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RESEARCH ARTICLE

Insect diversity and guild composition in seasonal tropical fruit orchards

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ABSTRACT

Tropical seasonal fruit orchards are dynamic ecosystems that support a wide range of insect species, contributing significantly to regional biodiversity and various ecological functions. This study aims to assess the diversity and guild structure of insects in fruit orchards in Northern Malaysia during both the off-season (December 2022–January 2023) and the flowering season (February 2023 – April 2023). Insects were collected using pheromone traps, malaise traps, and sticky traps across four locations in Penang and Kedah, Malaysia. A total of 1,930 individual insects, representing 11 orders and 56 families, were captured during the off-season, while 4,569 individuals from 11 orders and 58 families were recorded during the flowering season. Chrysopidae (Neuroptera) was the most abundant family during the off-season (688 individuals), whereas Tephritidae (Diptera) dominated the flowering season (1,863 individuals). The flowering season exhibited greater insect diversity (H'=2.134) and evenness (E=0.526), although the off-season had higher species richness (IMargalef = 7.27). In terms of guild structure, pests were the dominant insect guild in both seasons, followed by pollinators. By comparing the relative abundance across the two seasons, pest abundance increased from the off-season to the flowering season, while pollinator abundance significantly decreased. This finding provides valuable insights into the insect fauna within the fruit orchards which can contribute to a better understanding of insect ecology and aid in the development of sustainable pest management strategies.

1. INTRODUCTION

Malaysia is a tropical country that provides an optimal environment for cultivating a variety of tropical fruits such as durian, mango, rambutan, and mangosteen, owing to its favourable temperature and rich soil. The country's tropical climate enables fruit cultivation throughout the year, facilitating continuous production and availability. This perennial growing potential is further enhanced by the diverse microclimates and soil conditions that influence the types of fruits that can be cultivated and the insect communities inhabiting these orchards.

Insects are essential components of agricultural ecosystems, significantly affecting the health and productivity of fruit orchards. The complex interactions between insects and their environments play vital roles in pollination, pest control, and nutrient cycling (Sanjeeth et al., 2023). Seasonal changes add another layer of complexity to the dynamics of insect populations in agricultural settings. Malaysia's tropical climate typically includes distinct wet and dry seasons, each bringing different environmental conditions and resource availability. During the wet season, increased rainfall can lead to lush vegetation growth and a proliferation of floral resources, attracting a wide range of pollinators and other beneficial insects (Majewska & Altizer, 2020). In contrast, the dry season might witness a reduction in floral resources and a corresponding decline in insect activity. These seasonal variations influence the availability of resources, affecting insect diversity and guild structure. Additionally, the distinction between off and flowering seasons within these broader climatic periods further affects the composition and behavior of insect communities. The off-season in fruit orchards often features lower floral resource availability, potentially reducing insect activity and diversity. Conversely, the flowering season provides abundant floral resources, which can support a higher diversity and abundance of insects, particularly pollinators.

Despite the crucial role that insect communities play in maintaining healthy and productive fruit orchards, there is a significant gap in understanding how seasonal variations specifically influence these communities in Malaysia's tropical climate. Existing research often overlooks the distinct dynamics of insect populations during off- and flowering seasons, leading to a lack of comprehensive data on how resource availability affects insect activity, diversity, and guild composition. This gap in knowledge hinders effective pest management and conservation strategies, as the potential benefits of promoting beneficial insect communities during critical periods remain unexamined. Therefore, this study seeks to address this issue by comparing the diversity and guild structure of insects in fruit orchards during these contrasting seasonal phases, providing insights that are essential for enhancing sustainable agricultural practices and improving fruit production in tropical regions.

