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Diversity of Diptera in mixed-used agroforestry area of Tun Razak Agricultural Research Centre, Pahang, Malaysia

PUTERI RAIHANA MEGAT SAHRIR[1], MUZAMIL MUSTAFFA[1], NUR AMALINA MOHD IZAM[1], DZULHELMI MUHAMMAD NASIR[2], SITI KHAIRIYAH MOHD HATTA[3], NUR ATHIRAH ABDULLAH[1,4,♥]

[1]Faculty of Applied Sciences, Universiti Teknologi MARA. Pahang Branch, Jengka Campus, 26400 Bandar Tun Abdul Razak Jengka, Pahang, Malaysia
[2]Department of Crop Protection & Biosolution, FGV R&D Sdn. Bhd., Pusat Penyelidikan Pertanian Tun Razak, 27000 Jerantut, Pahang, Malaysia
[3]Faculty of Applied Sciences, Universiti Teknologi MARA. 40450 Shah Alam, Selangor, Malaysia
[4]Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah. Jalan UMS, 88400 Kota Kinabalu Sabah, Malaysia.
Tel: +6088-320104, Fax.: +608-8329246, ♥ email: athirahabdullah@ums.edu.my

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Abstract. *Sahrir PRM, Mustaffa MB, Izam NAM, Nasir DM, Hatta SKM, Abdullah NA. 2024. Diversity of Diptera in mixed-used agroforestry area of Tun Razak Agricultural Research Centre, Pahang, Malaysia. Biodiversitas 25: 3576-3584.* The order Diptera, comprising flies, mosquitoes, midges, and gnats, plays a significant role in the agricultural ecosystem as pests and pollinators. With agricultural activities posing a threat to insect populations globally, there is a need for studies on the potential of managed agroecosystems as habitats for this order. This study provides preliminary information on Diptera diversity in a mixed-used agroforestry area at the Tun Razak Agricultural Research Centre (Pusat Penyelidikan Pertanian Tun Razak/PPPTR), Pahang, Malaysia. The diversity assessment was conducted using malaise traps in various areas within the PPPTR, including a small forest fragment, a rubber plantation, an oil palm plantation, and an orchard, over two weeks in February and March 2023 yielded promising results. A total of 1,077 individuals representing 17 families, 36 genera, and 82 morphospecies of Diptera were collected during the research. The most abundant family recorded was Dolichopodidae, with 429 individuals, followed by Phoridae (140 individuals) and Calliphoridae (130 individuals). Notably, rubber plantations exhibited the highest diversity of Diptera (H'=3.228), while forest fragments showed the lowest diversity (H'=2.745), as indicated by the Shannon-Wiener Diversity Index. These findings highlight the potential of managed agroforestry areas as crucial Diptera conservation habitats, instilling hope and optimism in the scientific community.

Keywords: Entomofauna, flies, fragmented forest, horticulture

INTRODUCTION

Anthropogenic activity is a global issue that has caused a decline in biodiversity by around 30%, and many ecosystems have experienced irreversible damage (Prakash and Verma 2022). Agriculture is considered one of the main threats to biodiversity loss, especially when almost 40% of the earth has been converted to farming (Williams et al. 2020). Agricultural intensification has been shown to influence biodiversity with the associated ecosystem services it provides, such as pollination and biological control (Ahmed et al. 2021). Therefore, to face the pressure of food insecurities, the agricultural sector needs to find a balance between producing enough food for the increasing population without compromising the environment and natural resources. Malaysia is not an exception in this worldwide concern, with agriculture being one of the largest contributors to the country's GDP, with RM 100,770 million in 2024 (Ministry of Finance 2024). Thus, sustainable farming practices are an essential component of policy in Malaysia's long-term food security (Wong et al. 2024).

