

Love for Diversity: An Insect Community Study on *Turnera* sp. at the Perbaungan Oil Palm Plantation for the Development of Animal Ecology Teaching Materials

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Abstract

This study aims to analyze the diversity of insects in the eight-o'clock flowering plant (*Turnera* sp.) at PTPN IV Adolina Perbaungan Garden and compile the results as teaching materials for Animal Ecology in the form of a monograph book. The study used a quantitative descriptive method with purposive sampling techniques at three observation stations representing microhabitat variations. Data collection was carried out through direct observation, insect capture using sweeping nets and hand picking, morphological identification, and air temperature and humidity measurements. The results of the study found 356 individual insects consisting of 21 species, 5 orders (Hymenoptera, Lepidoptera, Diptera, Coleoptera, and Hemiptera), and 16 families. The value of the Shannon-Wiener diversity index (H') ranges from 1.1395-1.1547 (medium category), the Pielou uniformity index (E) ranges from 0.3870-0.3995 (low category), and the Simpson dominance index (C) ranges from 0.0830-0.0919 (low category). The pollinator group dominated the community with 215 individuals (60.39%). The results of the research were compiled into a monograph book containing species identification, morphological characteristics, visual documentation, ecological roles, and analysis of community structure as a contextual learning resource in the Animal Ecology course.

Keywords: *Turnera* Sp.; Insect Diversity; Community Structure; Oil Palm Agroecosystem; Monograph Book.

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INTRODUCTION

Insects are among the most diverse and ecologically important groups of organisms and occupy a wide range of terrestrial habitats, from natural ecosystems to human-managed agricultural landscapes. Their diversity is closely associated with their ability to utilize different resources and occupy various ecological niches (Ramola et al., 2024). In agricultural ecosystems, insects may function as pollinators, herbivores, predators, parasitoids, decomposers, and other components of food webs. These ecological roles contribute to nutrient cycling, plant reproduction, biological control, and the maintenance of ecological interactions within agroecosystems (Losey & Vaughan, 2006; Zhou et al., 2023). Consequently, documenting insect diversity is important not only for biodiversity assessment but also for understanding the ecological processes that support agricultural landscapes.

Insect communities can also provide information about environmental conditions because many insect taxa respond to changes in habitat structure, resource availability, and environmental disturbance. Characteristics such as relatively short life cycles, mobility, and habitat associations can make insect communities responsive to changes in environmental conditions (Ramola et al., 2024). Changes in species composition, abundance, and community structure may therefore provide useful information for evaluating ecological conditions. However, the use of insects as bioindicators requires consideration of taxonomic composition, sampling design, habitat characteristics, and the ecological characteristics of the taxa being studied. Thus, insect diversity studies need to be conducted using systematic field observations and appropriate ecological indices.

The importance of insect biodiversity has become increasingly relevant in agricultural landscapes because land-use change, habitat simplification, agricultural intensification, and chemical inputs can alter insect habitats and food resources. Habitat loss and fragmentation can reduce the availability of resources required by beneficial insects, while intensive agricultural management can further modify the structure of insect communities (Ashton-Butt et al., 2018; Dislich et al., 2017). These changes are particularly relevant in monoculture systems, where vegetation diversity may be lower than in more heterogeneous landscapes. Maintaining vegetation that provides food and shelter for beneficial insects is therefore increasingly considered an important component of ecological management in agricultural systems.

Oil palm (*Elaeis guineensis*) plantations represent an important agricultural landscape in tropical regions, including Indonesia and Malaysia. Oil palm is a highly productive commodity and contributes substantially to agricultural economies (Ashton-Butt et al., 2018). Nevertheless, large-scale plantation systems may create relatively simplified habitats in which the availability of alternative food resources and shelter for beneficial arthropods can be limited. Reduced habitat complexity may influence interactions among herbivores, predators, parasitoids, and other arthropod groups, potentially affecting biological control processes within the plantation ecosystem (Norhisham et al., 2024). Therefore, increasing vegetation diversity within oil palm plantations has ecological relevance for maintaining arthropod communities and supporting ecosystem functions.

Ground vegetation is an important component of habitat heterogeneity in oil palm plantations. Although some understorey plants may compete with crops or interfere with plantation management, vegetation beneath and around oil palm stands can provide shelter, microhabitats, nectar, pollen, and other resources for arthropods (Ashton-Butt et al., 2018). Certain flowering plants can function as refugia by providing resources for pollinators and natural enemies of agricultural pests. The presence of diverse understorey vegetation can consequently contribute to greater habitat heterogeneity and provide complementary resources for beneficial insect communities (Gurr et al., 2017; Dislich et al., 2017). However, the ecological value of individual refugia plants may differ according to their floral characteristics, surrounding vegetation, flowering period, and the insect taxa present in a particular landscape.

One flowering plant commonly associated with agricultural and plantation environments is *Turnera* sp., particularly *Turnera subulata*. The plant produces conspicuous flowers and floral



resources that can be utilized by different groups of flower-visiting insects. Previous research has documented visits by insects belonging to Hymenoptera, Diptera, Lepidoptera, and Coleoptera, indicating that *Turnera* can provide resources for a diverse assemblage of flower-visiting insects (Kurniansyah et al., 2023). Comparative research has also reported a relatively high proportion of Hymenoptera visiting *T. subulata*, suggesting that the plant can be an important floral resource in agricultural landscapes (Sarip, 2019). Nevertheless, the composition and abundance of insects associated with *Turnera* may vary according to habitat conditions, season, surrounding vegetation, and observation period.

The ecological significance of *Turnera* is not limited to flower-visiting insects. Its vegetation structure can provide shelter and foraging sites for predatory arthropods. For example, predatory insects belonging to Reduviidae have been reported in association with *Turnera* vegetation, while members of Coccinellidae may utilize the plant environment for resting and foraging (Hindarto et al., 2014; Elsa et al., 2022). Butterflies and other flower-visiting insects may also contribute to pollination while responding to environmental factors such as light intensity and the availability of floral resources. These interactions demonstrate that flowering refugia can form part of a broader ecological network involving pollinators, predators, parasitoids, herbivores, and plants.

The role of *Turnera* as a resource for natural enemies is also relevant to biological control in oil palm agroecosystems. Research has documented predator and parasitoid species associated with oil palm stands containing *T. subulata* and *Turnera ulmifolia* (Sari et al., 2024). Floral resources may provide nectar that can contribute to the survival and activity of adult parasitoids, although the magnitude of these effects depends on the species involved and the availability of other resources. For example, parasitoids belonging to Braconidae and Ichneumonidae have been reported to benefit from access to nectar resources associated with *Turnera* (Rizali & Buchori, 2024). These findings suggest that flowering refugia may contribute to the availability of resources for beneficial arthropods, although field-level ecological effects should be evaluated through direct observation and appropriate comparative studies.

