed diet (1.99±0.12 g), followed by glucose (1.58±0.14 g) and mealworms (1.41±0.09 g). In contrast, coconut oil (0.27±0.06 g) and canola oil (0.32±0.08 g) were consumed in the least amount. The number of ants present per food source was highest for sugar (73.33±3.88), followed by mealworms (52.89±3.17) and mackerel (44.22±3.12), while coconut and canola oils had the fewest ants (11–12 per observation). Regarding food returned to the nest, protein-based diets such as mealworms (8.44±1.71 g) and mackerel (7.67±0.68 g) contributed the most. Diets high in fat or sugar showed little to no food return. The mean number of ants involved per food visit was 70.48, and the mean number of ants contributing to food return was 25.33. These results indicate that *O. smaragdina* workers preferentially process protein-rich foods for nest return, while carbohydrate- and fat-rich diets are primarily consumed at the source.

Table 1. Feeding preferences of *O. smaragdina* across different choice diets

Diet Type	Amount Consumed	Number Of Ants Per Visit	No. Of Ants Per Food Return
Mackerel (g)	1.16±0.10^{b}	44.22±3.12^{b}	7.67±0.68^{a}
Mealworm (g)	1.41±0.09^{a}	52.89±3.17^{b}	8.44±1.71^{a}
Cricket (g)	0.98±0.27^{c}	22.44±1.71^{e}	2.00±0.88^{b}
Sugar (ml)	1.99±0.12^{a}	73.33±3.88^{a}	0.00±0.00^{b}
Honey (ml)	1.19±0.09^{b}	27.44±1.71^{d}	0.00±0.00^{b}
Glucose (ml)	1.58±0.14^{a}	38.22±2.27^{c}	0.00±0.00^{b}
Olive oil (ml)	0.58±0.09^{d}	19.44±2.08^{e}	0.00±0.00^{b}
Canola oil (ml)	0.32±0.08^{e}	12.33±1.16^{f}	0.00±0.00^{b}
Coconut oil (ml)	0.27±0.06^{e}	11.78±1.09^{f}	0.33±0.33^{b}

Means followed by different letters in the same column differ significantly according to Tukey's HSD test (P<0.05).

Non-choice Diet of Feeding Preferences of *Oecophylla smaragdina*

In the non-choice feeding trials, clear differences were observed among the diet types in both ant visitation and food consumption (Figure 3). Bagworm recorded the highest percentage of ant visitation (69.33%), followed by mealworm (46.67%), cricket (33.00%), and mackerel (25.67%). A similar trend was observed for the amount of food consumed. Bagworm showed the highest consumption (2.23 g), followed by mealworm (1.73 g) and cricket (1.60 g), while mackerel recorded the lowest consumption (0.93 g). Statistical analysis indicated that differences in ant visitation among diet types were significant (mean square = 1105.56, F = 7.95, P<0.001). Post hoc analysis using Tukey's HSD test revealed that bagworm differed significantly from mackerel, while mealworm and cricket showed intermediate values and did not differ significantly from either group. In contrast, variation in the amount of food consumed was not statistically significant (mean square = 0.86, F = 3.13, P=0.09), and Tukey's HSD test showed no significant differences among diet types, with all means assigned the same letter.