Following the goal of sustainable agriculture, conservation agriculture has emerged as an alternative to conventional agricultural practices where the activities are based on three main principles focusing on minimal mechanical soil disturbance, maintenance of crop biomass and cover crops, as well as diversification of cropping system (Jat et al. 2020). As such, Malaysia has been one of the forerunners in agroforestry and mixed farming for more sustainable land productivity while keeping important environmental resources. These methods have been adopted by major agriculture stakeholders, including the Malaysian Rubber Board, Malaysian Palm Oil Board (MPOB), Federal Land Development Authority (FELDA), Farmers Organization, Department of Agriculture, and Forestry Department (Ahmad 2001). Besides allowing maximum utilization and returns of the land, agroforestry also offers help in mitigating climate change through carbon sequestration (Yirga et al. 2019)

Nevertheless, sceptical debates arise with key questions on whether an agroforestry system helps to sustain biodiversity (Haggar et al. 2019; Torralba et al. 2016). As an organism that is particularly sensitive to the changes in its environment, insects have been a useful indicator to clear up the dispute regarding this matter (Chowdhury et al. 2023). Insects play an important role in many ecosystem services, such as pollination (which is crucial for the production of many crops), nutrient recycling (which helps maintain soil fertility), and predation (which controls pest populations), all of which may indicate ecosystem sustainability (Hasan et al. 2020). Monoculture activities, for example, have led to a decline in insect species richness and have been exacerbated by the use of toxic pesticides (Jankielsohn 2018). In contrast, conservation agricultural practices, on the other hand, have been shown to increase the abundance successfully, diversity as well as functional diversity of insects (Jankielsohn 2021; Grabovska et al. 2020). Other studies, however, have highlighted the need to investigate the capability of a managed agroecosystem to become an optimized habitat for the conservation of insect species (Slandonja et al. 2023).

Playing a crucial role in the various ecosystem functions, Diptera is among the major group of insects with approximately 160,000 described species from 150 families recorded in multiple habitats and continents (Courtney et al. 2017). Diptera are known to be significant in agricultural landscapes. As many as 200 Diptera species are considered pests of ripening fruits (Little et al. 2020), with other species functioning as pollinators (Cook et al. 2020) and decomposers (de Sousa et al. 2021). While agroforestry was shown to support other groups of insects (Jankielsohn 2021; Kingazi et al. 2024), more is needed to know about its capacity to support the Dipteran community. The only existing studies rather focus on single Dipteran taxa (Harterreiten-Souza et al. 2016) and are done outside tropical climate settings (Paquette et al. 2013). Therefore, this study aimed to investigate the potential of managed agroforestry areas as habitats for Dipteran communities. This preliminary study compares the diversity and abundance of Diptera across different tree general structures (oil palm, rubber, forest fragment, and fruit orchard) in a mixed-use agroforestry area. These findings will assist agriculture managers in maintaining insect biodiversity within the agroforestry landscapes.

MATERIALS AND METHODS

Study area

Tun Razak Agricultural Research Centre (PPPTR) in Sungai Tekam, Pahang, Malaysia (3°52'53.59"N, 102°31'52.87"E) is an agroforestry research complex with a heterogenous landscape including multiple tree land covers including oil palm plantation, fruit orchard, forest fragment, and rubber plantation. All land covers are interspersed with each other in a 2379-hectare area belonging to FGV Holdings Berhad (Figure 1). As PPPTR is also an agrotourism destination, it is designed to have a village atmosphere with various flowering plants planted as ornamental hedgerows throughout the landscape.

Field sampling

Four sampling sites were established throughout the PPPTR, Pahang representing different tree land covers within the agroforestry area: oil palm plantation, fruit orchards, forests, and rubber plantation (Table 1). The minimum distance between each site is 1 km to minimise the overlap of the Diptera community. In each sampling site, one Malaise trap was strategically deployed in the inner center of each land cover to minimize the edge effect and to maximize the likelihood of representing the diversity of Diptera in the area. All traps were left for a continuous two weeks (Schmidt et al. 2019; Chowdhury et al. 2023) in February and March 2023, with the collection bottles changed each week. All collected samples were brought back to the laboratory and preserved in 70% alcohol. Samples were sorted morphologically and identified to the lowest taxonomic level possible using multiple references (Baharudin (2002); Evenhuis and Grootaert (2002); Kurahashi (2002); Triplehorn et al. (2005); Disney (2012); Grootaert and Foo (2019). The functional group of each morphospecies is also determined following various literatures. All samples were deposited in the Faculty of Applied Science, Universiti Teknologi Mara, Jengka Campus, Pahang.