Another characteristic that has been associated with *Turnera* is the presence of extrafloral nectaries. Unlike floral nectar, extrafloral nectar can be available independently of the reproductive function of the flower and may attract ants and other arthropods. Such interactions can potentially influence herbivore activity and plant defense through interactions between plants and predatory arthropods (Irsan & Margaretha, 2024; Hutajulu et al., 2023). However, the presence of extrafloral nectar does not by itself demonstrate a specific mutualistic or co-evolutionary relationship in every ecological context. The ecological significance of these interactions depends on the species involved, resource availability, and the surrounding habitat. Therefore, field-based documentation of insect communities associated with *Turnera* is necessary to provide a more accurate description of the ecological relationships occurring in plantation environments.

Despite the ecological importance of flowering refugia, information concerning insect communities associated with *Turnera* in the Perbaungan oil palm landscape remains limited. Previous research at Adolina Plantation reported 327 insect individuals representing 15 families associated with *T. subulata* (Parinduri, 2025). Although this finding provides evidence of considerable insect diversity, it does not fully describe the community structure of insects associated with *Turnera* under different observation conditions. Information concerning species composition, abundance, diversity, evenness, and dominance remains necessary to provide a more comprehensive description of the insect community. In addition, existing findings from one plantation or observation period cannot automatically be generalized to other locations because insect communities may vary according to habitat characteristics, vegetation composition, management practices, and temporal conditions.

This knowledge gap provides the basis for conducting a systematic assessment of insects associated with *Turnera* sp. in the oil palm agroecosystem of Perbaungan, North Sumatra. The present study focuses on documenting the taxonomic composition and abundance of insects visiting or associated with *Turnera* and analyzing their community structure using ecological

indices. The Shannon-Wiener diversity index is used to describe species diversity, the Pielou evenness index to assess the distribution of individuals among species, and the Simpson dominance index to evaluate the relative dominance of species within the observed community. The use of these complementary indices allows the insect community to be described from several dimensions rather than relying solely on the number of individuals or species.

The study is also relevant to biology education, particularly courses addressing animal ecology, entomology, biodiversity, and community ecology. Field-based learning can help students connect ecological concepts such as species richness, abundance, diversity, evenness, dominance, and species interactions with biological phenomena occurring in their surrounding environment. However, learning resources are often dominated by generalized examples that are not necessarily connected to local ecosystems. Research-based learning materials derived from local biodiversity can provide students with contextual scientific information and facilitate the application of ecological concepts to real field conditions (Afifa et al., 2021; Sukmawati, 2014).

One potential form of research-based learning resource is a monograph that presents a focused scientific discussion of a particular biological phenomenon. A monograph based on insect diversity associated with *Turnera* can integrate taxonomic identification, morphological documentation, habitat descriptions, ecological roles, abundance data, and community-structure analysis. Such a resource can complement conventional learning materials by providing locally relevant examples of how ecological data are collected, analyzed, and interpreted. The development of the monograph is therefore positioned as an educational output derived from the empirical findings of the ecological study rather than as a substitute for the ecological analysis itself.

Accordingly, this study aims to analyze the diversity and community structure of insects associated with *Turnera* sp. in the oil palm agroecosystem of Perbaungan, North Sumatra. Specifically, the study seeks to identify the taxonomic composition of the insects recorded, determine their abundance, and analyze community diversity, evenness, and dominance using the Shannon-Wiener, Pielou, and Simpson indices. In addition, the research findings are intended to provide the empirical basis for developing a research-based monograph as a contextual learning resource for the Animal Ecology course. By combining ecological field research with the development of locally relevant learning materials, this study is expected to contribute to the documentation of insect biodiversity in oil palm landscapes and to the enrichment of contextual biology education.

RESEARCH METHODS

Research Design and Study Site

This study employed a quantitative descriptive design using a field survey approach to characterize the diversity, abundance, distribution, and community structure of insects associated with *Turnera* sp. in an oil palm agroecosystem. The descriptive approach was selected because the study aimed to document the existing insect community without manipulating environmental conditions or applying experimental treatments (Sugiyono, 2022). Sampling sites were selected purposively based on the presence of flowering *Turnera* sp., accessibility, and variation in habitat and microenvironmental conditions relevant to insect activity.

The study was conducted at PTPN IV Regional II Afdeling III Kebun Adolina, Perbaungan, North Sumatra. Three observation stations were established to represent different habitat conditions. Station I was located along the plantation edge near residential areas and the main road, representing a habitat exposed to relatively high anthropogenic activity. Station II was located in the central plantation area and represented a relatively homogeneous core habitat with comparatively stable microclimatic conditions. Station III was located near a river, representing a habitat with relatively higher moisture availability and humidity. Differences in habitat structure and microclimatic conditions among these stations were considered in interpreting variation in insect abundance and community structure (Yudiyanto et al., 2015; Equiza et al., 2017).

Sampling Design and Observation Units



Sampling was conducted using transect and systematic plot methods. Because *Turnera* sp. was not uniformly distributed throughout the oil palm blocks but predominantly occurred along collection-road margins and drainage ditches, a 250-m transect was established at each observation station following the distribution of flowering *Turnera* sp. (Magurran, 2004).

Three observation plots were systematically established along each transect, with a distance of approximately 50 m between adjacent plots. Each plot measured 1 × 50 m. The plot width was determined according to the effective sampling range of the observer using a sweeping net, while the transect length and inter-plot distance were intended to provide adequate spatial coverage of the *Turnera* sp. habitat (Krebs, 2009). Thus, the study consisted of nine observation plots distributed across three stations. Sampling was repeated three times during the study period to account for temporal variation and reduce potential bias associated with short-term fluctuations in weather and insect activity (Begon et al., 2021).

Insect Sampling and Environmental Measurements

Insect observations and collections were conducted during three daily observation periods: morning (08:00–10:00 WIB), midday (12:00–14:00 WIB), and late afternoon (16:00–18:00 WIB). These periods were selected to capture variation in insect activity in relation to the flowering pattern of *Turnera* sp., whose flowers generally show peak availability during the morning and subsequently change in condition throughout the day (Sabrina et al., 2025; Ramola et al., 2024).

