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ASSESSMENT OF INSECTS ABUNDANCE AND DIVERSITY THAT ATTRACTED TO BENEFICIAL PLANT (*Turnera trioniflora* SIMS) IN PADDY FIELD AT DIFFERENT SAMPLING TIMES

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ABSTRACT

Beneficial plants such as *Turnera* sp. serve as an ideal shelter and food source for insects, especially natural enemies, and this has attracted them to fields and helped in controlling insect pests. However, studies and information on the composition of insects visited and attracted to *Turnera* plants remain scarce, especially in Malaysia. Therefore, we identified insects attracted to *Turnera trioniflora* and compared the insect's abundance and diversity between different times in paddy fields planted with *T. trioniflora* in Besut, Terengganu, Malaysia. We also evaluated the relationship between insects attracted to *T. trioniflora* and abiotic factors (i.e. temperature, rainfall, and relative humidity). Insects visiting *T. trioniflora* were collected using sweep nets and beating techniques at two different times (i.e. morning from 9:00 to 11:00 am and afternoon from 2:00 to 4:00 pm). The insects were collected once every two weeks during the paddy growing season (August-October 2023) and all samples were brought to the laboratory for identification process. A total of 177 insects individuals consisting of 17 species representing 10 families and six orders were successfully collected. It was found that 12 insect species were categorized as beneficial insects while five were insect pests. Libellulidae dominated the number of individuals collected with 32.20%, followed by Apidae (25.42%) and Formicidae (24.86%). T-test showed that the abundance of insects collected in the morning was significantly 64% higher than in the afternoon (36%). The diversity of insects in the morning was also significantly higher (H'=1.657) than in the afternoon time (H'=1.584). Abiotic factors have a significant correlation with the insects visiting *T. trioniflora* with rainfall alternated between positive and negative correlations, while relative humidity and temperature generally showed stronger positive correlations. In conclusion, the results show that *T. trioniflora* attracts more beneficial insects than insects pests of paddy, particularly in the morning, thereby helping the balance of the ecosystem in paddy fields. Therefore, this study can be the basic data for future studies of paddy pest management in Malaysia.

Keywords: Beneficial plants, biological control, insect-plant interaction, paddy, *Turnera*

ABSTRAK

Tumbuhan berfaedah seperti *Turnera* spesies berfungsi sebagai tempat perlindungan dan sumber makanan yang sesuai untuk serangga, terutamanya musuh semula jadi, dan ini telah menarik mereka ke ladang dan membantu mengawal perosak serangga. Walau bagaimanapun, kajian tentang komposisi serangga yang melawat dan tertarik kepada tumbuhan *Turnera* masih kurang, terutamanya di Malaysia. Oleh itu, kami mengenal pasti serangga yang tertarik kepada *Turnera trioniflora* dan membandingkan kelimpahan dan kepelbagaian serangga di antara masa berbeza di sawah padi yang ditanam dengan *T. trioniflora* di Besut, Terengganu, Malaysia. Kami juga menilai hubungan antara serangga yang tertarik kepada *T. trioniflora* dan faktor abiotik. Serangga yang melawat *T. trioniflora* dikumpul menggunakan jaring sapu dan teknik pukulan pada dua masa berbeza (iaitu pagi dari jam 9 hingga 11 dan petang dari jam 2 hingga 4). Serangga dikutip setiap dua minggu sekali semasa musim penanaman padi (Ogos-Oktober 2023) dan semua sampel dibawa ke makmal untuk proses pengecaman. Sejumlah 177 individu serangga yang terdiri daripada 17 spesies mewakili 10 famili dan enam order telah berjaya dikumpulkan. Didapati bahawa 12 spesies serangga dikategorikan sebagai serangga yang bermanfaat manakala lima adalah perosak. Libellulidae mendominasi jumlah individu yang dikumpulkan dengan 32.20%, diikuti oleh Apidae (25.42%) dan Formicidae (24.86%). Ujian T menunjukkan bahawa kelimpahan serangga yang dikumpulkan pada waktu pagi adalah 64% lebih tinggi secara signifikan berbanding petang (36%). Kepelbagaian serangga pada waktu pagi juga lebih tinggi secara signifikan (H'=1.657) daripada pada waktu petang (H'=1.584). Faktor-faktor abiotik mempunyai korelasi yang signifikan dengan serangga yang melawat *T. trioniflora* dengan hujan berselang seli antara korelasi positif dan negatif, manakala kelembapan relatif dan suhu secara amnya menunjukkan korelasi positif yang lebih kuat. Kesimpulannya, hasil kajian menunjukkan bahawa *T. trioniflora* menarik lebih banyak serangga yang bermanfaat daripada serangga perosak padi, terutamanya pada waktu pagi, dengan demikian membantu mengekalkan keseimbangan ekosistem di sawah padi. Oleh itu, kajian ini boleh menjadi data asas untuk kajian masa depan pengurusan perosak sawah padi di Malaysia.
Katakunci: Kawalan biologi, interaksi serangga-tumbuhan, padi, *Turnera*