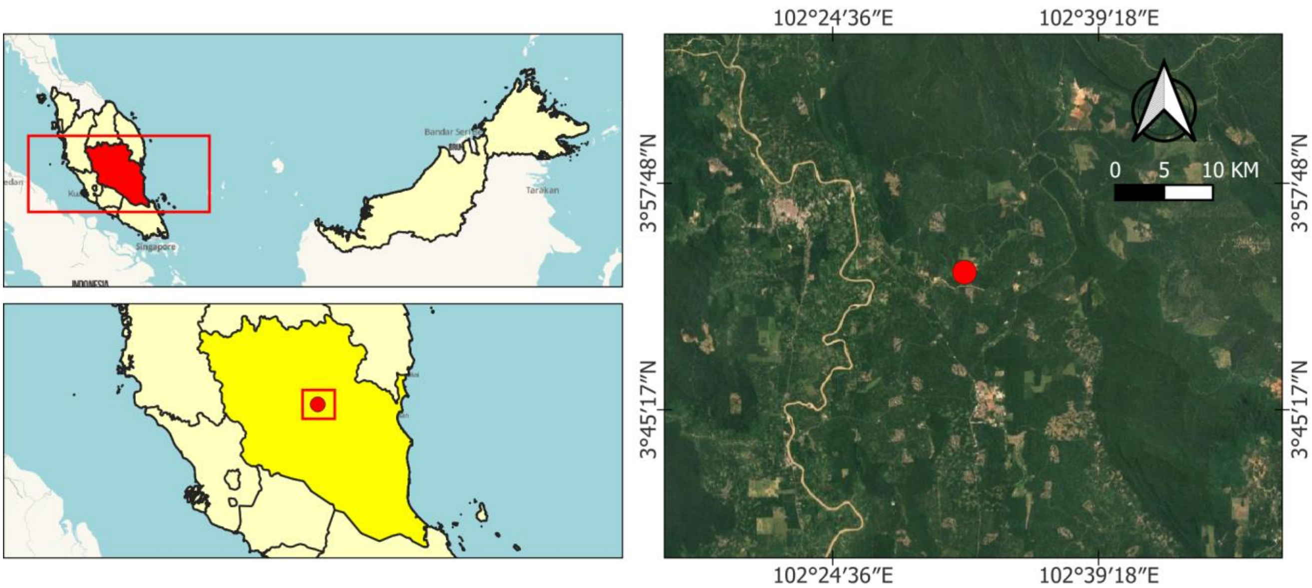

Figure 1. Study sites located within Tun Razak Agricultural Research Centre (Pusat Penyelidikan Pertanian Tun Razak/PPPTR) in Sungai Tekam, Pahang, Malaysia

Table 1. Description of study sites in PPPTR, Pahang, Malaysia

Sites	Location	Ecosystem description
Oil Palm Plantation	N 03053'06.3" E 102032'19.3"	Areas cultivated with oil palm trees have low understorey vegetation. The plantation area has frond stacks, harvesting paths, and weeded circles. Specific beneficial plants such as *Turnera subulata* and *Antigonon leptopus* are planted as hedgerows.
Fruit Orchard	N 03053'27.0" E 102032’08.9"	Areas actively cultivated with multiple crops, including jackfruit, pomelo, sapodilla, and rambutan. Pomelos, sapodilla, and jackfruit all bear fruits at the time of sampling. A lot of these fruits ripened and fell to the ground.
Rubber Plantation	N 03053'30.6" E 1020 32'20.2"	A rubber plantation actively tapped for its latex is located near cocoa (*Theobroma cacao*), anona (Annonaceae), and guava (Myrtaceae) planting areas. The cocoa was fully ripened, with some falling to the ground during the sampling.
Forest Fragment	N 03 53'11.2" E 102 32'04.3"	Small (<500 hectares) fragmented forest areas were shrubs and higher woody plants. Hedgerows of flowering plants were planted close to the forest remnant.

Data analysis

The normality test was conducted using the Shapiro-Wilk analysis of homogeneity. As data was not normally distributed, the differences in Dipteran abundance between each tree land cover were tested using the Kruskal-Wallis test. Chi-squared test of independence was conducted to test for any significant difference in the composition of Dipteran species between each tree group. The dendrogram was generated from two-way cluster analysis to exhibit any similarities or differences throughout the Dipteran community in the agroforestry area. The diversity of Diptera in each land cover is measured using the Shannon-Wiener (H) Diversity Index, Evenness Index (e^H/S), and Margalef Richness Index. The similarity of community land covers was analyzed using two-way cluster analysis using UPGMA algorithm with Bray-Curtis similarity index. All statistical analyses were conducted in PAST Version 4.0.