Two complementary sampling techniques were used. First, the sweeping-net method was applied using 20 standardized sweeps in each observation plot to collect flying insects actively visiting or moving around *Turnera* sp. vegetation. Second, hand collection was used to collect insects observed directly on flowers, leaves, and stems that could not be effectively captured using the sweeping net (Gullan & Cranston, 2023). The combination of these techniques was intended to increase the probability of detecting both active flying insects and individuals resting or foraging directly on the plant.

Captured specimens were transferred to appropriately labelled specimen containers. Specimens requiring euthanasia were placed in a killing jar containing ethyl acetate and subsequently preserved in 70% ethanol for laboratory identification (Triplehorn & Johnson, 2022). Each specimen was labelled with information concerning the station, plot, observation period, date, and collection method to maintain traceability throughout the identification and analysis process.

Environmental variables were also recorded during each observation period. Air temperature and relative humidity were measured using a thermohygrometer before or at the beginning of insect sampling. In addition, the number of fully opened *Turnera* sp. flowers or florets within the observation area was recorded as an indicator of floral resource availability. These environmental and floral-resource measurements were used as supporting variables when interpreting differences in insect abundance among stations and observation periods (Molles, 2023).

Specimen Identification

All collected specimens were transported to the Biology Laboratory for identification. Identification was conducted using a stereomicroscope based on external morphological characteristics, including body form, coloration, wing characteristics, antennae, legs, and other diagnostic structures. Identification was supported by standard insect identification manuals and relevant taxonomic literature (Gullan & Cranston, 2023; Triplehorn & Johnson, 2022).

Specimens that could not be identified to species level were retained at the lowest reliable taxonomic level. This procedure was applied to minimize taxonomic misidentification and ensure that the community analysis was based only on specimens with adequate identification confidence.

Data Analysis

The insect community data were analyzed quantitatively using species abundance and community-structure indices. Absolute abundance (K) was calculated to describe the number of individuals of each insect taxon recorded within the observation units, whereas relative

abundance (KR) was used to determine the proportion of each taxon relative to the total number of individuals recorded (Odum, 1996, as cited in Hindarto et al., 2014).

Species diversity was evaluated using the Shannon-Wiener Diversity Index (H'), which incorporates both species richness and the relative abundance of individuals among species (Magurran, 2004). Species evenness was assessed using the Pielou Evenness Index (E), which describes the degree to which individuals are distributed evenly among the taxa recorded (Pielou, 1966, as cited in Melketa et al., 2022). The Simpson Dominance Index (C) was calculated to determine the extent to which the community was dominated by one or a few taxa (Simpson, 1949, as cited in Hindarto et al., 2014).

The values obtained from the three indices were compared among the three observation stations and observation periods. Abundance patterns were interpreted in relation to differences in habitat characteristics, temperature, relative humidity, and the availability of flowering *Turnera* sp. Because the study used a descriptive field-survey design, the results were interpreted primarily to identify ecological patterns rather than to establish causal relationships between environmental variables and insect abundance.

Development of the Monograph

The empirical findings from the field survey were subsequently used as the scientific basis for developing a monograph for the Animal Ecology course. The monograph incorporated the taxonomic identification of insects, morphological descriptions, photographic documentation, abundance data, diversity, evenness and dominance indices, habitat characteristics, and ecological roles of the insects associated with *Turnera* sp.

The development of the monograph was intended to transform local biodiversity data into contextual learning material that connects ecological concepts with field observations. The content was organized systematically to support students' understanding of insect community structure, species interactions, habitat characteristics, and the ecological function of refugia plants in oil palm agroecosystems. The use of research-based and locally contextualized learning materials is expected to improve the relevance of Animal Ecology learning and provide students with authentic examples of ecological phenomena occurring in their surrounding environment (Pahriah et al., 2022; Hayati et al., 2025).

RESULTS AND DISCUSSION

Habitat Characteristics and Environmental Conditions

The study was conducted at three observation stations representing different microhabitat conditions within the oil palm plantation of PTPN IV Regional II Afdeling III Kebun Adolina, Perbaungan, North Sumatra. Station I was located along the plantation perimeter adjacent to residential areas and the main access road (3°33'14.8"N, 98°57'09.3"E), representing an open habitat with relatively high anthropogenic exposure. Station II was located in the central part of the plantation (3°31'56.2"N, 98°56'55.3"E), representing a relatively sheltered core habitat under a dense oil palm canopy. Station III was located near a river channel (3°29'13.6"N, 98°56'17.0"E), representing a habitat characterized by greater moisture availability. These differences in habitat structure provided a basis for examining variation in insect occurrence in relation to local environmental conditions.

Measurements of air temperature and relative humidity indicated clear variation among stations and observation periods. The recorded environmental parameters are presented in Table 1.

Table 1. Air Temperature and Relative Humidity Measurement Data at Each Research Station

Stations	Time	Beat	Temperature In(°C)	Out Temperature (°C)	Humidity (%)
I	Morning	08.00-10.00	29,13	29,23	87,00
	Afternoon	12.00-14.00	35,13	35,33	48,00
	Afternoon	16.00-18.00	30,29	30,43	68,33



II	Morning	08.00-10.00	26,03	26,25	90,33
	Afternoon	12.00-14.00	30,10	30,21	70,00
	Afternoon	16.00-18.00	27,54	27,80	80,33
III	Morning	08.00-10.00	26,59	26,03	93,66
	Afternoon	12.00-14.00	35,80	33,33	66,00
	Afternoon	16.00-18.00	28,53	27,80	83,00

Source: Primary Data Processed (2026)

The environmental measurements indicate that Station I experienced the greatest daily thermal fluctuation. Air temperature increased from 29.13°C in the morning to 35.13°C at midday, while relative humidity decreased substantially from 87.00% to 48.00%. The relatively exposed position of Station I and its proximity to an access road and open areas may have contributed to greater exposure to solar radiation and consequently higher daytime temperature and lower humidity. Such conditions can influence insect activity because temperature and moisture affect flight capacity, metabolic activity, and water balance in insects.

Station II exhibited comparatively moderate environmental fluctuations. Temperature increased from 26.03°C in the morning to 30.10°C at midday, while relative humidity remained between 70.00% and 90.33%. The relatively stable conditions are consistent with the station's location within the plantation under a dense oil palm canopy. Canopy cover can reduce direct solar radiation and buffer temperature fluctuations, thereby creating a more stable microclimate.

Station III showed the highest morning relative humidity, reaching 93.66%, followed by 83.00% in the late afternoon. This condition is consistent with its proximity to a river channel, which may contribute to greater moisture availability. However, the temperature at midday increased to 35.80°C, indicating that proximity to a water source does not necessarily eliminate daytime thermal variation. Instead, the interaction between vegetation cover, solar exposure, and water availability may jointly determine the microclimatic conditions experienced by insects.

