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Functional Group of Spiders on Durian Plantations in Tarakan Island: The Influence of Ant Predator *Oecophylla smaragdina* on Spiders

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Abstract.

This study aimed to examine the guild composition of spiders in durian plantations, specifically focusing on the influence of *O. smaragdina*. For data collection, branch sampling was employed to gather *O. smaragdina* and spiders from Durian (*Durio zibethinus*) trees in the plantations, and the density of both predators was determined by counting the number of individuals. The results showed that a total of 3,049 individual belonging to 74 species of spiders were collected from 44 durian trees, and the community exhibited eight distinct functional groups, namely Stalkers, Orb Weavers, Foliage Runners, Ambushers, Tangled Weavers, Ground Runners, and unknowns. Stalkers also emerged as the dominant group within the durian trees, and the average number of *O. smaragdina* workers in trees did not show a negative correlation with Foliage Runners. However, there was a negative effect of the nest presence and the number of workers on the spider community, particularly impacting the Foliage Runners and Ambusher groups. This study also suggested that *O. smaragdina* acted as a competitor and predator for certain guilds of spiders in durian plantations, but the influence on the functional groups within mixed cropping systems was found to be relatively weak.

Keywords: Durian, *Oecophylla*, Plantations, Predator, Spider

1. Introduction

Grouping spiders into guilds or functional groups based on similar behaviour in accessing resources is an important approach to understanding their roles and interactions within plantations (Perkins *et al*. 2017). Furthermore, the structure and distribution patterns in farming systems can be influenced by microclimatic conditions, emphasizing the importance of studying their guild composition and functional groups in different agricultural landscapes (Rosas-Ramos *et al*. 2020). The diversity of species and groups is also influenced by the structure of vegetation (Lia *et al*. 2022). It has been reported that various biological components exert an influence on spider composition within ecosystems. Certain biological components, such as insects microorganisms and birds, have been found to significantly impact their respective habitats(Katayama *et al*. 2015; Zhang *et al*. 2018; Gunnarsson and Wiklander 2015).

In terrestrial ecosystems, both ants and spiders have been identified as generalist predators (Samiayyan, 2014). In the specific context of a plantation area using a mixed cropping system, this approach has been found to provide benefits for promoting predator biodiversity and the availability of prey within the ecosystem (Lia *et al*. 2022). Consequently, these predators play a crucial role in pest control within the plantation. It is also important to acknowledge that the system can also give rise to competition among predators and an increase in pest populations due to the diverse range of available food sources. For instance, ants and spiders, being potential competitors or engaging in intraguild predation, may exhibit such dynamics (Potter *et al*. 2018). The abundance of natural enemies does not always exhibit a strong correlation with pest populations since simple taxa, including spiders and predatory insects, can display varying responses (Paredes *et al*. 2015). In contrast, predators can coexist and have similar effects on plant ecosystems (Rákóczi and Samu 2014; Stefani *et al*. 2015), or may mutually interfere with the functional response of an omnivorous animal (Papanikolaou *et al*. 2020).

There have been reports highlighting the interaction between ants and other predators within plantations. Specifically, ants have been found to exert a disadvantageous effect and interfere with the competition faced by others, such as spiders (Yip 2014). In terrestrial ecosystems, the diversity of spiders (Araneae) indicates whether the correlation is positive or negative. This observation supports the hypothesis that insects act as predators of spiders (Dimitrov and Hormiga 2021). A study conducted in the Bornean tropical forest showed that ants and spiders exhibited significant spatial distribution exclusively in canopy trees (Katayama *et al*. 2015).

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Another study reports a case in which spiders coexist with predators of ants (Stefani *et al*. 2015). However, studies examining the relationship between ants and spiders remain limited, particularly regarding the impact of the predators on various functional groups.

The utilization of biological agents, specifically ants, has been widely implemented in plantation areas. The strategy of biological control encompasses three key approaches, namely introduction or transfer, augmentation, and conservation of ants (Offenberg 2015). These techniques are implemented through various means, such as relocating ant nests to different locations, employing artificial nests with supplementary food sources, and transferring workers from one colony to another tree using ropes, among other methods (Offenberg 2015; Abdulla *et al.* 2015). The weaver ants *O. smaragdina* are most plentifully and widely distributed in Southeast Asia and northeast Australia (Wetterer 2017). Meanwhile, *Oecophylla* has been recognized as biological control in cashew plants (Offenberg 2015; Olotu *et al.* 2013), mango fruits, and citrus (Offenberg *et al*. 2013). In another case, these predators are known to affect pollinators (Gonzálvez *et al*. 2013), parasitoids (Appiah *et al*. 2014; Tanga *et al.* 2016), and other beneficial insects. This is because weaver ants are general predators which can provide benefits and be harmful to other organisms (Thurman *et al.* 2019).