RESULTS AND DISCUSSION

The overall collection of Diptera in Tun Razak Agricultural Research Centre, Pahang

This present study assesses the Diptera diversity in agroforestry areas that may reflect the capability of an agricultural landscape to sustain a rich biodiversity. A total of 1,077 individuals from 17 families, 36 genera, and 82 morphospecies of Diptera were successfully collected from the agroforestry area of PPPTR, Pahang, Malaysia (Table 2). Dolichopodidae was the most abundant family, with 429 individuals, followed by Phoridae (140 individuals) and Calliphoridae (130 individuals). There were 37 morphospecies identified as decomposers (~45%), 34 species as predators, eight species of herbivores with potential becoming pests, four species of pollinators, and six generalist species (Table 2). Most of the Diptera species reported in this study are important decomposers in agricultural ecosystems. The decomposers are crucial in agriculture, especially to help with the breakdown of crop residue, which helps in nutrient recycling, ensuring continuous nutrient availability for plants (Pearsons and Tooker 2021; Hore and Banerjee 2017). Amongst significant records of decomposers in PPPTR Pahang was the *Dohrniphora* Dahl (1898) (Phoridae), known to be easily attracted to decaying organic matter, such as rotting fruits, vegetables, and garbage (Courtney et al. 2017). Nevertheless, the effectiveness of Diptera in decomposing organic materials leads to them having a high potential to become a pest. Calliphoridae, which was found in high abundance, was also among common household pests attracted to garbage, decaying plant matter, and manure, which might be the main attraction of this Diptera family in the PPPTR. This is also adding to several other families that act as plant pests, causing considerable economic damage to fruits and vegetables. The economic impacts include a reduced crop yield apart from increasing costs for control and fruit treatment. The fruit flies (Tephritidae) consisting of *Bactrocera* Macquart, 1835, *Dacus* Fabricius, 1805, and *Campiglossa* Rondani (1870) have been recorded in PPPTR. However, the number is not high following an integrated pest management program implemented in the agroforestry areas. Following the balanced ecosystem in the well-managed agricultural practices in the PPPTR, there is no known outbreak of Dipteran pests in the agroforestry areas.

PPPTR Pahang also recorded various Dipteran predators. At least 42 dipteran families are known to be predaceous as larvae, while Dolichopodidae, Asilidae, and Empididae are also predatory as adults (Skevington and Dang 2002); the Dolichopodidae dominates PPPTR. The presence of predatory flies such as the Dolichopodidae and Syrphidae assists in natural pest control, leading to sustainable agriculture. These families prey on soft-bodied pests of crops, such as aphids, gall midges, and psyllids (Bortollotto et al. 2016). The presence of hedgerows in the PPPTR helps in boosting the number of Dolichopodidae and other Dipteran predators, as these plants are reported to provide favorable habitats for the predatory flies in the agricultural landscape (Pfister et al. 2017). These results highlight the need for hedgerows within any agroecosystem to provision a heterogeneous landscape to maximise beneficial ecological service by this group of Diptera. As this group relies upon high vegetation area, it is also a promising indicator taxon of site value over a range of non-forest habitats (Courtney et al. 2017).

Table 2. List of Diptera collected from the agroforestry areas of Tun Razak Agricultural Research Centre, Pahang, Malaysia