The observed variation in temperature and relative humidity is ecologically relevant because insects are ectothermic organisms whose activity is strongly influenced by ambient environmental conditions. Moderate temperature and sufficient humidity generally support insect movement and foraging, whereas excessive temperature combined with low humidity may constrain activity because of increased thermal and desiccation stress. Therefore, differences in microclimate among the three stations provide an important ecological context for interpreting subsequent patterns of insect abundance and community structure.

Floral Resource Availability of *Turnera* sp.

In addition to abiotic environmental variables, the availability of floral resources was assessed by recording the number of fully open *Turnera* sp. florets in each observation plot and period. The results are presented in Table 2.

Table 2. Number of Perfectly Blooming *Turnera* sp. Florets

Stations	Time	Plot I	Plot II	Plot III	Total
I	Morning	48	52	45	145
	Afternoon	6	4	5	15
	Afternoon	0	0	0	0
II	Morning	65	72	60	197
	Afternoon	14	18	11	43
	Afternoon	0	0	0	0
III	Morning	40	44	38	122
	Afternoon	12	9	10	31
	Afternoon	0	0	0	0

Source: Primary Data Processed (2026)

A total of 553 fully open *Turnera* sp. florets were recorded across the three observation stations and observation periods. Station II had the highest number of open florets, with 240



florets, followed by Station I with 160 florets and Station III with 153 florets. The highest floral availability at Station II occurred during the morning, when 197 fully open florets were recorded. This was followed by 43 florets during midday, whereas no fully open florets were recorded during the late-afternoon observation period.

A similar temporal pattern occurred at Stations I and III. Station I had 145 fully open florets in the morning and only 15 at midday, while Station III had 122 in the morning and 31 at midday. No fully open florets were recorded at any station during the late-afternoon observation period. These results indicate a pronounced diurnal flowering pattern in *Turnera* sp., with floral availability concentrated during the morning and decreasing markedly as the day progressed.

The concentration of fully open flowers during the morning is important for interpreting insect activity because flowers represent a principal source of nectar and pollen for many flower-visiting insects. Consequently, the greater availability of floral resources during the morning may provide greater foraging opportunities and potentially contribute to increased insect visitation during this period. Conversely, the substantial reduction in open flowers at midday and their complete absence during the late afternoon may reduce the availability of floral resources and influence the observed composition and abundance of flower-associated insects.

An important finding is that Station II had the highest floral resource availability despite being located in the relatively sheltered central plantation area. This indicates that the number of flowering *Turnera* sp. florets was not determined solely by openness or proximity to human activity. Local plant density, growth conditions, moisture availability, and canopy characteristics may also contribute to flowering intensity. Therefore, floral resource availability should be considered together with microclimatic conditions when interpreting differences in insect abundance among stations.

The combined environmental and floral-resource observations demonstrate that the three stations differed not only in their physical microclimates but also in the availability of floral resources. Station I was characterized by relatively high daytime temperature and low humidity, Station II by comparatively stable microclimatic conditions and the highest number of open *Turnera* sp. florets, while Station III was characterized by high humidity, particularly in the morning, and intermediate floral availability. These differences provide an ecological basis for examining whether variation in insect abundance, diversity, evenness, and dominance corresponds with habitat conditions and resource availability.

However, the present data describe environmental variation rather than establish a causal relationship between individual environmental variables and insect abundance. Therefore, interpretations concerning the influence of temperature, humidity, and flower availability on insect communities should be considered ecological associations unless supported by inferential statistical analyses. Subsequent analysis of insect abundance and community indices is therefore necessary to determine the extent to which these habitat characteristics are reflected in the structure of the insect community associated with *Turnera* sp.

Habitat Characteristics Discussion

The differences in physical environmental conditions among the three observation stations indicate the presence of heterogeneous microhabitats within the oil palm agroecosystem. Station I, which was located in a relatively open area with limited canopy shade, recorded the highest daytime temperature (35.33°C) and the lowest relative humidity (48.00%). In contrast, Station II, which was located under a relatively dense oil palm canopy, exhibited a more moderated microclimate, with a daytime temperature of 30.21°C and relative humidity of 70.00%. Station III, located near a river channel, recorded the highest relative humidity during the morning observation period (93.66%). These differences demonstrate that canopy structure, openness of the habitat, and proximity to water bodies can contribute to spatial variation in microclimatic conditions within oil palm plantations.

The relatively high temperature and low humidity at Station I may be associated with greater exposure to solar radiation due to the absence of dense canopy cover. Dislich et al. (2017) noted



that changes in vegetation structure and canopy cover can modify microclimatic conditions in oil palm landscapes, particularly temperature and moisture availability. From an ecological perspective, such conditions are important because insects are ectothermic organisms whose physiological processes and behavioral activities are influenced by environmental temperature and humidity (Molles, 2023). However, the present study did not experimentally evaluate the direct effects of temperature and humidity on individual insect taxa. Therefore, the differences in microclimate should be interpreted as environmental characteristics associated with the observed insect community rather than as direct causal determinants of insect abundance.

Station II exhibited relatively more stable environmental conditions, with a daytime temperature of 30.21°C and higher relative humidity than Station I. The dense oil palm canopy likely reduced direct solar radiation and moderated temperature fluctuations at ground level. Vegetation structure can create heterogeneous microclimates by modifying light penetration, air movement, temperature, and moisture, thereby providing different environmental conditions that may be utilized by insects with different ecological requirements (Gullan & Cranston, 2023). The relatively sheltered conditions at Station II may therefore provide suitable habitat conditions for insects that are sensitive to excessive heat or desiccation. Nevertheless, this interpretation should be considered as an ecological association because insect abundance was influenced by multiple factors beyond microclimate, including floral-resource availability, vegetation structure, and surrounding habitat characteristics.

Station III, which was located adjacent to a river channel, recorded the highest relative humidity during the morning period (93.66%). The proximity of surface water may contribute to increased local moisture through evaporation and reduced drying of the surrounding environment. Water availability can influence vegetation productivity and habitat complexity, which subsequently affects the resources available to insects (Begon et al., 2021). The relatively humid conditions at Station III may therefore contribute to the maintenance of vegetation and microhabitats that are suitable for different insect groups. However, because vegetation structure and resource availability were not quantitatively compared among stations, the relationship between humidity and insect diversity should be interpreted cautiously.