INTRODUCTION

Paddy fields are agricultural landscapes designed explicitly for rice cultivation. In Malaysia, paddy ranks as the third most significant crop, after oil palm and rubber (Dorairaj & Govender 2023), with an average paddy production area approximately of 677,000 hectares (Rahmat et al. 2019). Peninsular Malaysia has 10 paddy granary sites, guaranteeing food security and acting as the nation's rice bowl (DOA 2022). One of the granary sites is located in Besut district, Terengganu, which includes 13,000 ha of paddy cropland (MAMPU 2022) and is managed by the North Terengganu Integrated Agricultural Development (IADA KETARA) (DOA 2022).

Nevertheless, paddy cultivation in Malaysia is not exempted from significant production losses due to pest infestation. Yaakop et al. (2022) stated that the paddy field is a habitat for many kinds of living organisms including algae, vertebrates, and invertebrates such as insects. According to Fahad et al. (2021), pest infestation such as yellow stem borers, planthoppers and leaf folders is one factor contributing to low rice production at the plant level. Thus, rice yield losses in global output to pests range from up to 20% to at least 30% of the attainable yield (Oerke 2006). International Rice Research Institute (IRRI) found that farmers lose an estimated average of 37% of their rice yield to pests and diseases every year, depending on the production situation (IRRI 2020). In 2021, a total of 72.1% of rice crop area damage was reported due to insects infestation during paddy season while 79.8% was recorded in off-season in Peninsular Malaysia (DOA 2021a; 2021b). Thus, lost production due to pest attacks is therefore one of the main challenges faced by farmers (Amzah et al. 2018). Numerous species of insect pests found the paddy plants provide an ideal food source for them. For example, brown planthopper which a sucking insect that attack leaf blades and leaf sheaths of rice plants cause leaves to initially turn orange-yellow before becoming brown and dry and this is a condition called hopperburn that kills the plant, while rice stem borer can destroy rice at any stage of the plant from seedling to maturity and feed upon tillers and causes deadhearts or drying of the central tille (Iamba & Dono 2021). Due to this, various paddy pest control methods are available, including chemical, cultural, and biological controls (Deguine et al. 2021). Hence, to reduce pesticide dependency, biological control as a part of Integrated Pest Management (IPM) has been suggested. Biological control uses beneficial plants able to attract insects particularly the natural enemies and pollinators by providing them with nectars as food sources and shelter (Amzah et al. 2018). This approach is known as ecological engineering which manipulates the environment by increasing the population of natural enemies in agricultural habitats (Lu et al. 2015).

Beneficial plants, such as *Turnera*, a genus of flowering plants from the family Passifloraceae, have gained global attention for their potential in natural pest management (Ahmad et al. 2023). Native to Central and South America, *Turnera* has been widely introduced in various regions, including Malaysia, Indonesia, several Pacific Islands, the Caribbean, and Florida, where it is commonly cultivated as a garden plant (USDA 2020). Its bright flowers, rich in nectar and pollen, attract various pollinators and beneficial insects, including the bee (*Trigona spinipes*), butterfly (*Nisoniades macarius*), and beetle (*Pristimerus calcaratus*) (Sari 2015; Schlindwein & Medeiros 2006). The *Turnera* genus comprises approximately 100 species, with *T. ulmifolia* and *T. trioniflora* commonly referred to as yellow alder, while *T. subulata* is known as white alder (Amzah et al. 2018). Previous studies in China, Vietnam, and Thailand have demonstrated the effectiveness of beneficial plants, including *Turnera*, in controlling paddy pests at acceptable levels (Lu et al. 2015; Thakur 2015). For example, Lu et al. (2015) indicated that both predators and parasitoids significantly increased in density in the ecological engineering fields, which *Anagrus* spp. (parasitoid) and damselfly (predator) were four times higher than in the control field.