Family	Genera/species	Functional group	Oil palm plantation	Forest fragment	Rubber plantation	Fruit orchard
Asilidae	*Asilidae* sp.1	Pr	0	1	0	0
	Asilidae sp.2	Pr	0	1	0	0
Calliphoridae	*Bengalia* sp.1	Pr	0	4	0	0
	Bengalia sp.2	Pr	0	8	1	1
	Bengalia sp.3	Pr	8	27	21	6
	Bengalia sp.4	Pr	2	36	4	1
	Lucilia sp.1	D	0	1	3	0
	Lucilia sp.2	D	2	0	0	4
	Phormia sp.	D	0	0	0	1
Chloropidae	*Chloropidae* sp.1	Ph	0	2	0	0
Dolichopodidae	*Chrysomya megacephala*	Pr D Po	0	1	0	0
	Chrysosoma sp.	Pr	1	0	11	0
	Condylostylus sp.	Pr	0	0	2	0
	Neurigona sp.1	Pr	9	74	1	0
	Neurigona sp.2	Pr	22	38	0	1
	Neurigona sp.3	Pr	10	0	0	0
	Neurigona sp.4	Pr	1	0	0	0
	Neurigona sp.5	Pr	2	5	0	0
	Neurigona sp.6	Pr	0	6	0	0
	Neurigona sp.7	Pr	0	15	0	0
	Neurigona sp.8	Pr	1	0	0	0
	Sciapus sp.	Pr	0	0	2	0
	Dolichopodidae sp.1	Pr	0	3	0	0
	Dolichopodidae sp.2	Pr	4	0	0	0
	Dolichopodidae sp.3	Pr	14	3	0	0
	Dolichopodidae sp.4	Pr	67	13	2	3
	Dolichopodidae sp.5	Pr	0	0	7	2
	Dolichopodidae sp.6	Pr	11	0	12	12
	Dolichopodidae sp.7	Pr	18	1	8	0
	Dolichopodidae sp.8	Pr	0	0	2	0
	Dolichopodidae sp.9	Pr	18	0	0	0
	Dolichopodidae sp.10	Pr	23	0	1	3
Drosophilidae	*Drosophila* sp.1	D	0	0	7	10
	Drosophila sp.2	D	30	0	2	2
	Drosophila sp.3	D	0	0	0	2
	Drosophila sp.4	D	19	0	0	0
	Drosophila sp.5	D	2	3	13	1
	Drosophila sp.6	D	0	0	19	0
Fanniidae	*Fannia* sp.1	G	0	1	0	1
	Fannia sp.2	G	0	1	0	0
	Fannia sp.3	G	8	0	3	7
	Fannia sp.4	G	0	0	0	1
	Fannia sp.5	G	0	0	0	2
	Fannia sp.6	G	6	3	3	2
Micropezidae	*Micropezidae* sp.	D	10	0	0	2
Muscidae	*Atherigona orientalis*	D	0	0	2	0
	Atherigona sp.1	D	0	0	3	6
	Atherigona sp.2	D	0	0	11	3
	Atherigona sp.3	D	0	0	23	7
	Musca sp.	D	0	1	3	1
	Stomoxys sp.	D	2	1	1	16
	Muscidae sp.1	D	0	1	0	0
	Muscidae sp.2	D	1	2	0	0

Nerriidae	*Neriidae* sp.	D	0	0	0	3
Phoridae	*Dohrniphora* sp.1	D/ Pr/ Pa	35	35	9	28
	Dohrniphora sp.2	D/ Pr/ Pa	0	1	0	0
	Megaselia sp.	D	16	3	10	3
Platystomatidae	*Scholastes* sp.1	D, Po	0	25	0	0
	Scholastes sp.2	D, Po	3	23	0	0
	Scholastes sp.3	D, Po	0	0	2	0
	Platystoma sp.	Po	0	0	1	0
Sarcophagidae	*Sarcophaga* sp.1	D	4	3	2	5
	Sarcophaga sp.2	D	0	0	1	3
	Sarcophaga sp.3	D	0	0	1	0
Scathophagidae	*Scathophagidae* sp.	Pr	0	0	3	0
Sepsidae	*Nemopoda* sp.1	D	0	3	0	0
	Nemopoda sp.2	D	0	2	0	0
	Nemopoda sp.3	D	0	0	0	1
	Nemopoda sp.4	D	0	0	2	0
Stratiomyidae	*Hermetia illucens*	Ph D	0	0	0	5
	Ptecticus sp.	D	1	12	0	4
	Stratiomyidae sp.1	D	0	0	1	1
	Stratiomyidae sp.2	D/ Pr	1	0	0	3
	Stratiomyidae sp.3	D/ Pr	2	0	0	1
	Stratiomyidae sp.4	D/ Pr	1	0	0	0
Syrphidae	*Syrphidae* sp.	Po	0	0	1	0
Tephritidae	*Bactrocera umbrosa*	Ph	0	0	0	1
	Bactrocera dorsalis	Ph	0	0	5	0
	Bactrocera musae	Ph	0	0	1	0
	Dacus sphaerodalis	Ph	0	0	1	0
	Campiglossa sp.	Ph	0	0	0	1
	Tephritidae sp.	Ph	0	1	0	0