2. MATERIALS AND METHODS

2.1 The study area

The study was conducted at four distinct fruit orchard locations (Figure 1) which were Kampung Sepulau and Relau in Kedah and in Penang, the location of the fruit orchard was at Sungai Ara and Kampung Sungai Baong. The topography of fruit orchards in Kedah was flat or landed compared to the hillier fruit orchards in Penang. Insects were collected to assess the impact of local fruit tree seasonality on insect diversity and guild structure. The sampling process was conducted twice at each location. The first sampling occurred during the off-season, from December 2022 to January 2023. The off-season is defined as a period when fruit trees are not actively producing flowers or fruit, typically characterized by lower floral resource availability and reduced insect activity. The second sampling was carried out during the flowering season, from February 2023 to April 2023, coinciding with the flowering period of most seasonal fruit trees such as durian, rambutan, and mangosteen. The flowering season is defined as the period when fruit trees are in bloom and producing flowers, which attracts a higher diversity and abundance of pollinators and other beneficial insects.

2.2. Insect Sampling and Identification

The insect sampling was conducted using three sampling methods: a malaise trap, pheromone trap, and sticky trap. The malaise trap, made of white polyester netting, was set at a height of two meters and a width of one meter to capture flying insects. At the highest point of the trap, a cylinder containing 75% ethanol was attached for insect preservation. For the pheromone trap, methyl eugenol was used as an attractant, with five traps deployed at each sampling location. Additionally, five two-sided yellow sticky traps, measuring 20 x 25 cm, were placed randomly at each site. All the traps were set randomly in the orchards at 0900 and left for three days. The traps and samples were collected during the daytime, and the samples were kept in universal bottles containing 75% ethanol for preservation before identification. The insects were brought back to the laboratory at Universiti Sains Malaysia and were identified up to the family level using taxonomic keys by Triplehorn & Johnson, (2004). To assess the functional feeding characteristics of the analyzed communities, insects were classified into feeding guilds following Olivier (2014). Insects were grouped into predators, pests, scavengers, parasitoids, pollinators, and omnivores.

2.2.1 Data analysis and biological indices

The relative abundance of insects was calculated by determining the total number of insects captured during each season. The dominance of insect guilds was calculated as a percentage, reflecting the proportion of each guild relative to the total insect population captured. The diversity indices including Shannon Weiner Index (H'), Margalef Richness Index (IMargalef), and Evenness Index (E), were used to determine the insect's diversity and richness for the two seasons (flowering season and off-season).

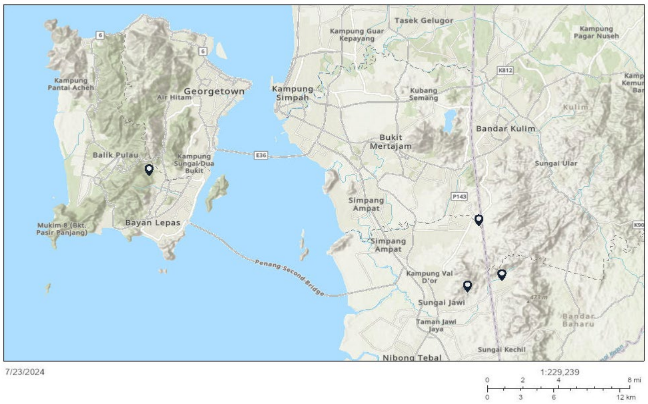

Figure 1: Map of the sampling locations.

3. RESULTS AND DISCUSSION

During the off-season, a total of 1,930 individual insects were captured, representing 11 orders and 56 families (Table 1). This data indicates a greater insect abundance during the flowering season compared to the off-season in fruit orchards. The order Diptera was the highest in abundance and diversity (17 families including Tephtritidae) followed by the order Coleoptera (13 families) and Hymenoptera (8 families). Meanwhile, captured insects were found greatest in the flowering season to 4,569 individuals, encompassing 11 orders and 58 families (Table 2). In the off-season, the family Chrysopidae (lacewings) from the order Neuroptera exhibited the greatest abundance, with 688 individuals recorded. This was followed by the family Tephritidae or fruit flies from the order Diptera, which accounted for 667 individuals. Contraries, during the flowering season, the trend was reversed. Tephritids exhibited the greatest abundance, with 1,863 individuals, surpassing the family Chrysopidae, which had 824 individuals.