Durian (*Durio* spp) cultivation and distribution in Kalimantan primarily involve a mixed cropping system that provides resources for *O. smaragdina* (green ants) and spiders (Rahim 2015, unpublished data). However, these areas may also have a higher presence of herbivorous insects. To evaluate the hypothesis regarding the predation dynamics between insects and spiders, as well as the impact of *O. smaragdina* within the spider guild, studying this interaction in the mix cropping system becomes interesting. This study assesses species classifications that share similarities in resource exploitation or guild membership. Additionally, the relationship between *O. smaragdina* and spiders, both acting as predators, is investigated. The results provide insights into the conservation of predators in mixed tree cropping systems and offer guidance on managing local predators in plantations. The conservation of *O. smaragdina* by efforts to move one colony to another tree with a rope is an attempt to ensure the ant colony can access other types of trees. (Offenberg 2015). However, it needs to be combined with additional feed (Abdulla *et al.* 2015) to prevent competition between predators.

2. Materials AND METHODS

2.1. Study area

This study was carried out in the plantation area in Tarakan Island, North Kalimantan (3°18'15"N, 117°37'12"E). The study site was chosen in a mixed tree plantation, where durian trees dominate over other crops. In addition, the site was located near both urban areas and horticulture plantations. *Durio zibethinus*, *Citrus spp*, and *Musa spp* were the dominant species, occupying more than 80%. The average temperature and humidity recorded on the site were 27.7 ℃ and 84%, respectively, as shown in Figure 1.

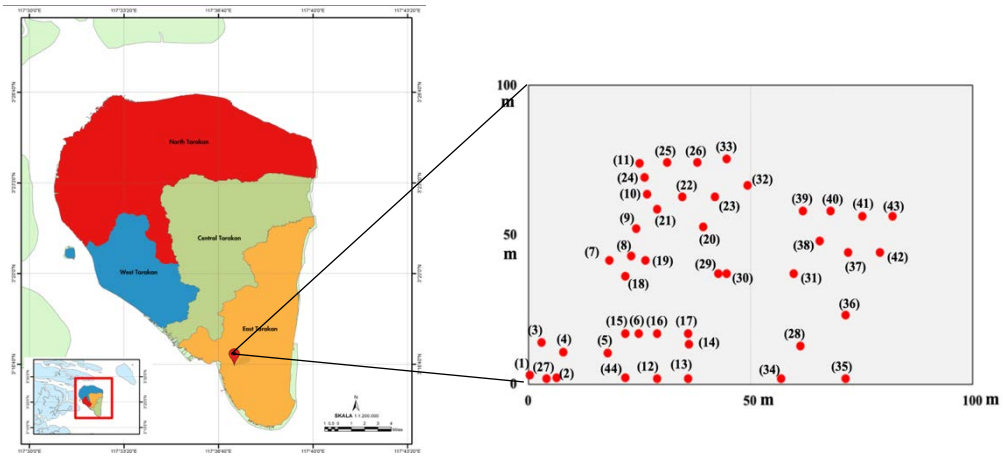


Figure 1. Location of the studied sites in Tarakan Island of North Kalimantan. The point of distribution of sampling in the durian plant cultivation area

2.2. Field collection of O. smaragdina and spiders

The collection of *O. smaragdina* and spiders was conducted on 44 durian trees on Tarakan Island. The age of durian was 5-6 six years old and it was not fruiting periods. In the studied sites, 10 branches measuring between 50 and 80 cm in length, with a diameter ranging from 5 to 10 cm, were selected. The branches were chosen at the bottom, middle and top of the canopy as the place for the beating method. Furthermore, each branch point is given a code so that the next sampling is carried out at the same place. In addition, we measured the number of nests of *O. smaragdina* in each durian tree sample which used direct observation methods.

From March to September 2016, we sampled seven times with an interval of 30 days between each sampling. All the collected samples, including spiders, were preserved in specimen tubes filled with 99% ethanol and sorted in the laboratory. The identification of spiders was conducted in both the field and laboratory. The families, genera, and species (morphospecies) were identified using manual guides and online resources, e.g.

https://www.asianarachnology.com/online-spider-identification-websites/.

The spiders have been classified into different functional groups based on their scientific classification and foraging traits. These functional groups are as follows: (1) Ambushers, Foliage runners, Stalkers, and Orb weavers belonging to the family Thomisidae (Uetz *et al*. 1999), Clubionidae (Uetz *et a*l. 1999), Salticidae and Oxypidae (Uetz *et a*l. 1999), and Araneidae and Tetragnathidae (Lia *et al*. 2022).

2.3. Data analysis

For the examination of species composition and collection frequency in the sites, the average number of spiders collected on each tree branch during sampling was calculated. Based on the Kolmogorov-Smirnov test and the Shapiro-Wilk test, the data were normally distributed. To assess the interactions between ant *O. smaragdhina* and spiders, the R-value (rank Spearman correlation) was computed between the dominant spider species and functional spider groups. Additionally, differences were analyzed using a one-tailed t-test to estimate the effects of *O. smaragdina* on the spider groups. The statistical analysis of the data was conducted using SPSS Ver 23 software.