Note: Pr: Predator, D: Decomposer, Ph: Phytophage, Pa: Parasitoid, G: Generalist, Po: Pollinator

The abundance and diversity of Diptera across different tree land cover

The abundance of Diptera was relatively highest in the Forest Fragment (360 individuals) and lowest in the Fruit Orchard (156). However, Dipteran abundance between the tree groups does not differ significantly (*H(3)*=0.2961, p>0.05). While many studies reported a significant detrimental impact of agriculture on insects and several Diptera species (Pramual and Kuvangkadilok 2009; Paquette et al. 2013; Raven and Wagner 2021), this study has shown otherwise with a high value of overall diversity (H'=3.663) of Diptera in PPPTR, Pahang. In comparison to the study done by Khairiyah et al. (2013) in a homogenous plantation area, the PPPTR agroforestry area is shown to possess a wider range of sources to support Diptera coming from multiple trophic groups. Although this study was conducted over a shorter period, the recorded diversity of Diptera in the agroforestry area is notably higher compared to that observed in a forest reserve as reported by Amin et al. (2023). As such, a well-managed agroforestry area such as PPPTR seems to be able to support a reasonably rich biodiversity within its complex heterogeneous habitat. It is also important to note that the higher diversity of flies in the agroecosystem can be attributed to the presence of exotic species that may have the potential to become invasive. In such cases, the presence of fruit fly species such as the *Bactrocera* is evident in the fruit orchards and rubber plantations that are located near cocoa and guava plantation areas. The *Bactrocera* is known to cause damage to soft fruits such as mango, guava, melons, and squashes (Salmah et al. 2017; Wee and Shelly 2013). While fruit fly species of *Bactrocera, Dacus,* and *Campiglossa* are present in the PPPTR, there is no major outbreak occurring to the crops following the scheduled integrated pest management program conducted within the agroecosystem.

While the abundance of individuals was relatively high, the oil palm plantation and the small forest fragment in the PPPTR, however, recorded lower diversity in comparison to the rubber plantation and fruit orchard. The highest Shannon-Wiener Diversity Index (H') of Diptera was found in Rubber Plantations (3.299), followed by Fruit Orchard (3.259), Oil Palm (2.953), and Forest (2.813). These values are also relatively comparable to the Evenness Index (E') and Margalef Index (R') of each area shown in Table 3. The oil palm plantation and the forest fragment may offer moist and shaded habitats for the predatory Diptera. However, more diverse trophic groups were recorded in rubber plantations and fruit orchards. The small proportion of forest fragments in this agroforestry area also seems not enough to support a diverse set of species. This is common for smaller remnant sizes where insects tend to experience a higher extinction rate with a lower probability of recolonization (Rösch et al. 2013). To overcome this issue, management efforts of any agroforestry area should also consider increasing the connectivity of this small, isolated forest fragment apart from increasing heterogeneity of the overall landscape. The results suggest that both rubber plantations and fruit orchards have provisions and microhabitats supporting not just the predatory species but also the decomposers, pollinators, and other generalists. The establishment of corridors between each tree land cover is believed to enhance the overall diversity of Diptera within the agroforestry areas of PPPTR, Pahang.

There was also no significant difference ($H(3)$=0.07, p>0.05) in Diptera species richness. However, the number of species appeared to be higher in rubber plantations (40 taxa) when compared to the other three groups. The insignificant difference in species richness between various tree groups in the agroforestry areas indicates that the landscape mosaic still retains elements of its native vegetation, thereby providing sufficient resources for the Dipteran community to survive in the changing environment. While species richness does not differ across different tree land covers, species composition was shown to be significantly different (X^2=1507.2, P<0.05). Following two-way cluster analysis, the composition of Diptera in oil palm and forest fragments is highly different when compared to communities in fruit orchards and rubber plantations (Figure 2). This is consistent with the study done by Furtado and Martins (2018), where the distinct species composition reflects changes in the structure and microclimate of the ecosystem following agricultural activities. Diptera communities are highly separated between oil palm and forests with fruit orchards and rubber plantations, indicating the influence of local habitat type upon this group of insects (Scherber et al. 2014).