During flowering season, orchards are rich with floral resources such as nectar, pollen, and plant sap, which attract a wide variety of insects including pollinators, pests, and other beneficial insects (Fowler et al., 2016), leading to increased insect activity and population density. In contrast, the off-season generally lacks abundant floral resources, resulting in reduced food availability and consequently lower insect populations. Many insects synchronize their reproductive cycles to coincide with the availability of resources (Aluja et al., 2011). The flowering season offers optimal conditions for mating and egg-laying, leading to a significant increase in insect numbers. The increased reproductive success during this period contributes to higher insect abundance. Conversely, during the off-season, the reproductive cycles of many insects may slow down (Salminen et al., 2015). This adaptation allows insects to survive unfavourable conditions but also results in lower population counts during this period.

During the off-season, Chrysopidae, known for their role as pollinators, exhibited the greatest abundance. The reduced competition from other pollinators during this period may allow Chrysopidae to dominate available niches, leading to their increased numbers as they more effectively exploit the limited resources. However, during the flowering season, this trend was reversed, with Tephritidae becoming the most abundant. The flowering season provides an abundance of floral resources, which are particularly attractive to Tephritidae. These pests are known to exploit the flowers and fruits, resulting in a significant surge in their population as they take advantage of the ample food supply. The favourable conditions during the flowering season, such as higher temperatures and increased humidity, which coincide with the peak flowering of the host plant, create an optimal environment for Tephritidae reproduction (Fondriest & Price, 1996). Their lifecycle is likely synchronized with the flowering period, ensuring their populations peak when food resources are most abundant.

The biodiversity indices for each season were calculated and are presented in Table 3. The flowering season exhibits greater insect diversity, as indicated by a higher Shannon-Wiener Index (H') value of 2.134, compared to the off-season (1.909). The Evenness Index for the flowering season (0.526) is slightly higher than that of the off-season (0.474), indicating a more balanced distribution of individuals among species during the flowering season. However, the off-season demonstrates higher species richness, with a Margalef Index (IMargalef) of 7.27, compared to 6.764 during the flowering season. This suggests that while the flowering season has a greater number of individuals and overall diversity, the variety of species is slightly higher during the off-season.

The collected insects were classified into seven groups: pests, predators, parasitoids, pollinators, scavengers, omnivores, and others. The overall percentage of guild structure classification of insects captured in fruit orchards during the off-season and flowering season is shown in Figure 2. During the off-season, the highest percentage of insects captured belonged to pests (50.8%), followed by pollinators (36.7%). Similarly, pests were recorded as the highest during the flowering season, with 57.8%, followed by pollinators with 19.6%. Comparing the relative abundance across the two seasons, the abundance of pests increased from 50.8% in the off-season to 57.8% during the flowering season. In contrast, pollinators exhibited a substantial decrease in relative abundance, from 36.7% in the off-season to 19.6% in the flowering season. Additionally, scavengers and parasitoids showed significant increases during the flowering season, from 6.9% to 14.7% and from 0.6% to 2.2%, respectively. The proportion of predatory insects slightly decreased, from 3.4% in the off-season to 2.5% during the flowering season.

In this study, pests are the most dominant guild in both seasons, with their percentage increasing from the off-season to the flowering season. This increase could be due to the availability of more floral resources during the flowering season, which may also attract a higher number of pest species. Flowers can provide additional food sources and breeding sites for pests, leading to their increased relative abundance. Furthermore, the flowering season often creates a more favourable environment for pests due to the abundant plant growth and reduced competition from other guilds (Skendžić et al., 2021).