3. Results and Discussion

3.1. Taxonomic and guild composition of spiders

In this study, a total of 3049 individuals were collected, representing 74 species/morphospecies from 12 families. The results showed that the dominant families on the durian trees were Salticidae (41.1%), Araneidae (22.7%), and Thomisidae (11.7%). Additionally, it was observed that 10 species were frequently collected and exhibited dominance on the durian trees. All samples from the tree were occupied by species belonging to the Araneus genus, as shown in Table 1 and Fig. 1. Among the collected species, 10 stood out as dominant and accounted for over 50% of the spider population on the durian trees. Furthermore, the average number occupying more than 80% of the trees ranged from 2 to 7 individuals per tree, indicating a relatively high density, as shown in Table 1.

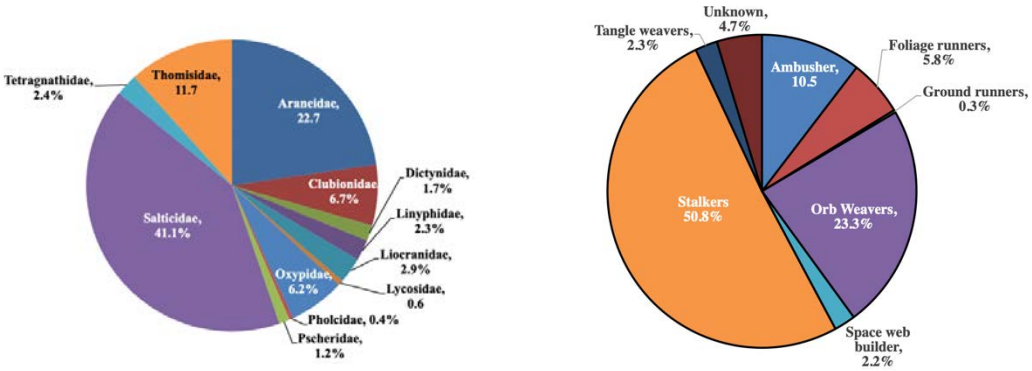
Table 1. Species/Morphospecies dominant of spider collected in Durian tree. The functional group were classified into eight groups: Stalkers (S), Orb Weavers (OW), Foliage Runners (FR), Space Web Builders (SWB), Ambusher (A), Tangle Weavers (TW), Ground Runners (G) and Unknown (U).

Family	Species/Morphospecies	Functional Group	Number of Trees Occupied	Total Individuals	Percentage Individuals (%)
Araneidae	*Araneus* sp2	OW	44	314	10.3
Salticidae	*Neon* sp2	S	43	309	10.1
Salticidae	*Neon* sp1	S	43	281	9.2
Thomisidae	Unknown sp1	A	39	181	5.9
Salticidae	Unknown sp2	S	38	124	4.1
Liocranidae	Liocranidae sp1	U	37	107	3.5
Araneidae	*Araneus* sp6	OW	29	91	3.0
Salticidae	*Leptorechestes* sp1	S	35	90	3.0
Araneidae	*Araneus* sp3	OW	27	83	2.7
Salticidae	*Leptorechestes berolinensis*	S	30	80	2.6
Thomisidae	*Xysticus* sp1	A	21	69	2.3
Oxypidae	*Oxyopes* sp3	S	26	66	2.2
Clubionidae	*Clubiona* sp1	FR	32	65	2.1
Araneidae	*Cyrtarachne* sp1	OW	21	64	2.1
Oxypidae	*Oxyopes* sp2	S	27	60	2.0
Salticidae	*Myrmachine formacaria*	S	18	58	1.9
Araneidae	*Araneus* sp4	OW	29	56	1.8
Salticidae	*Neon valentulus*	S	24	56	1.8
Dictynidae	*Dcytina* sp1	SWB	16	51	1.7
Tetragnathidae	*Tetragnatha dearmata*	OW	20	47	1.5
Salticidae	*Chalcoscirtus* sp1	S	23	45	1.5
Clubionidae	*Clubiona* sp4	FR	25	42	1.4
Salticidae	*Chalcoscirtus* sp2	S	24	41	1.3
Salticidae	Salticidae sp1	S	21	41	1.3
Salticidae	*Synageles* sp1	S	17	36	1.2
Pscheridae	*Psechrus* sp1	U	17	34	1.1
Linyphidae	*Floronia* sp1	TW	17	33	1.1