In addition to abiotic conditions, the availability of flowering resources showed a pronounced temporal pattern. A total of 553 fully blooming *Turnera* sp. florets were recorded during the observation periods, with flowering strongly concentrated in the morning. The number of fully blooming florets decreased substantially during the midday period, and no fully blooming florets were recorded during the 16.00–18.00 observation period. This pattern indicates that the availability of floral resources was temporally concentrated and potentially coincided with the period of greatest flower-visiting insect activity.

The temporal availability of flowers is ecologically important because nectar and pollen constitute essential resources for many flower-visiting insects. Sabrina et al. (2025) reported that *Turnera* sp. flowers generally begin blooming in the morning and gradually contract toward midday. This flowering pattern may contribute to the concentration of insect visitation during periods when floral resources are most accessible. Potts et al. (2010) further emphasized that the temporal continuity and synchronization of flowering resources can influence the abundance and activity patterns of pollinating insects within agricultural landscapes.

The present findings therefore suggest that both **microclimatic heterogeneity and temporal variation in floral-resource availability** are important characteristics of the *Turnera* sp.-associated habitat in the study area. The combination of different temperature and humidity conditions among stations and the concentration of flowering resources during the morning provides a plausible ecological context for understanding variation in insect occurrence and activity. Nevertheless, because this study was descriptive and did not employ experimental manipulation or statistical modeling to test causal relationships, the observed associations should not be interpreted as definitive evidence that a particular environmental factor directly determines insect abundance.

Overall, the findings support the ecological significance of maintaining flowering vegetation within oil palm plantation landscapes. *Turnera* sp. can provide floral resources that potentially support diverse insect assemblages, while variation in canopy cover and landscape features creates different microhabitat conditions. From a management perspective, maintaining appropriate flowering vegetation and habitat heterogeneity may contribute to the conservation of beneficial insects in plantation ecosystems. Further research using replicated environmental measurements and inferential statistical analyses would be useful to determine the relative contribution of temperature, humidity, floral abundance, canopy cover, and other habitat variables to insect diversity and abundance.

Composition and Species Richness of Insects

Taxonomic identification of the specimens collected from *Turnera* sp. yielded 356 individuals belonging to 20 insect species, 7 orders, and 15 families. The specimens represented the orders Lepidoptera, Hymenoptera, Odonata, Diptera, Coleoptera, Hemiptera, and Orthoptera. The presence of these taxonomic groups indicates that *Turnera* sp. supports a relatively diverse assemblage of flower-visiting and other insects within the oil palm agroecosystem. The composition of insects based on family is presented in Table 3.

Table 3. Composition of Insects by Family at the Research Site

No.	Family	Number of Species	Number of Individuals	Percentage (%)
1.	Nymphalidae	3	82	23,03
2.	Apidae	1	58	16,29
3.	Formicidae	1	50	14,04
4.	Hesperiidae	2	43	12,08
5.	Pieridae	1	21	5,89
6.	Reduviidae	2	21	5,89
7.	Coccinellidae	1	14	3,93
8.	Stuart O'Neill	1	12	3,37
9.	Papilionidae	1	11	3,09
10.	Gomphidae	1	11	3,09
11.	Pompilidae	1	9	2,53
12.	Sarcophagidae	1	9	2,53
13.	Libellulidae	1	6	1,69
14.	Acrididae	2	5	1,40
15.	Scarabaeidae	1	4	1,12
16.	Araneidae*	1	0	0
TOTAL		21	356	100

*Note: Araneidae is a class of Arachnids that does not belong to the class Insecta

Source: Primary Data Processed (2026)

The Nymphalidae family had the highest number of individuals, with 82 individuals (23.03%), followed by Apidae with 58 individuals (16.29%), Formicidae with 50 individuals (14.04%), and Hesperiidae with 43 individuals (12.08%). These four families alone accounted for 65.44% of all individuals recorded. The relatively high representation of Nymphalidae, Apidae, Formicidae, and Hesperiidae suggests that the vegetation surrounding *Turnera* sp. provides resources that can be utilized by a range of insect taxa with different ecological requirements.

The species composition identified during the study is presented in Table 4.

Table 4. List of Insect Species Found in *Turnera* sp.

No.	Order	Family	Species	Number of Individuals
1.	Lepidoptera	Nymphalidae	Junonia orithya	36
2.	Lepidoptera	Nymphalidae	Ideopsis vulgaris	23
3.	Lepidoptera	Nymphalidae	Hypolimnas bolina	23



4.	Lepidoptera	Pieridae	Appias olferna	21
5.	Lepidoptera	Papilionidae	Papilio memnon	11
6.	Lepidoptera	Hesperiidae	Potanthus omaha	24
7.	Lepidoptera	Hesperiidae	Pelopidas mathias	19
8.	Odonata	Gomphidae	Ictinogomphus decoratus	11
9.	Odonata	Libellulidae	Neurothemis fluctuans	6
10.	Hymenoptera	Apidae	Apis cerana	58
11.	Hymenoptera	Formicidae	Dinomyrmex gigas	50
12.	Hymenoptera	Stuart O'Neill	Vespa affinis	12
13.	Hymenoptera	Pompilidae	Tachypompilus analvst	9
14.	Diptera	Sarcophagidae	Sarcophaga sp.	9
15.	Coleoptera	Coccinellidae	Coelophora inaequalis	14
16.	Coleoptera	Scarabaeidae	Rhinoceros Oryctes	4
17.	Hemiptera	Reduviidae	Rhynocoris rapax	11
18.	Hemiptera	Reduviidae	Sycanus collaris	10
19.	Orthoptera	Acrididae	Oxva chinensis	1
20.	Orthoptera	Acrididae	Phlaeoba antennata	4
21.	Alexandria*	Araneidae*	Gastaracantha hasseltii	0
TOTAL				356

*Note: Araneidae and Araneae are a group of Arachnids that are not included in insects

Source: Primary Data Processed (2026)

The taxonomic composition indicates that Lepidoptera was the most species-rich order, represented by seven species belonging to four families: Nymphalidae, Pieridae, Papilionidae, and Hesperiidae. Hymenoptera followed with four species from three families, whereas Odonata, Diptera, Coleoptera, and Hemiptera each contributed species from one or two families. Orthoptera was represented by two species within the family Acrididae. This composition demonstrates that the vegetation associated with *Turnera* sp. is used by insects with diverse feeding habits and ecological functions.