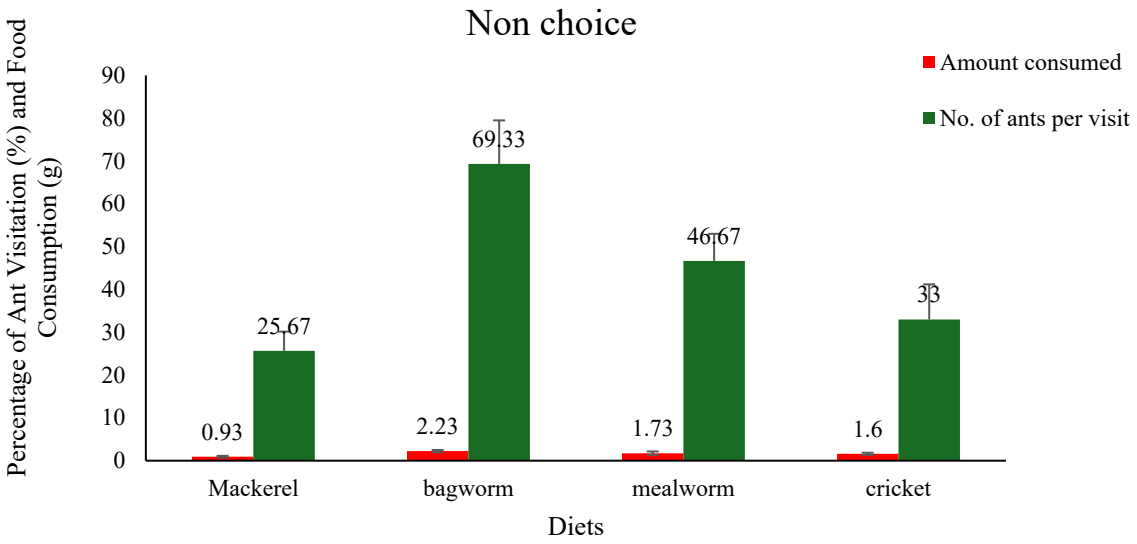

Figure 3. Feeding preferences of *O. smaragdina* in a non-choice diet experiment

Colony Development of *Oecophylla smaragdina* Under Different Temperature Conditions

Table 2 presents the effect of temperature on colony performance of *O. smaragdina*. The mean final colony size (±SE) varied across temperature treatments, with values of 277±19.16, 427.00±33.17, and 625.67±24.99 individuals at 22°C, 25°C, and 29°C, respectively. The corresponding lower and upper bounds for each treatment are also provided in the table. Population increase, expressed as absolute change in colony size, was 175.41, 421.98, and 705.43 for 22°C, 25°C, and 29°C, respectively. When expressed as percentage population increase, the values were 58.44±15.44%, 140.62±15.17%, and 235.14±27.05% across the three temperature treatments. One-way ANOVA revealed significant differences among treatments for both final colony size (F = 43.86, P=0.001) and percentage population increase (F = 24.37, P=0.001). Pairwise comparisons using Tukey's HSD test showed that all treatments were significantly different from one another, as indicated by the different superscript letters.

Table 2. Effect of temperature on final colony size and population increase of *Oecophylla smaragdina* (mean±SE)

Temperature	Initial Colony	Final Colony	Final Colony Size (Mean±SE)	Growth Rate	Growth Rate (%)	Lower Bound	Upper Bound
22(°C)	537	831	277±19.16c	175.41	58.44±15.44c	194.57	359.43
25(°C)	540	1281	427.00±33.17b	421.98	140.62±15.17b	284.28	569.72
29(°C)	564	1877	625.67±24.99a	705.43	235.14±27.05a	518.12	733.21

Means with different superscript letters within a column are significantly different (Tukey HSD, $P<0.05$).

DISCUSSION

The results demonstrate clear dietary preferences in *O. smaragdina*, reflecting both consumption patterns and foraging behaviour. Sugar was the most commonly consumed food source, followed by glucose and mealworms, while oil-based diets, such as coconut and canola, were the least preferred. However, protein-rich diets, including mealworms and mackerel, were transported back to the nest in the highest quantities, whereas sugar and fat-rich diets contributed little to nest provisioning. This suggests a functional distinction between immediate energy consumption and nutritional storage for colony needs (Hendriksma et al. 2019). High consumption of sugar aligns with the known preference of *O. smaragdina* for carbohydrate-rich resources, which provide quick energy for foraging and worker activity (Poissonnier 2018). In contrast, the preferential transport of protein-rich foods to the nest reflects their role in brood development and queen nutrition, as protein is critical for larval growth and colony reproduction (Fèvre & Dearden 2024). Fat-rich diets, such as oils, were poorly consumed and rarely transported, likely because they are less relevant to the immediate protein requirements of brood and reproductive individuals. The higher number of ants visiting carbohydrate sources indicates strong recruitment to energy-rich resources. In contrast, fewer ants were involved in protein foraging trips, possibly due to the higher handling costs and transport requirements associated with solid prey items (Vilcinskas 2016). Overall, these findings emphasise that *O. smaragdina* exhibits a sophisticated foraging strategy that balances immediate energy needs with colony nutritional demands, optimising survival and reproductive success.