Pollinators experienced a notable decrease in their relative abundance from the off- to the flowering season. This reduction might seem counterintuitive given the increased availability of flowering plants, which are typically beneficial to pollinators. This might be due to the varying abundance of pollinators throughout the flowering season. While some studies indicate that pollinator activity increases during peak flowering periods, the simultaneous blooming of numerous species can overwhelm pollinators, resulting in reduced visitation rates for individual plants (Alonso, 2004). Factors such as temperature and weather can also influence pollinator activity. For example, cooler temperatures early in the season may restrict pollinator activity, whereas later in the season, heightened competition may reduce the effectiveness of pollination efforts (Kehrberger & Holzschuh, 2019).

The slight decrease in predatory insects, from the off-season to the flowering season, may be related to changes in the prey-predator dynamics. During the flowering season, the increased number of pests might lead to heightened competition among predatory insects. As pest populations increase due to the abundance of flowering plants, predatory insects may experience increased competition for these food resources, leading to alterations in their foraging behaviour (Damien et al., 2017). Besides, predatory insects may adapt to the changing environment by shifting their focus to different prey types. For instance, when certain pests become overly abundant, predators might target alternative prey or even engage in scavenging (Nurin Izzati et al., 2021).

Table 1: List of insects captured and guild structure classification during the off-season

Order	Family	No. of individuals	Guild structure
Diptera	Dolicopodidae	16	Predator
	Drosophilidae	32	Pest
	Tachinidae	1	Predator
	Tephritidae	667	Pest
	Tipulidae	3	Pest
	Ceratopogonidae	8	Pest
	Limoniidae	14	Pest
	Anisopodidae	2	Scavenger
	Cecidomyiidae	4	Pest
	Scenopinidae	2	Predator
	Stratiomyidae	2	Scavenger
	Muscidae	2	Predator
	Simulidae	2	Others
	Sarcophagidae	8	Scavenger
	Calliphoridae	2	Scavenger
	Culicidae	17	Others
	Tabanidae	7	Others
Hemiptera	Cicadellidae	169	Pest
	Reduviidae	18	Predator
	Achilidae	1	Pest
	Cercopidae	4	Pest
	Cixiidae	10	Pest
Hymenoptera	Formicidae	113	Scavenger
	Aphelinidae	1	Pest
	Vespidae	2	Omnivore
	Evaniidae	9	Parasitoid
	Braconidae	1	Parasitoid
	Torymidae	1	Parasitoid
	Chalcidoidea	1	Predator
	Pompilidae	1	Predator
Coleoptera	Chrysomelidae	36	Pest
	Curculionidae	3	Pest
	Staphylinidae	9	Predator
	Cerambycidae	1	Pest
	Cleroidea	1	Predator
	Scarabidae	5	Scavenger
	Meloidae	1	Pest
	Carabidae	3	Predator
	Anthicidae	1	Predator
	Coccinellidae	9	Predator
	Eucnemidae	8	Pest
	Buprestidae	1	Pest
Neuroptera	Chrysopidae	688	Pollinators
Lepidoptera	Erebidae	3	Pollinators
	Nymphalidae	2	Pollinators
	Tineidae	3	Pollinators
	Geometridae	1	Pollinators
	Sphingidae	8	Pollinators
	Crambidae	4	Pollinators
Dermaptera	Forficulidae	1	Pest
Orthoptera	Gryllidae	1	Scavenger
	Acrididae	1	Pest
Mantodea	Mantidae	2	Predator
Thysanoptera	Thriptidae	16	Pest
11 orders	56 families	1930	

Table 2: List of insects captured and guild structure classification during flowering season.