Salticidae	Unknown sp3	S	19	33	1.1
Oxypidae	*Oxypidae* sp1	S	22	32	1.0
Oxypidae	*Oxypidae* sp2	S	19	31	1.0
Clubionidae	*Clubiona* sp7	FR	19	30	1.0
Salticidae	*Neon* sp3	S	15	27	0.9
Oxypidae	*Oxyopes* sp1	S	14	26	0.9
Araneidae	*Araneus* sp5	OW	12	24	0.8
Thomisidae	Unknown sp2	A	14	24	0.8
Thomisidae	*Xysticus* sp3	A	13	23	0.8
Oxypidae	*Oxyopes* sp4	S	13	20	0.7
Linyphidae	*Floronia* sp2	TW	11	18	0.6
Linyphidae	*Drapetisca* sp1	TW	7	17	0.6
Pholcidae	*Pholcus* sp1	SWB	9	17	0.6
Araneidae	*Araneus praesignis*	OW	12	16	0.5
Clubionidae	*Clubiona* sp2	FR	13	15	0.5
Salticidae	*Agorius* sp1	S	7	13	0.4
Salticidae	*Marpissa* sp1	S	9	13	0.4
Clubionidae	*Clubiona* sp5	FR	8	12	0.4
Salticidae	*Plexippus* sp1	S	5	12	0.4
Clubionidae	*Clubiona* sp3	FR	9	10	0.3
Salticidae	*Leptorechestes* sp2	S	8	10	0.3
Salticidae	*Salticus* sp1	S	6	9	0.3
Thomisidae	*Thomisus* sp1	A	5	9	0.3
Lycosidae	*Lycosa* sp1	GR	4	8	0.3
Salticidae	*Euophrys* sp1	S	5	7	0.2
Salticidae	*Myrmachine melanostrata*	S	4	7	0.2
Salticidae	*Myrmarachn*e sp1	S	4	7	0.2
Araneidae	*Araneus* sp1	OW	5	6	0.2
Araneidae	*Araneus* sp7	OW	4	4	0.1
Clubionidae	*Clubiona* sp6	FR	3	4	0.1
Salticidae	Salticidae sp1	S	3	4	0.1
Tetragnathidae	*Tetragnatha* sp1	OW	4	4	0.1
Thomisidae	*Thomisus* sp2	A	2	4	0.1
Thomisidae	*Xysticus* sp2	A	4	4	0.1
Liocranidae	Unknown sp3	U	3	3	0.1
Salticidae	*Neon* sp6	S	3	3	0.1
Thomisidae	*Diaea* sp1	A	3	3	0.1
Thomisidae	Thomisidae sp3	A	3	3	0.1
Araneidae	*Zygiella* sp1	OW	2	2	0.1
Linyphidae	*Micrargus* sp1	TW	1	2	0.1
Salticidae	Unknown sp4	S	2	2	0.1
Salticidae	*Neon* sp8	S	2	2	0.1
Araneidae	*Araniella* sp1	OW	1	1	<0.1
Linyphidae	*Hypselistes* sp1	TW	1	1	<0.1
Salticidae	Unknown sp	S	1	1	<0.1
Salticidae	*Thianitara* sp1	S	1	1	<0.1
Thomisidae	*Misumena* sp1	A	1	1	<0.0

Furthermore, the spiders were classified into eight functional groups: Stalkers, Orb Weavers, Foliage Runners, Space Web Builders, Ambushers, Tangle Weavers, Ground Runners, and Unknown. Among these groups, four dominant categories were identified, namely Stalkers (50.8%), Orb Weavers (23.3%), Ambushers

(10.5%), and Foliage Runners (5.8%), as shown in Fig. 2. These results align with previous data, which show the presence or occurrence of the Stalkers functional group in all sampled trees.



A **B**

Figure 2. Percentage of spider group (A) family (B) guild or functional group in the studied site

3.2. Relationships among O. smaragdina and functional group of spiders

During this study, all relationship analyses consistently indicated a negative correlation between the number of *O. samaragdina* per branch or tree and the average abundance of the functional groups of spiders. The number of worker ants had no significant negative correlation on the functional group of spiders (Ambusher, R^2=0.025; Stalkers, R^2=0.02; Orb weavers, r=0.04, Fig. 3). However, the correlation among *O. smaragdina* was significant on Foliage Runner (R^2=0.07, P=0.012, Fig. 3). The result showed that *O. smaragdina* had no strong relationship on functional groups of spiders.

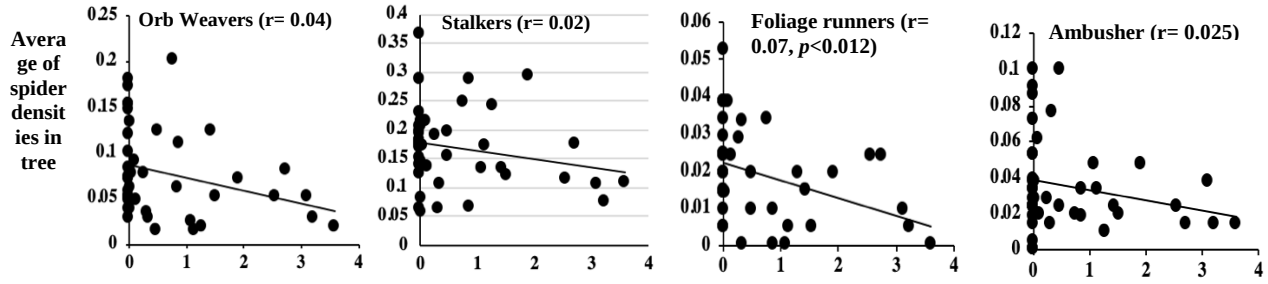


Figure 3. The relationships among the worker densities of *O. smaragdina* and of spider densities by Functional group in durian tree

3.3. Effect of Predator O. smaragdina Presence on Spiders

This study further assessed the impact of *O. smaragdina* presence on durian trees on the spiders guild. The analysis showed a significant difference in the average number of individual spiders observed on durian trees (Ambusher, p = 0.03, Fig. 4a; Foliage Runner p = 0.04, Fig. 4b; Orb Weavers, p = 0.015, Fig. 4d). However, there was no significant result on Foliage Runner (Stalkers, p = 0.06; Fig. 4c). The data showed that the number of spiders in the absence of *O. smaragdina* workers was lower.