In Besut, IADA KETARA has started a program of planting beneficial plants using *T. trioniflora* in selected paddy fields since 2019 (Wan 2021, pers. comm.). However, limited studies have been undertaken, specifically on the effectiveness of *Turnera* in attracting beneficial insects. Consequently, agricultural authorities face challenges in convincing paddy farmers to adopt this biological control technique because they may perceive biological control as less effective or slower in delivering results, which can delay its acceptance. To overcome this challenge, future efforts should focus on conducting extensive awareness campaigns and educational programs that demonstrate the effectiveness of biological control techniques like the use of *T. trioniflora*. Therefore, further research and evidence-based studies are necessary to promote the application of *Turnera* and its positive influence on pest control in paddy cultivation. Hence, this study aims to identify the insects attracted to *T. trioniflora* and to determine their population abundance and diversity in paddy fields cultivated with *T. trioniflora* at different times in Besut, Terengganu. This differentiation of time is crucial because insect activity is influenced by several factors, including plant blooming patterns and environmental conditions. The correlation between insects attracted to *T. trioniflora* and abiotic factors was also evaluated in this study, as environmental conditions such as temperature, humidity, and rainfall may affect the abundance and diversity of insects. Understanding these relationships can help optimize the use of beneficial plants like *T. trioniflora* in paddy fields, enhancing pollination services and pest management strategies.

MATERIALS AND METHODS

Location of Study and Sampling Time

This study was conducted at a paddy field managed by IADA KETARA, which is located in Batang Gergaji Village, Besut, Terengganu (5.6772940, 102.5556250) (Figure 1). The location of study covers approximately of three acres. Insect sampling was carried out during the paddy planting season, from August 2023 until October 2023, starting from transplanting to the harvesting stage. Sampling plots were planted with MR220 CL2 rice variety using a direct seeding method with conventional practice control treatment by applying pesticide using drone technology, where this variety of paddy took about 105 days for one season. About 50 *Turnera trioniflora* shrubs with yellow flowers that are 24 months old are cultivated closer to paddy plots along the roadside (Figure 2). The plants were well maintained by farmers and applied organic fertilizer every two to three months so that the beneficial plants could flourish healthily and promote flowering. Abiotic data (i.e temperature, rainfall, relative humidity) were obtained from the nearest station of the Malaysian Meteorological Department.

Figure 1. A) Insect sampling plot in IADA KETARA paddy fields located in Besut, Terengganu. B) The two yellow lines indicate the line of Turnera trioniflora shrubs were planted.

(Source: Google Map 2023)

Figure 2. *Turnera trioniflora* shrubs cultivated along the paddy roadside

Sampling Method

Insect sampling was done four times in a row or once every two weeks during the paddy growing season at the age of paddy of 13 days (Week 1), 27 days (Week 2), 41 days (Week 3) and 55 days (Week 4) after sowing (DAS) under field conditions in a Completely Random Design (CRD) by using active traps (i.e., sweep net and beating techniques).

A sweep net is an instant method of collecting sample assessment of insects. The net was swept on the canopy of the *T. trioniflora* plants with ten sweeps for each time, with five minutes elapsing between each of the designated rest periods for the insects before the net was cleaned once again (Abdullah & Rahim 2018). While for the beating technique was applied and modified based on Montgomery et al. (2021). To do so, a beating sheet which a piece of heavy-duty cloth (three feet square) stretched across two diagonal pieces of wood joined at in the middle. The sheet was positioned on the ground adjacent to *T. trioniflora* plants that are closer to the ground. When taller plants were encountered, the beat sheet was held with one hand while the plant was repeatedly struck with a net handle using the other hand. The insects on the plant were dropped onto the sheet and collected as soon as possible to prevent their escape. Each sample occurrence had three-time replications of the sampling.

The insect sampling was performed from 9 to 11 am and 2 to 4 pm in the afternoon (Abdullah & Rahim 2018). The collected insects were then placed in the collecting bottles containing 70% ethanol for preservation purposes before being brought to the laboratory for sorting, enumeration, and identification process.

Insect Identification

The insect specimens were brought to the Laboratory of Entomology, Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin (UniSZA), Besut Campus, for the identification process. They were sorted and enumerated to determine their family and species. Utilizing a stereomicroscope (Olympus SZ51, Japan), all specimens underwent identification based on their external morphological characteristics following the guidelines provided by

Triplehorn and Johnson (2005), Goulet and Huber (1993), and other related references. The number of individuals per family per sampling time was recorded.