The relatively high representation of Lepidoptera is ecologically plausible because adult butterflies commonly utilize flowering plants as sources of nectar. The availability of nectar-producing flowers can influence butterfly visitation and distribution, particularly in agricultural landscapes where floral resources may be spatially and temporally limited. The high abundance of Nymphalidae in the present study may therefore be associated with the availability of floral resources around *Turnera* sp. and the surrounding vegetation. Shi et al. (2024) reported that many Nymphalidae species have relatively broad habitat use and can utilize different plant resources, allowing them to persist in heterogeneous agricultural landscapes.

The Apidae family, represented by *Apis cerana*, was the second most abundant family, with 58 individuals (16.29%). The relatively high abundance of *A. cerana* indicates that the flowers of *Turnera* sp. were frequently visited by bees during the observation period. Flowering plants that provide accessible nectar and pollen are important food resources for bees, particularly in agricultural landscapes where floral resources can fluctuate spatially and temporally. Hung et al. (2023) emphasized that the availability and quality of nectar and pollen are important factors influencing bee populations in agroecosystems. However, because the present study recorded insect visits rather than directly measuring pollen transfer or fruit set, the term flower visitor or potential pollinator is more appropriate than assuming that every recorded visitor functioned as an effective pollinator.

Formicidae was represented by 50 individuals (14.04%) and constituted the third most abundant family. The presence of ants around *Turnera* sp. may be associated with their ability to utilize diverse food resources, including plant-derived carbohydrates. In particular, extrafloral nectar can provide an energy source for ants and facilitate interactions between plants and arthropods. Camurça et al. (2024) reported that flowering vegetation can support multitrophic interactions involving ants, predators, herbivores, and pollinators. Similarly, Hutajulu et al. (2023)



indicated that ants can utilize extrafloral nectar associated with *Turnera* and may contribute indirectly to plant defense by interacting with herbivorous insects.

The ecological roles of the recorded insects were subsequently classified based on their known feeding and ecological characteristics. Because the study focused on field occurrence and morphological identification rather than experimentally determining feeding behavior, these classifications should be interpreted as inferred ecological roles based on published biological characteristics, rather than direct observations of ecological interactions. The classification is presented in Table 5.

Table 5. Composition of insects based on ecological role

Ecological Role	Family	Number of Families	Number of Individuals	Percentage (%)
Pollinators	Nymphalidae, Pieridae, Papilionidae, Hesperidae, Apidae	5	215	60,39
Predator	Gomphidae, Libellulidae, Vespidae, Pompilidae, Coccinellidae, Reduviidae	6	73	20,51
Omnivor	Formicidae	1	50	14,04
Phytophage	Scarabaeidae, Acrididae	2	9	2,53
Decomposer	Sarcophagidae	1	9	2,53
TOTAL		15	356	100

Source: Primary Data Processed (2026)

The potential pollinator/flower-visitor group constituted the largest functional category, comprising 215 individuals (60.39%) from five families. Predators accounted for 73 individuals (20.51%), followed by omnivores with 50 individuals (14.04%). Phytophagous and decomposer/scavenger groups each accounted for 9 individuals (2.53%). This composition indicates that *Turnera* sp. is associated not only with insects that potentially utilize floral resources but also with insects occupying different trophic positions.

The high representation of Nymphalidae (23.03%) suggests that butterflies were an important component of the insect assemblage associated with *Turnera* sp. Flowering plants can provide adult butterflies with nectar resources, while the surrounding vegetation may provide additional resources required during different stages of their life cycle. Nevertheless, the abundance of adult butterflies should not be interpreted solely as evidence of habitat quality because butterfly occurrence is also influenced by larval host plants, landscape structure, microclimate, and seasonal dynamics. Therefore, the presence of Nymphalidae in this study is better interpreted as an indication that the *Turnera* sp. habitat provides usable floral resources within the observed landscape.

The relatively high abundance of *Apis cerana* also indicates the importance of *Turnera* sp. as a floral resource for bees. The species is a recognized social bee that actively exploits flowering plants for nectar and pollen. The 58 individuals recorded in this study demonstrate substantial visitation during the sampling period. However, visitation frequency alone cannot establish the effectiveness of *A. cerana* as a pollinator of *Turnera* sp.; such a conclusion would require additional observations of pollen deposition, pollen loads, or reproductive outcomes.

The occurrence of Formicidae in relatively high numbers may be associated with the availability of plant-derived resources and structural refuges around *Turnera* sp. The presence of extrafloral nectar can create opportunities for ant-plant interactions and may attract ants to vegetation where herbivorous insects are also present. Hutajulu et al. (2023) reported that ants associated with *Turnera* can utilize extrafloral nectar, suggesting that the plant may contribute to the maintenance of ant populations within agricultural landscapes. In this context, the presence of ants may represent an additional trophic interaction rather than a direct contribution to pollination.



The predator group accounted for 20.51% of the total individuals and included dragonflies, wasps, pompilid wasps, ladybird beetles, and assassin bugs. The presence of these groups is ecologically relevant because several of them are known to prey on other arthropods. Thus, the occurrence of predator taxa around *Turnera* sp. suggests that the plant-associated habitat may provide resting sites, prey resources, or other conditions suitable for natural enemies. Flowering vegetation has been reported to contribute to the maintenance of natural enemies by increasing resource availability and habitat complexity in agricultural systems (Duque-Trujillo et al., 2023).

The coexistence of potential pollinators, predators, omnivores, phytophages, and decomposer/scavenger insects indicates that *Turnera* sp. is embedded in a multitrophic insect community rather than functioning solely as a nectar source. The availability of flowers may directly benefit nectar-feeding insects, while the vegetation structure can indirectly provide habitat and resources for predatory and other arthropod groups. This interpretation is consistent with the broader role of flowering plants in agroecosystems, where vegetation diversification can contribute to habitat heterogeneity and support beneficial arthropods (Benvenuti, 2024; Kleijn et al., 2024).

The findings therefore support the potential of *Turnera* sp. as a component of ecological management in oil palm plantations. Its flowering resources are associated with a substantial number of potential pollinators and other beneficial insect groups. However, the present data do not by themselves establish that *Turnera* sp. causes an increase in insect diversity or directly improves pest suppression. Such causal relationships would require comparative studies involving plots with and without *Turnera* sp., measurements of floral resource availability, and direct observations of insect-plant interactions. The present study instead provides baseline empirical information on the taxonomic composition and inferred ecological roles of insects associated with *Turnera* sp. in the PTPN IV Regional II Afdeling III Adolina oil palm landscape.

Overall, the identification of 356 individuals representing 20 insect species, 7 orders, and 15 families demonstrates that *Turnera* sp. is associated with a relatively heterogeneous insect assemblage. The predominance of potential pollinators and the simultaneous occurrence of predators and other trophic groups highlight the ecological relevance of flowering vegetation within oil palm agroecosystems. These findings provide an empirical basis for further investigation of *Turnera* sp. as a refugia plant and for the development of locally contextualized learning materials for the Animal Ecology course.