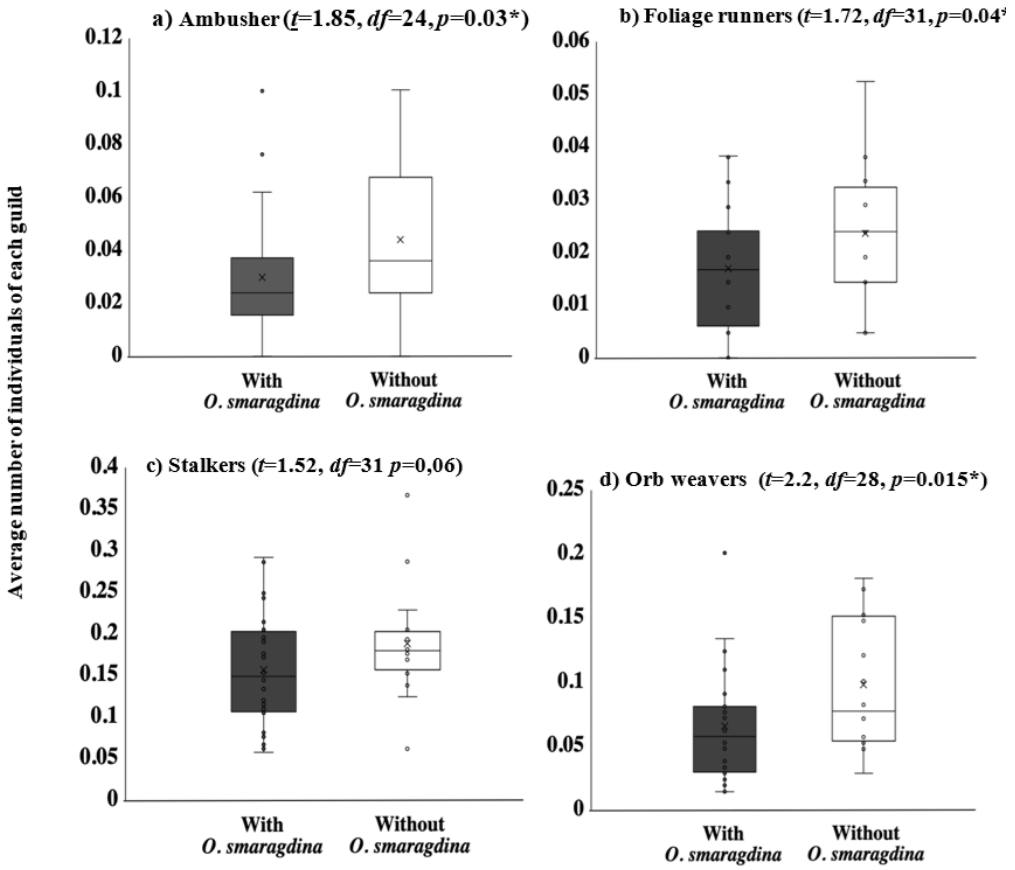


Figure 4. Box plot the differences between the average number of spiders and trees with and without *O. smaragdina* workers densities on durian trees. The average of the collected number (/branch/tree/collection time) was compared by using a t-test. Bar means standard error. Asterisk (*) means a significant difference between trees with and without *O. smaragdina* workers

This study investigated the impact of the presence or absence of *O. smaragdina* nests on the spider guild. The results showed that the average number of nests at the sampling locations ranged from 2 to 3 per tree. A significant difference in the average number of individual spiders was observed on durian trees with *O. smaragdina* nests (Ambusher, p = 0.04, Fig. 5a; Foliage Runner p = 0.002, Fig. 5b). However, there was no significant result on Foliage Runner (Stalkers, p = 0.32; Fig. 5c; Orb Weavers, p = 0.13 Fig. 5d). The presence of *O. smaragdina* nests in trees was associated with a lower number of individual spider.