Data Analysis

The abundance of insects attracted to *T. trioniflora* was compared between morning and afternoon time using a T-test analysis. To analyze the different families of insects attracted to *T. trioniflora*, One-Way Analysis of Variance (ANOVA) was employed, with a significance level of 95%. The relationship between insects attracted to the *T. trioniflora* and abiotic factors was evaluated through Pearson correlation analysis. The analysis was performed using MINITAB 17 software. The diversity of insects attracted to *T. trioniflora* was assessed using the Shannon-Weiner Index, facilitated by the Paleontological Statistics (PAST) 4.0 software.

RESULTS

Identification of Insect Attracted to *Turnera trioniflora*

Overall, a total of 177 individuals of insect species attracted to *T. trioniflora* were collected which consisted of six orders with 10 families and 17 different species as shown in Table 1. Among them, 12 species were considered as beneficial insect either as predators, pollinators or scavengers whilst only five species were categorized as insect pests.

Based on Table 1, Family Libellulidae (dragonflies) has recorded five species namely *Potamarcha congener*, *Pantala flavescens, Orthetrum sabina, Crocothemis erythreaea* and *Libellula luctosa* with 17, 14, 14, 11 and 1 individuals collected, respectively. Two species from Apidae (bees) were *Xylocopa latipes* and *Apis mellifera* with 43 and 1 individual, respectively. Species collected from Formicidae (ants) was *Lasius niger* with 45 individuals while Vespidae (hornet) was *Vespa affinis* with 8 individuals. Mycetophilidae (fungus gnats) also recorded 8 individuals from the species *Tarnania nemoralis*. Family Calliphoridae (blow flies) has one species, *Calliphorina vicina* with 3 individuals and Gryllidae (crickets) recorded one species, *Gryllodes sigillatus* with 5 individuals. Family Acrididae (grasshoppers) has recorded 3 species namely *Pseudochorhippus paralleus, Valanga nigricornis, Ceracris kiangsu* with 2, 1, and 2 individuals, respectively. Whilst family Carabidae (ground beetles) and Ectobidae (cockroaches) recorded only one species namely *Pheropsophus siamensis* and *Blattella germanica,* respectively.

Table 1. Total number of insects attracted to *Turnera trioniflora* collected at paddy field

Order	Family	Species	Category	No. of Individuals
Odonata	Libellulidae (dragonflies)	Potamarcha congener	Benefical insect (predator)	17
		Pantala flavescens	Benefical insect (predator	14
		Orthetrum sabina	Benefical insect (predator)	11
		Crocothemis erythreaea	Benefical insect (predator)	14
		Libellula luctosa	Benefical insect (predator)	1
Hymenoptera	Apidae (bees)	Xylocopa latipes	Benefical insect (pollinator)	43

		Apis mellifera	Benefical insect (pollinator	1
	Formicidae (ants)	Lasius niger	Benefical insect (pollinator)	45
	Vespidae (wasp)	Vespa affinis	Benefical insect (predator)	8
Diptera	Mycetophilidae (fungus gnat)	Tarnania nemoralis	Benefical insect (scavenger	8
	Calliphoridae (blowfly)	Calliphorina vicina	Benefical insect (pollinator)	3
Orthoptera	Gryllidae (cricket)	Gryllodes sigillatus	Insect pest	5
	Acrididae (grasshopper)	Pseudochorhippus paralleus	Insect pest	2
		Valanga nigricornis	Insect pest	1
		Ceracris kiangsu	Insect pest	2
Coleoptera	Carabidae (beetle)	Pheropsophus siamensis	Benefical insect (predator)	1
Blattodea	Ectobidae (cockroach)	Blattella germanica	Insect pest	1
Total of individuals				**177**

Determination of Insect Abundance

The abundance of insect families attracted to *T. trioniflora* in paddy fields at different times was displayed in Table 2. Obviously, the total number of insects attracted to *T. trioniflora* was significantly higher in the morning (113 individuals) compared to the afternoon (64 individuals).