Analysis of Insect Community Structure

The structure of the insect community associated with *Turnera* sp. was analyzed using absolute abundance (K), relative abundance (KR), the Shannon–Wiener diversity index (H'), the Pielou evenness index (E), and the Simpson dominance index (C). These indices were used to describe the abundance, species composition, distribution of individuals, and degree of dominance within the insect community at each observation station.

Based on the species-level observations, 20 insect species were recorded across the three stations, comprising seven orders and 15 families. The spider *Gasteracantha hasselti* was excluded from the insect community analysis because Araneidae belongs to Arachnida rather than Insecta. Therefore, the community structure analysis was based exclusively on the 20 insect species listed in Table 6.

Absolute and Relative Abundance

The absolute and relative abundance of the insect species recorded at each station is presented in Table 6.

Table 6. Absolute Abundance (K) and Relative Abundance (KR) Values of Insects at Each Station

No.	Species	Station I	Station II	Station III			
		K (ind/m ²)	KR (%)	K (ind/m ²)	KR (%)	K (ind/m ²)	KR (%)
1.	Junonia orithya	0,080	8,21	0,073	11,57	0,086	11,30
2.	Ideopsis vulgaris	0,053	5,47	0,026	4,21	0,073	9,56
3.	Hypolimnas bolina	0,073	7,53	0,040	6,31	0,040	5,21



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4.	<u>Appias olferna</u>	0,073	7,53	0,260	4,21	0,040	5,21
5.	<u>Papilio memnon</u>	0,046	4,79	0,013	2,10	0,013	1,73
6.	<u>Potanthus omaha</u>	0,073	7,53	0,053	8,42	0,033	4,34
7.	<u>Pelopidas mathias</u>	0,066	6,84	0,033	5,26	0,026	3,47
8.	<u>Ictinogomphus decoratus</u>	0,020	2,05	0,006	1,05	0,046	6,08
9.	<u>Neurothemis fluctuans</u>	0,006	0,68	0,020	3,15	0,013	1,73
10.	<u>Apis cerana</u>	0,166	17,12	0,100	15,78	0,120	15,65
11.	<u>Dinomyrmex gigas</u>	0,140	14,38	0,066	10,52	0,126	16,52
12.	<u>Vespa affinis</u>	0,046	4,79	0,020	3,15	0,013	1,73
13.	<u>Tachypompilus analyst</u>	0,026	2,73	0,013	2,10	0,020	2,60
14.	<u>Sarcophaga sp.</u>	0,026	2,73	0,000	0,00	0,033	4,34
15.	<u>Coelophora inaequalis</u>	0,020	2,05	0,053	8,42	0,020	2,60
16.	<u>Rhinoceros Orvctes</u>	0,006	0,68	0,013	2,10	0,006	0,86
17.	<u>Rhynocoris rapax</u>	0,020	2,05	0,033	5,26	0,020	2,60
18.	<u>Svcanus collaris</u>	0,020	2,05	0,033	5,26	0,013	1,73
19.	<u>Oxya chinensis</u>	0,006	0,68	0,000	0,00	0,000	0,00
20.	<u>Phlaeoba antennata</u>	0,000	0,00	0,006	1,05	0,020	2,60
	TOTAL	0,973	100,00	0,633	100,00	0,766	100,00

Source: Primary Data Processed (2026)

Based on the recorded abundance, *Apis cerana* was among the most frequently encountered insects at all three stations, with the highest relative abundance at Station I (17.12%), followed by Station III (15.65%) and Station II (15.78%). *Dinomyrmex gigas* also showed a relatively high abundance, particularly at Station III (16.52%) and Station I (14.38%). The relatively high occurrence of these species indicates that the flowering vegetation and surrounding habitat provide resources that can be exploited by both flower-visiting insects and ants.

The distribution of individual species differed among stations. Several species, such as *Ictinogomphus decoratus*, showed relatively higher abundance at Station III, whereas *Coelophora inaequalis* was relatively more abundant at Station II. Such differences suggest that species respond differently to local habitat conditions, including vegetation structure, humidity, temperature, and the availability of food and shelter. However, these patterns should be interpreted as associations rather than direct causal effects because the study was based on observational field sampling.

Diversity, Evenness, and Dominance

The Shannon–Wiener diversity index, Pielou evenness index, and Simpson dominance index were calculated for each station. The results are presented in Table 7.

Table 7. Insect Community Structure Index Values at Each Station

Stations	Total Individuals (N)	Species Richness (S)	H'	E	C	Category H'	Category E	Category C
I	146	19	1,1395	0,3870	0,0894	Medium	Low	Low
II	95	18	1,1547	0,3995	0,0830	Medium	Low	Low
III	115	19	1,1423	0,3879	0,0919	Medium	Low	Low

Source: Primary Data Processed (2026)

Note: The values of H', E, and C should be recalculated from the verified raw individual-count matrix before publication. The values currently reported in the manuscript are not fully consistent with the abundance data presented in Table 6.

Based on the species-count data, Station I and Station III each contained 19 species, whereas Station II contained 18 species. The difference in species richness among stations was therefore relatively small. This indicates that the three stations shared a substantial proportion of the insect community, although the abundance of individual species varied among locations.



The diversity index should be interpreted together with species richness and the distribution of individuals. A higher number of individuals does not necessarily produce a higher diversity value because the Shannon–Wiener index incorporates both species richness and the relative distribution of individuals among species (Magurran, 2004). Consequently, a station with fewer individuals may have a comparable or higher diversity value when individuals are distributed more evenly among species.

The evenness index provides additional information about how individuals are distributed among the species present. A high evenness value indicates a relatively balanced distribution, whereas a low value indicates that several species contribute disproportionately to the total number of individuals. Therefore, interpretation of evenness should be based on the verified H' and species-richness values rather than on the previously reported values alone.

Similarly, the Simpson dominance index should be interpreted as a measure of the degree to which community composition is concentrated in particular species. A low dominance value indicates that no single species accounts for a disproportionately large share of the community. Although *Apis cerana* and *Dinomyrmex gigas* were relatively abundant, their presence does not by itself establish ecological dominance unless the calculated Simpson index supports that conclusion.

These indices collectively provide a quantitative description of community composition but should not be interpreted as direct evidence of ecosystem stability or resilience. Stability and resilience require temporal monitoring and/or experimental evidence beyond a single field survey. In the present study, the indices are therefore more appropriately interpreted as describing the current structure and distribution of the insect community associated with *Turnera* sp.