Order	Family	No. of individuals	Guild structure
Diptera	Dolicopodidae	24	Predator
	Drosophilidae	52	Pest
	Tephritidae	1863	Pest
	Asilidae	1	Predator
	Tipulidae	7	Pest
	Stratiomyidae	1	Scavenger
	Muscidae	8	Predator
	Pipunculidae	16	Parasitoid
	Sarcophagidae	21	Scavenger
	Calliphoridae	44	Scavenger
	Culicidae	63	Others
	Tabanidae	2	Others
Hemiptera	Cicadellidae	398	Pest
	Aphididae	2	Pest
	Delphacidae	2	Pest
	Psyllidae	8	Pest
	Reduviidae	9	Predator
	Pentatomidae	1	Pest
	Plataspidae	13	Pest
	Cercopidae	15	Pest
	Cixiidae	12	Pest
Hymenoptera	Formicidae	550	Scavenger
	Aphelinidae	2	Pest
	Vespidae	81	Omnivore
	Sphecidae	8	Predator
	Halictidae	10	Pest
	Evaniidae	6	Parasitoid
	Braconidae	35	Parasitoid
	Chalcidoidea	36	Predator
	Apidae	16	Pest
	Ichneumonidae	1	Parasitoid
	Pompilidae	1	Predator
Coleoptera	Chrysomelidae	36	Pest
	Lampyridae	6	Predator
	Cicinelidae	4	Predator
	Curculionidae	8	Pest
	Staphylinidae	6	Predator
	Cerambycidae	1	Pest
	Scarabidae	11	Scavenger
	Carabidae	3	Predator
	Silphidae	2	Predator
	Rhipiphoridae	7	Parasitoid
	Coccinellidae	39	Predator
	Eucnemidae	10	Pest
	Cantharidae	4	Omnivore
Neuroptera	Chrysopidae	824	Pollinators
Lepidoptera	Erebidae	29	Pollinators
	Noctuidae	32	Pollinators
	Nymphalidae	9	Pollinators
Dermaptera	Forficulidae	1	Pest
Orthoptera	Pyrgomorphidae	1	Pest
	Tettigonidae	4	Pest
	Tetrigidae	1	Pest
	Acrididae	4	Pest
Mantodea	Mantidae	7	Predator
Blattodea	Termitidae	26	Scavenger
	Ectobidae	18	Scavenger
Thysanoptera	Thriptidae	168	Pest
11 orders	58 families	4569	

Table 3: The biodiversity indices value of insects in the off- and flowering season.

Season	Shannon-Wiener Index (H')	Evenness Index (E)	Margalef Index ($I_{Margalef}$)
Off-season	1.909	0.474	7.27
Flowering season	2.134	0.526	6.764

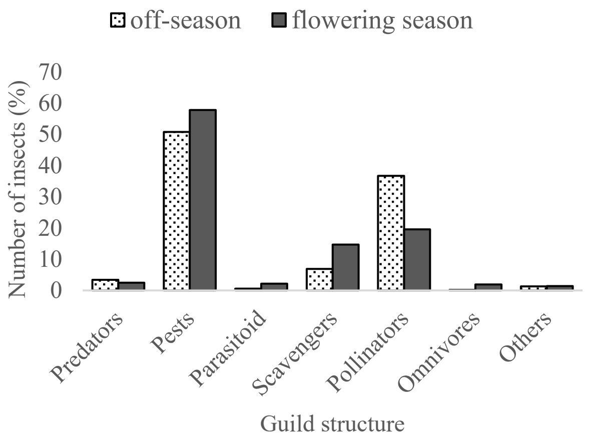

Figure 2: Composition of insects captured during off- and flowering season.

4. CONCLUSION

In conclusion, tropical seasonal fruit orchards harbour a diverse array of insect species, significantly contributing to the region's biodiversity. The findings of this study reveal that insect abundance and diversity are notably higher during the flowering season with index H'=2.134, and evenness, E=0.526, compared to the off-season. However, the off-season shows higher species richness, with index Margalef, IMargalef=7.27. Order Diptera or flies dominating the fruit orchard. Herbivore pests consistently dominate the insect guilds in both seasons, with the pest family Tephritidae, commonly known as fruit flies, exhibiting the highest number of individuals. These results underscore the importance of flowering periods in shaping insect populations and highlight the critical role of these orchards in maintaining ecological balance and biodiversity within tropical ecosystems.

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