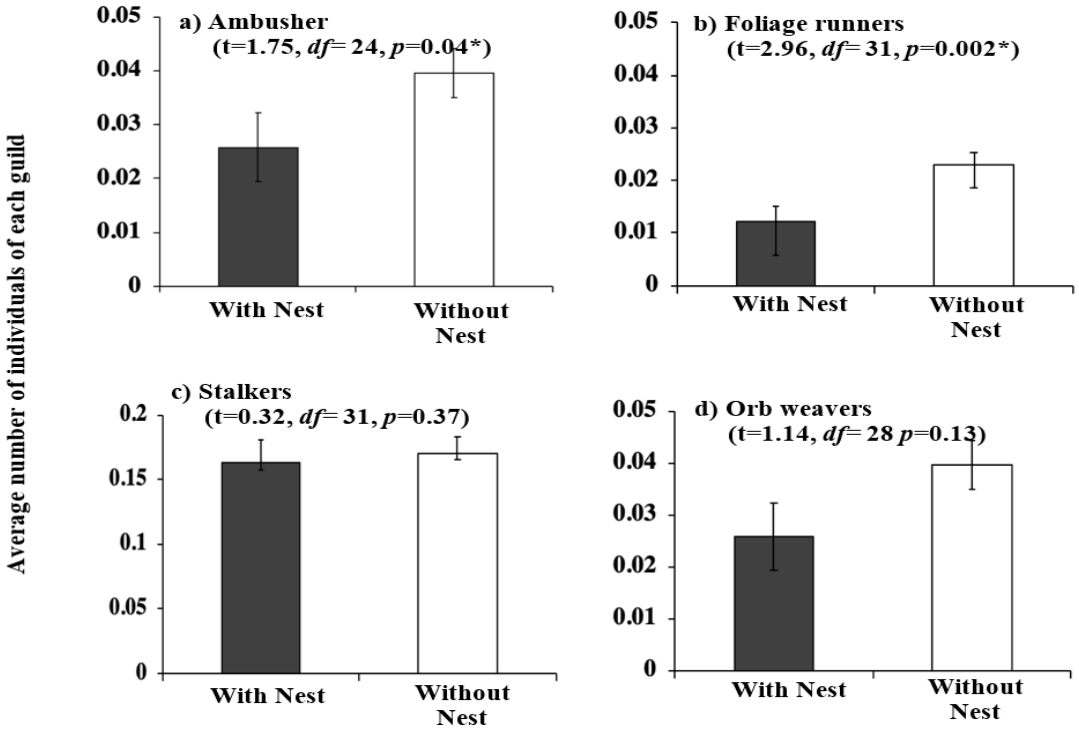


Figure 5. Comparison of average number of four groups of spiders among trees with and without *O. smaragdina* nests in durian trees

4. Discussion

More than seventy morphospecies were recorded within the study region, indicating high species richness in the mixed crop ecosystem. The coexistence of various plant species within this ecosystem provides ample space and food sources for insects, particularly herbivorous insects. Meanwhile, Rahim and Ohkawara (2019) documented the presence of more than 50 species of herbivorous insects thriving in mixed plant ecosystems dominated by horticultural crops. The dominant functional group of herbivores consists of aphids, mealybugs, and leaf beetles. This finding reinforces the notion that the species richness of predators is influenced by the richness of herbivorous insects. Furthermore, a direct proportional relationship is observed between the species richness of herbivorous and other predatory insects.

The species belonging to the families Aranneidae and Salticidae are dominant and can live in the canopy of plants and parts of tree branches. This result has also been described by Lia *et al*. (2020) where the Araneidae family dominates forest vegetation and oil palm plantations, specifically in the canopy. The genera Lycosidae and Oxyopidae dominated the corn plantation area.

The spider community within the Durian tree plantations is confirmed by examining the composition of functional groups or guilds. The Stalkers and Orb Weavers are the dominant groups in the plantations. Previous studies reported that these two groups were associated with canopies in tropical trees. In addition, two species stand out as more dominant than others due to their behavior (Battirola *et al*. 2016). The Stalkers consist of two families, namely Salticidae and Oxypidae, and there are several reasons why Salticidae are currently dominant in this study. Firstly, they exhibit behavior that allows access to all parts of the tree, including branches, leaves, and flowers. Moreover, they are active throughout the middle, bottom, and upper canopy of the tree. Another reason is that the beating sampling method may be influenced by the Salticidae families due to their ability to jump. The Orb Weaver species also emerge as dominant due to their ability to construct intricate webs on the Durian trees. According to Lia *et al*. (2022), spider families are denser and more prevalent in fully-grown vegetation. The Orb Weavers in particular are represented by the families Araneidae and Tetragnathidae, which have shown dominance in certain plantation areas. For example, the Araneidae family has been reported as dominant in Cocoa plantations (Oyewole and Oyelade, 2014) and Coffee agroecosystems (Marin and Perfecto, 2013). These findings indicate that the Durian tree provides a conducive environment for spider coexistence within the plantations.