Table 2. Total numbers of insect attracted to *Turnera trioniflora* at different times

Family	**Time**	
	Morning (9-11 am)	**Afternoon (2-4 pm)**
Libellulidae	31	26
Apidae	36	8
Formicidae	26	19
Vespidae	6	2
Mycetophilidae	5	3
Acrididae	3	2
Gryllidae	3	2
Calliphoridae	2	1
Carabidae	1	0
Ectobidae	0	1
Total	**113**	**64**

Notably, the family Libellulidae exhibited the highest abundance, with 31 individuals observed in the morning and 26 individuals in the afternoon. Following closely, Apidae displayed 36 individuals in the morning and 8 individuals in the afternoon. Formicidae accounted for 26 individuals in the morning and 19 individuals in the afternoon. Additionally, Vespidae had 6 individuals in the morning and 2 individuals in the afternoon, while Mycetophilidae recorded 5 individuals in the morning and 3 individuals in the afternoon. Acrididae displayed 3 individuals in the morning and 2 individuals in the afternoon, Gryllidae exhibited 36 individuals in the morning and 8 individuals in the afternoon, and Calliphoridae showed 36 individuals in the morning and 8 individuals in the afternoon. On the other hand, the families Carabidae and Ectobidae exhibited the lowest abundance, with only 1 individual observed for both times, respectively.

Figure 3 shows the abundance of insects collected at different weeks at different times. Week 1 represents insects collected from *T. trioniflora* at paddy age 13 days after sowing (DAS), Week 2 at age 27 DAS, Week 3 at 41 DAS, and Week 4 at 55 DAS (Figure 3). It was observed that the abundance of insects was higher in the morning than in the afternoon for all weeks. However, the number of insect populations collected was reduced gradually after a few weeks.

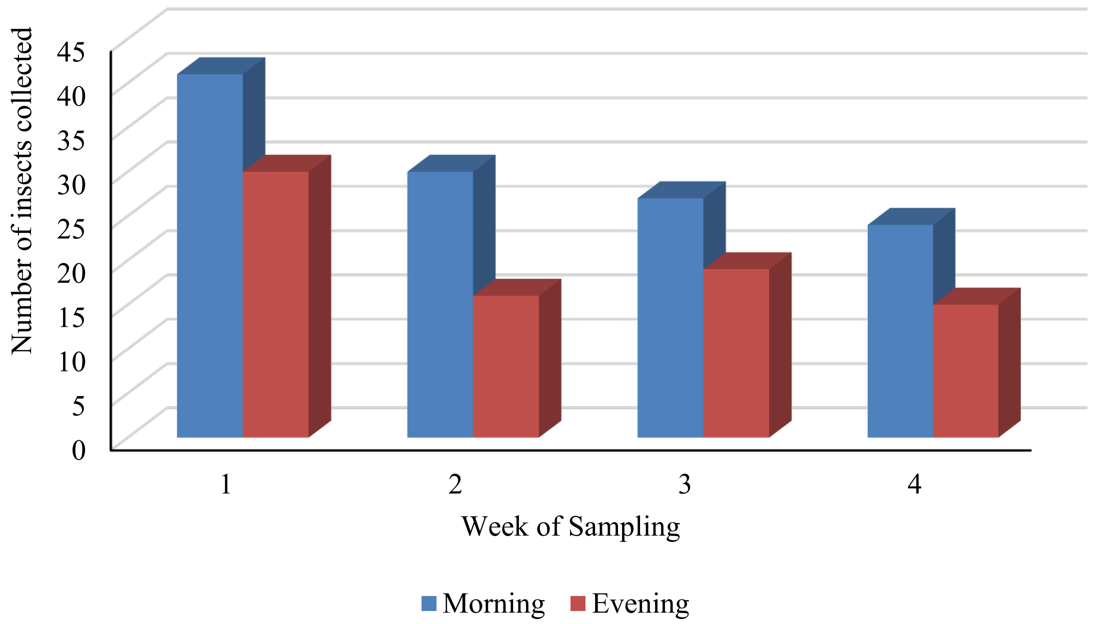

Figure 3. The abundance of insects collected between different weeks and times

Table 3 shows the mean abundance of different families collected for four weeks of sampling. Results showed that there was a significant difference (*P<0.05*) in insect abundance between different families. Among them, the Libellulidae showed significantly the highest individuals compared to other families, with 57 individuals (32.2 %) but no significant difference with Apidae (45 individuals, 25.42 %), and Formicidae (44 individuals, 24.86%) (Table 3). The remaining 16.40 % of the total number of individuals collected were not significantly different which were Vespidae and Mycetophillidae (8 individuals, 4.52%), Acrididae and Gryllidae (5 individuals, 2.82%), Gryllidae (5 individuals), and Calliphoridae (3 individuals, 1.69%). Whilst the Carabidae and Ectobidae recorded the lowest number of individuals collected with only 1 individual (0.56 %).