The non-choice feeding experiment highlights a pronounced preference of *O. smaragdina* for protein-rich diets, particularly bagworms and mealworms. Approximately 73% of workers visited the bagworm diet, followed by 52% on mealworms, with lower visitation to mackerel (29%) and crickets (27%). This indicates an apparent selectivity for prey items that likely provide essential amino acids and other nutrients required for colony growth and brood development (Hendriksma et al. 2019). Despite high visitation rates, the total amount of food consumed was relatively low across all diets, suggesting that factors beyond mere presence, such as digestibility, palatability, or nutrient content which modulate actual intake. Similar findings have been reported in other ant species, where food preference does not always equate to consumption volume, but rather reflects targeted foraging behaviour for nutrient acquisition (Csata & Dussutour 2019). The pronounced preference for protein-rich diets aligns with earlier observations in choice experiments, reinforcing the role of such food sources in supporting colony maintenance and reproduction. This behaviour ensures that workers allocate energy efficiently between foraging and nutrient delivery to the nest, emphasising the ecological and physiological importance of selective feeding strategies in *O. smaragdina* (Exélis et al. 2024).

The results demonstrate an evident influence of temperature on the growth dynamics of *O. smaragdina* colonies. Colonies maintained at 29°C exhibited the highest population growth

and colony expansion, whereas those at 22°C showed the slowest development. These findings indicate that moderate to high ambient temperatures favour faster colony growth, likely by enhancing metabolic activity, brood development, and worker activity (Xu et al. 2023). The significant differences observed among temperature treatments suggest that *O. smaragdina* colonies are thermally sensitive, with optimal growth occurring near 29°C. Lower temperatures may slow physiological processes such as egg-laying, larval growth, and worker foraging efficiency, leading to reduced colony expansion (Ingole et al. 2024). Conversely, higher temperatures within the species' tolerance range likely accelerate developmental rates, as observed in other ant species, resulting in faster recruitment of workers and enhanced colony performance (Parr & Bishop 2022). These findings highlight the significance of environmental temperature as a crucial factor influencing colony dynamics in *O. smaragdina*. Understanding thermal effects on colony growth is crucial for predicting population establishment and effectiveness in biological control applications, especially in tropical agroecosystems where temperature fluctuations can influence ant activity and performance.

CONCLUSION

This study demonstrates that *O. smaragdina* exhibits distinct dietary preferences, favouring carbohydrate-rich foods such as sugar and glucose to meet immediate energy demands, while selectively transporting protein sources like mealworms and mackerel to sustain brood development and colony growth. These findings highlight the species' adaptive foraging strategies in balancing short-term energy requirements with long-term nutritional needs. Temperature was also identified as a critical abiotic factor, with colonies maintained at 29°C achieving significantly greater growth rates and final sizes than those reared at 25°C or 22°C, underscoring the thermal sensitivity and optimal performance of this tropical arboreal ant in warmer conditions. Collectively, these results provide practical insights for improving colony management in both laboratory and applied settings, including biological control programs, while advancing our understanding of the nutritional ecology and environmental adaptability of weaver ants. Future studies should investigate long-term colony dynamics, thermal tolerance thresholds, and interactions with additional environmental variables to optimise colony performance and ecological applications further.

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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, Lukman Idowu Gambari, and Hasber Salim conceptualized the study and designed the experiments. Kumara Thevan and Hasber Salim performed the data analysis and interpreted the results. All authors read and approved the final manuscript.

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