The findings of this research are significant as they provide a deeper understanding of the influence of local habitat types on Diptera communities. Oil palm and the forest area are shown to be characterized by more predaceous Dipteran species such as the *Chrysotus* Meigen, 1824, *Bengalia* Robineau-Desvoidy, 1830, and *Neurigona* Rondani, 1856 provisioned by woody areas and hedgerows of beneficial plants in the area. A similar result was also reported in Scherber et al. (2014). In contrast, fruit orchards and rubber plantations are defined by the presence of decomposer species such as the *Atherigona* Rondani, 1856 and *Drosophila* Fallen, 1823 due to the smell of rotting fruits and rubber latex. Apart from that, generalist species are more tolerant towards changes in land use (Paiva et al. 2020), making it dominant across different tree land covers. *Dohniphora* that feeds on various materials as decomposer, parasitoid, and predator thrives in all tree land covers in the PPPTR, while specialist species such as the fruit flies (*Drosophila*, *Bactrocera*) are more restricted to certain areas with fruit crops within the PPPTR.

While the findings in other studies vary (Khairiyah et al. 2013; Veríssimo et al. 2020; Paiva et al. 2020), it is shown in this study that the conservation agricultural areas such as the fruit orchard and rubber plantations relatively support a higher diversity of Diptera in comparison to the homogenous oil palm landscape. A managed agroforestry areas like PPPTR, Pahang exhibit increased complexity in vegetation structure, leaf litter, and soil conditions in comparison to monoculture landscapes. In return, it creates a wider variety of microhabitats for a diverse set of Diptera species. The habitat complexity of PPPTR, Pahang is achieved through multiple cropping systems with the integration of various cash crops, rubber, and oil palm. Beneficial plants, medicinal herbs, and other ornamental vegetation are planted throughout the agroforestry area, providing more ecological niches for the Diptera and other insects. PPPTR, Pahang also reduces the use of pesticides with the optimization of natural predators to suppress pest populations in the integrated pest management program. Such management approaches have the potential to conserve Diptera and other insect species, maintaining a balance between agricultural productivity and biodiversity conservation. This will lead to more resilient agroecosystems, ultimately benefiting both crop yields and ecological health.

Table 3. Species richness (S), Shannon-Wiener Diversity Index (H′), Evenness Index (E′), and Margalef Richness Index (R′) following different tree land covers in the agroforestry areas of Tun Razak Agricultural Research Centre (PPPTR), Pahang, Malaysia

Tree structure	Rubber	Fruit orchard	Oil palm	Forest fragment	Overall
Abundance	209	156	354	360	1077
S	40	38	33	35	147
H'	3.299	3.259	2.953	2.813	3.663
E'	0.6773	0.685	0.5804	0.4629	0.4753
R'	7.313	7.3276	5.452	5.946	11.6