This study examines the relationship between the number of workers and spiders in functional groups in Durian trees. It confirms that *O. smaragdina* tends to have a negative interaction with spider groups in the ecosystem, particularly with Foliage Runners on leaves (Fig 2). This is attributed to similarities in resource access, specifically leaves. According to Patel and Bhat (2020), weaver ants are eusocial insects that form nests in trees, forage for food, and protect their colony. However, *O. smaragdina* does not exhibit a negative relationship with Stalkers, Orb Weavers, and Ambushers due to their different behaviors in accessing resources. For example, jumping spiders that mimic weaver ants employ various mimicry strategies to coexist with other social insects, including ants (Ceccarelli, 2013). The low population density of *O. smaragdina* per branch per tree also contributes to these findings. Consequently, the presence of the worker insects has a negative relationship with the spiders based on their functional groups.

The activities of *O. smaragdina* are supported by the presence of a nest, and the organization is polydomous.

The colonies of *O. smaragdina* consist of reproductive castes, non-reproductive castes, workers, and soldiers (Offenberg *et al*. 2013). In this study, the presence of workers and nests significantly influenced two groups of spiders. Meanwhile, the average number of Foliage Runners and Ambushers is slightly lower on the durian tree, indicating competition between these predator groups. The presence of *O. smaragdina* does not impact Stalkers and Orb Weavers. Previous studies reported that *O. smaragdina* did not affect spiders and can coexist with other predators (Rákóczi and Samu, 2014; Stefani et al. 2015). They may also exhibit mutual interference (Papanikolaou *et al*. 2020) and avoid predation through mimicry (Ceccarelli, 2013). In addition, the ant predator is more active and distributed in the canopy, potentially accessing a wide range of resources. Then the location uses a mixed cropping system which will influence predator activity through competition from other possible groups of organisms.

In conclusion, the mix cropping system provides a richness of spider species and supports the presence of the predatory ant *O. smaragdina*. Several functional groups of spiders exist in the canopy of durian plantation trees, with the Salticidae group occupying a larger proportion. The relationship between the number of *O. smaragdina* and the spiders in each guild shows a moderate influence, suggesting a potential competition. Consequently, further study is needed to investigate the potential use of biological control agents, particularly focusing on the effects of spiders and *O. smaragdina* on herbivorous insects in mixed plantations.

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References

Abdulla NR, Rwegasira RM, Jensen KMV, Mwatamala MW, Offenberg J. 2016. Control of mango seed weevils (*Sternochetus mangiferae*) using the African Weaver Ant (*Oecophylla longinoda* Latreille) (Hymenoptera: Formicidae). *J. Appl. Entomol*, **140**: 500–506. DOI: 10.1111/jen.12260.

Appiah EF, Ekesia S, Afreh-Nuamah K, Obeng-Ofori D, Mohamed SA. 2014. African weaver ant-produced semiochemicals impact on foraging behavior and parasitism by the Opiine psarasitoid, *Fopius arisanus* on *Bactrocera invadens* (Diptera: Tephritidae). *Biological Control*, **79**: 49-57, DOI: 10.3390/insects7010001.

Battirola LD, Batistella BA, Rosado-Neto GH, Brescovit AD, Marques MI. 2016. Spider assemblage (Arachnida: Araneae) associated with canopies of *Vochysia divergens* (Vochysiaceae) in the northern region of the Brazilian Pantanal. *Zoologia* **33(4)**: 1-9. DOI: 10.1590/S1984-4689zool-20150170.

Ceccarelli FS. 2013. Ant-Mimicking Spiders: Strategies for Living with Social Insects. *Psyche* **2013**: 1-16. DOI: 10.1155/2013/839181

Dimitrov D, Hormiga G. 2021. Spider Diversification Through Space and Time. *Annu. Rev. Entomol*. **66**: 225–41. DOI: 10.1146/annurev-ento-061520-083414.

Gunnarsson B, Wiklander K. 2015. Foraging mode of spiders affects risk of predation by birds. *Biological Journal of the Linnean Society*, **115(1)**: 58–68. DOI: 10.1111/bij.12489.

Gonzálvez FG, Santamaría L, Corlett RT, Rodríguez-Gironés MA. 2013. Flowers attract weaver ants that deter less effective pollinators. Journal of *Ecology* **101(1)**: 78-85. DOI: 10.1111/1365-2745.12006.

Katayama M, Yamada KK, Tanaka HO, Endo T, Hashimoto Y, Yamane S, Itioka T. 2015. Negative Correlation between Ant and Spider Abundances in the Canopy of a Bornean Tropical Rain Forest. *Biotropica*, **47(3)**: 363–368. https://doi.org/10.1111/btp.12208.

Lia M, Rauf A, Hindayana D. 2022. Comparisons of the composition of spider assemblages in three vegetation habitats in Bogor, West Java, Indonesia. *Biodiversitas* **23(1)**: 244–255. DOI: 10.13057/biodiv/d230130.

Marin L, Perfecto I. 2013. Spider Diversity in Coffee Agroecosystems: The Influence of Agricultural Intensification and Aggressive Ants. *Environmental Entomology*, **42(2)**: 204-213. 2013. http://www.bioone.org/doi/full/10.1603/EN11223.

Offenberg J, Cuc NTT, Wiwatwitaya D. 2013. The effectiveness of weaver ant (*Oecophylla smaragdina*) biocontrol in Southeast Asian citrus and mango. *Asian Myrmecology*, **5**: 139–149. DOI: 10.20362/am.005015.