Temporal Pattern of Insect Activity

The number of insects recorded also varied according to observation time. The recapitulation of total individuals at each station and observation period is presented in Table 8.

Table 8. Recapitulation of Total Individual Abundance (N) per Station Based on Observation Time

Stations	Morning (Individual)	Noon (Individual)	Afternoon (Individual)	Total
I	74	56	16	146
II	38	39	18	95
III	47	45	23	115
Total	159	140	57	356

Source: Primary Data Processed (2026)

The highest number of individuals was recorded during the morning, with 159 individuals, followed by 140 individuals at midday and 57 individuals in the late afternoon. The higher number of insects during the morning coincided with the flowering pattern of *Turnera* sp., for which the number of fully open flowers was substantially higher during the morning observation period.

This temporal association is ecologically relevant because flower-visiting insects respond to the availability of floral resources as well as to environmental conditions such as temperature and humidity. The morning period in the study area generally provided more moderate temperatures and higher relative humidity than the midday period. Consequently, the concentration of insect observations in the morning may reflect the combined effects of floral resource availability and suitable microclimatic conditions.

The temporal pattern should nevertheless not be interpreted as evidence that flower opening alone determines insect activity. Other factors, including light intensity, wind, temperature, humidity, species-specific behavior, and the availability of alternative food resources, may also influence insect visitation. Therefore, the present findings indicate a temporal association between insect activity and *Turnera* sp. flowering rather than a definitive causal relationship.

Ecological Interpretation of the Insect Community



The composition of the insect community demonstrates that *Turnera* sp. provides resources used by insects with different ecological functions. The pollinator group represented the largest functional group, comprising 215 individuals (60.39%) from five families: Nymphalidae, Pieridae, Papilionidae, Hesperidae, and Apidae. This composition indicates that *Turnera* sp. is frequently visited by flower-associated insects, particularly butterflies and bees.

The relatively high abundance of *Apis cerana* is consistent with the ecological characteristics of flowering plants that provide nectar and pollen resources. Nectar supplies carbohydrates, whereas pollen provides protein and other nutrients required by bees. The availability of flowering resources can therefore influence the occurrence and foraging activity of bees in agricultural landscapes (Hung et al., 2023).

The Nymphalidae family also contributed substantially to the observed community, with 82 individuals (23.03%). The presence of three species—*Junonia orithya*, *Ideopsis vulgaris*, and *Hypolimnas bolina*—indicates that the flowering habitat is utilized by several butterfly species. However, abundance at flowers should not automatically be interpreted as evidence that *Turnera* sp. is responsible for maintaining their entire populations because adult butterflies may use other plant species and habitats for feeding, reproduction, and shelter.

Formicidae represented another important component of the community, with 50 individuals (14.04%). Ants may exploit plant-derived resources, including extrafloral nectar when available, as well as prey and other food sources. Their occurrence therefore reflects interactions extending beyond pollination and illustrates the multitrophic character of insect communities associated with flowering vegetation.

Predatory insects accounted for 73 individuals (20.51%) and included members of Gomphidae, Libellulidae, Vespidae, Pompilidae, Coccinellidae, and Reduviidae. Their presence is ecologically important because predators may contribute to the regulation of herbivorous arthropod populations. However, the present study did not directly measure predation rates or pest suppression; therefore, the data demonstrate the presence of potential natural enemies rather than proving a biological-control effect.

The phytophagous group consisted of Scarabaeidae and Acrididae, whereas Sarcophagidae represented the decomposer group. The occurrence of these functional groups indicates that *Turnera* sp. and its surrounding vegetation are associated with several trophic levels rather than functioning solely as a resource for pollinators.

Overall, the insect assemblage associated with *Turnera* sp. demonstrates the ecological value of flowering vegetation within an oil palm plantation. The high proportion of flower-visiting insects and the simultaneous presence of predators and other functional groups suggest that *Turnera* sp. may contribute to habitat heterogeneity and resource availability within the plantation landscape. Nevertheless, its classification as a refugia plant should be regarded as a potential ecological function that requires further comparative and experimental studies to establish its effectiveness in enhancing pollination services or biological pest control.

Implications for Biodiversity Conservation and Biology Education

The findings have implications for biodiversity management in oil palm plantations because maintaining flowering vegetation may provide additional resources for insects that use agricultural landscapes. Rather than viewing all understory vegetation solely as weeds, selected flowering plants may be considered as potential components of habitat management when their ecological functions and effects on crop production have been evaluated.

The species inventory and community-structure data also have educational value for the Animal Ecology course. The documented species, taxonomic classification, ecological roles, habitat characteristics, and community indices can be organized into a contextual monograph that connects ecological theory with field observations. However, the development of the monograph should be presented as a separate educational output of the study and, if claimed as a developed teaching material, should include a clear description of the development procedure and validation process. The field survey itself provides the empirical content for the monograph but does not, by itself, constitute evidence of the monograph's validity or effectiveness as a learning resource.



CONCLUSION

This study documented 20 insect species associated with *Turnera* sp. across three observation stations in the Perbaungan oil palm plantation, representing seven orders and 15 families. The recorded insects comprised several functional groups, with pollinators representing the largest group (215 individuals; 60.39%), followed by predators (73 individuals; 20.51%), omnivores (50 individuals; 14.04%), phytophages (9 individuals; 2.53%), and decomposers (9 individuals; 2.53%).

The insect community showed spatial variation in abundance among the three observation stations. Station I recorded the largest number of individuals, followed by Station III and Station II, while species richness varied only slightly among stations. Temporal observations showed that insect activity was highest during the morning, coinciding with the period when *Turnera* sp. produced the greatest number of fully open flowers.

The community-structure indices provide quantitative evidence of the composition and distribution of insects associated with *Turnera* sp. However, the H' , E , and C values must be recalculated from the verified individual-count dataset before the final manuscript is submitted because the values currently reported in the manuscript are inconsistent with Table 6. The interpretation should consequently focus on diversity, evenness, and dominance rather than making unsupported claims about ecosystem stability or resilience.

The predominance of pollinators and the presence of predators and other functional groups indicate that *Turnera* sp. has potential ecological value as flowering vegetation within an oil palm agroecosystem. Nevertheless, its effectiveness as a refugia plant and its contribution to pollination or biological control should be confirmed through comparative or experimental studies. The species inventory and ecological data generated by this study can also serve as empirical material for a contextual Animal Ecology monograph, provided that the development and validation of the teaching material are documented separately.

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