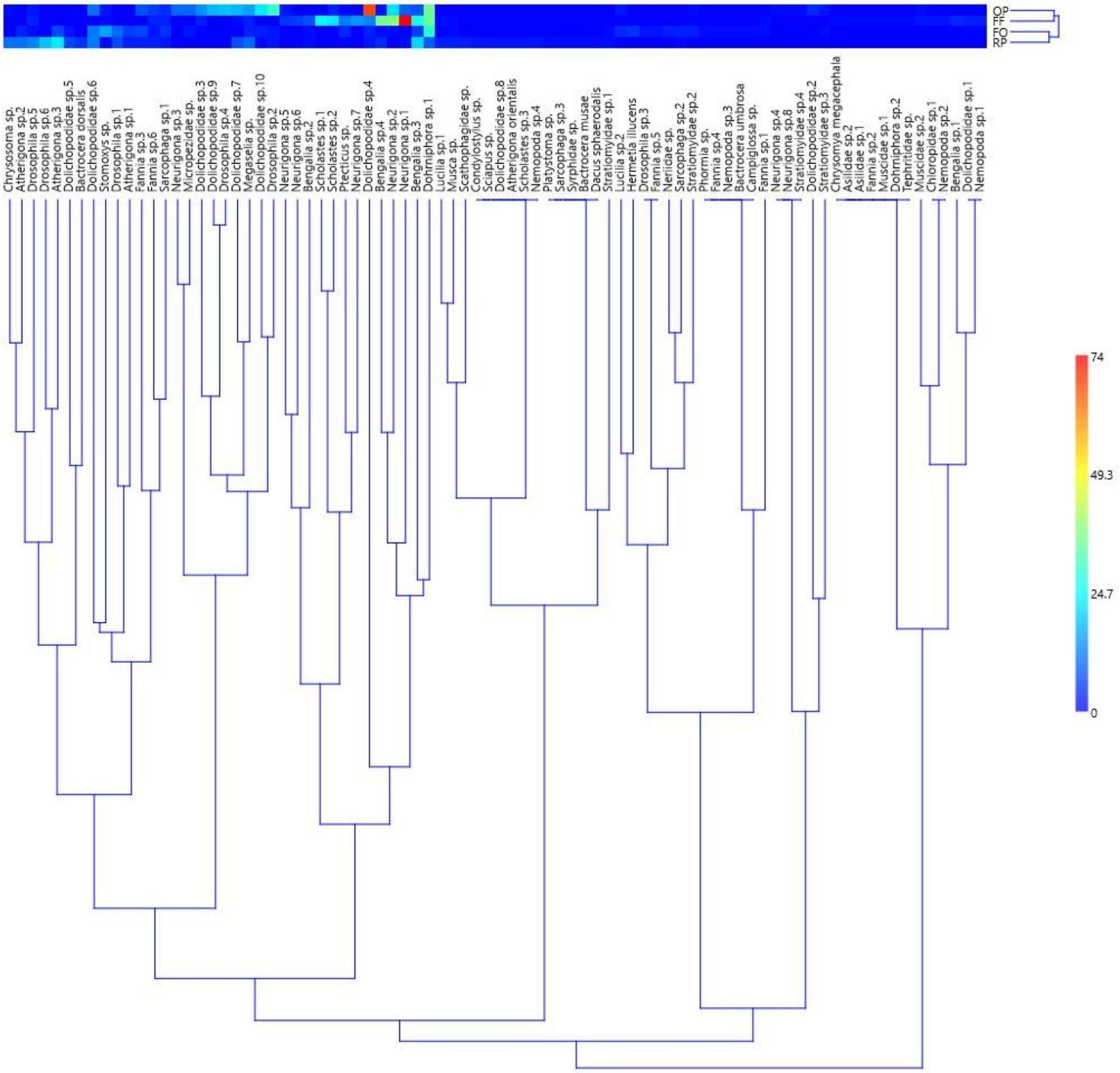

Figure 2. Dendrogram from two-way cluster analysis showing differences in the Dipteran community across the agroforestry area of Tun Razak Agricultural Research Centre (PPPTR), Pahang, Malaysia. Note: FO: Fruit orchard, RP: Rubber plantation, FF: Forest fragment, and OP: Oil Palm Plantation

However, a more robust and conclusive comparison of the mixed-use agroforest area can only be made with data collected from other management practices, such as intensive monoculture systems. It is acknowledged that this study was conducted in a limited timeframe, which does not factor in other environmental aspects such as variation in management practices, seasonal climate, and soil and vegetation composition. As seasonal variation has been reported to play an important role that influencing several dipteran families (Hernández-Ortiz et al. 2023), the influence is yet to be studied in the tropical agroforestry area of Malaysia. Some fly species are also promising indicators of soil health (De Bruyn et al. 2001), making them valuable for further study, particularly in agroforestry areas, where healthy soils are key to long-term sustainability and productivity. While the Malaise trap used in this study is a valuable method to capture flying insects, additional sampling methods such as sweep netting, yellow pan traps, and pitfall traps would enhance the representation of the Dipteran community within the agroforestry area in future research. Further research should also integrate multiple agroforestry settings that cover a wider range of ecological conditions and environmental factors for more robust findings.

In conclusion, this preliminary assessment found that the agroforestry area of PPPTR, Pahang, supports a fairly rich biodiversity of Diptera originating from various trophic groups. Retaining some native vegetation by including horticultural plants and other hedges can increase habitat complexity in agricultural landscapes. It's important to note that, unlike conventional monoculture plantation practices, agroforestry significantly improves habitat quality, especially for Diptera, which provides crucial services in nutrient cycling, pest control, and pollination.

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