Offenberg J. 2015. Ants as tools in sustainable agriculture. Journal of Applied Ecology, 52: 1197-1205. DOI: 10.1111/1365-2664.12496.

Olotu MI, Du Plessis H, Seguni ZS, Maniania NK. 2013. Efficacy of the African weaver ant *Oecophylla longinoda* (Hymenoptera: Formicidae) in the control of *Helopeltis* spp. (Hemiptera: Psyllidae) and *Pseudotheraptus wayi* (Hemiptera: Coreidae) in cashew crop in Tanzania. *Pest Management Science*, **69(8):** 911-918. DOI: 10.1002/ps.3451.

Oyewole OA, Oyelade OJ. (2014). Diversity and Distribution of Spiders in Southwestern Nigeria. *Natural Resources* **5**: 926-935. http://dx.doi.org/10.4236/nr.2014.515079.

Papanikolaou NE, Dervisoglou S, Fantinou A, Kypraios T, Giakoumaki V, Perdikis D. 2021. Predator size affects the intensity of mutual interference in a predatory mirid. *Ecol. Evol*., **11**: 1342–1351. DOI: 10.1002/ece3.7137.

Paredes D, Cayuela L, Gurr GM, Campos M. 2015. Single best species or natural enemy assemblages? a correlational approach to investigating ecosystem function. *BioControl*, **60**: 37–45. DOI: 10.1007/s10526-014-9620-9.

Patel B, Bhatt N. 2020. Nesting, Protective and Foraging Behavior of *Oecophylla smaragdina* (Weaver Ants) in Anand, Gujarat. *Advances in Zoology and Botany* **8(4)**: 351-357. DOI: 10.13189/azb.2020.0804.

Perkins MJ, Inger R, Bearhop S, Sanders D. 2017. Multichannel feeding by spider functional groups is driven by feeding strategies and resource availability. *Oikos*, **127(1)**: 23–33. DOI:10.1111/oik.04500.

Potter TI, Greenville AC, Dickman CR. 2018 Assessing the potential for intraguild predation among taxonomically disparate micro-carnivores: marsupials and arthropods. *R. Soc. open sci*. **5**: 171872. http://dx.doi.org/10.1098/rsos.171872.

Rosas-Ramos N, Baños-Picón L, Tormos J, Asís JD. 2020. Farming system shapes traits and composition of spider assemblages in Mediterranean cherry orchards. *PeerJ*. DOI 10.7717/peerj.8856.

Rahim A, Ohkawara K. 2019. Species composition of herbivorous insects and ants on trees in the plantations of durian *Durio zibethinus* and citrus fruits *Citrus amblycarpa* in Tarakan Island of Borneo. *Sci. Rep. Kanazawa Univ*, **63**: 45-58.

Rákóczi AM, Samu F. 2014. Coexistence Patterns Between Ants and Spiders in Grassland Habitats. *Sociobiology*, **61(2)**: 171-177. DOI: 10.13102/sociobiology.v61i2.171-177.

Samiayyan K. 2014. Spiders - The Generalist Super Predators in Agro-ecosystems. In: Abrol DP (eds). Integrated Pest Management. Current Concepts and Ecological Perspective. Academic Press, San Diego.

Stefani V, Pires TL, Torezan-Silingardi HM, Del-Claro K. 2015. Beneficial Effects of Ants and Spiders on the Reproductive Value of *Eriotheca gracilipes* (Malvaceae) in a Tropical Savanna. *PLoS ONE* **10(7)**: e0131843. DOI: 10.1371/journal.pone.0131843

Tanga CM, Sunday E, Prem G, Nderitu PW, Samira AM. 2016. Antagonistic interactions between the African Weaver Ant *Oecophylla longinoda* and the parasitoid *Anagyrus pseudococci* potentially limits auppression of the invasive mealybug *Rastrococcus iceryoides*. *Insects*, **7**, DOI:10.3390/insects7010001.

Thurman JH, Northfield TD, Snyder WE. 2019. Weaver Ants Provide Ecosystem Services to Tropical Tree Crops. Front. *Ecol. Evol*. **7**:120: 1-9. DOI: 10.3389/fevo.2019.00120

Uetz GW, Halaj J, Cady AB. 1999. Guild structure of spiders in major crops. *J Arachnol*, **27**: 270-280.

Wetterer JK. 2017. Geographic distribution of the weaver ant *Oecophylla smaragdina*. *Asian Myrmecology*, **9**: e009004. DOI: 10.20362/am.009004

Yip EC. 2014. Ants versus spiders: interference competition between two social predators. *Insectes Sociaux* **61**: 403–406. DOI: 10.1007/s00040-014-0368-0

Zhang L, Yun Y. Hu G, Peng, Y. 2018. Insights into the bacterial symbiont diversity in spiders. *Ecology and Evolution* **8**:4899–4906. DOI: 10.1002/ece3.4051