Table 3. Comparison of mean insect abundance between families that were collected

Family	Mean±SE	Total	Percentages (%)
Libellulidae	14.25±0.47b	57	32.20
Apidae	11 .00±0.70b	45	25.42
Formicidae	11.25±2.92b	44	24.86
Vespidae	2.00±0.40a	8	4.52
Mycetophilidae	2.00±1.08a	8	4.52
Acrididae	1.25±0.62a	5	2.82
Gryllidae	1.25±0.62a	5	2.82
Calliphoridae	0.75±0.75a	3	1.69
Carabidae	0.25±0.25a	1	0.56
Ectobidae	0.25±0.25a	1	0.56
	Total	**177**	**100**

Means with the same letter in different rows are not significantly different (*P>0.05*)

Determination of Insect Diversity

A summary of Shannon-Weiner Index is shown in Table 4. It was noted that the insects attracted to *T. trioniflora* in the morning were more diverse at H'=1.657 compared to the afternoon (H'=1.584). As for the evenness (R'), the insect recorded in the morning was higher (E'=0.754) than the afternoon (E'=0.720). However, the richness (R') of the insects attracted to *T. trioniflora* was similar between morning and afternoon time.

Table 4. Shannon-Weiner Diversity Index, Evenness Index and Margalef's Richness Index of insect attracted to *Turnera trioniflora* at different times

Index	Time	
	Morning	**Afternoon**
Diversity (H')	1.657	1.584
Richness (R')	9.000	9.000
Evenness (E')	0.754	0.720

Correlation between Insects Attracted to *Turnera trioniflora* and Abiotic Factors

Table 5 illustrates the Pearson correlation coefficients (r) between the population of insects attracted to *T. trioniflora* and three abiotic factors namely rainfall, relative humidity, and temperature across four different weeks. It was noted that in Week 1, rainfall showed a significant strong positive correlation (r = 0.948), while relative humidity and temperature had weaker positive correlations (r = 0.440 and 0.419, respectively). In Week 2, rainfall exhibited a significant negative correlation (r = -0.776), whereas relative humidity and temperature demonstrated strong positive correlations significantly (r = 0.941 and 0.967, respectively). Whilst, Week 3 displayed consistent, strong, and significant positive correlations between insect population for all three abiotic factors (r = 0.955 for rainfall, relative humidity, and temperature). Finally, in Week 4, rainfall continued to have a significant strong positive correlation (r = 0.907), but relative humidity and temperature showed weaker positive correlations (r = 0.358 and 0.641, respectively).

Table 5. Pearson correlation coefficient (r) between population of insects attracted to *Turnera* trioniflora and abiotic factors by different weeks

Week	**Abiotic Factor**		
	Rainfall	**Humidity**	**Temperature**
1	0.948*	0.440	0.419
2	-0.776*	0.941*	0.967*
3	0.955*	0.955*	0.955*
4	0.907*	0.358	0.641

*Correlation is significant at 0.05 level.

These findings indicated that the relationship between insect population and abiotic factors varies across weeks. Rainfall's influence alternates between positive and negative correlations, while relative humidity and temperature generally exhibit stronger and more consistent positive correlations during certain weeks, highlighting their potential importance in determining insect attraction to *T. trioniflora*.

DISCUSSION

Our findings confirm that *Turnera trioniflora* effectively attracts a greater number of insects in the morning than in the afternoon time, especially beneficial insects to the paddy fields, including natural enemies such as predators, alongside pollinators. However, no parasitoids were collected through this study although previous studies recorded a few families of hymenopteran parasitoids (Muniruddin et al. 2023). This might be due to differences in the type of sampling method used which they used passive traps, such as Malaise traps and yellow pan traps, which can trap small flying insects around the paddy fields, such as parasitoids but our traps target insects that visit and are attracted to *T. trioniflora* at real-time. Nonetheless, the presence of flowering plants such as *T. trioniflora* are capable of attracting variations of insects which can be beneficial in terms of protection of crops against pests (Abdullah & Rahim 2018). Furthermore, this study highlights that various insect species are abundant in paddy fields, as the paddy ecosystem serves as a primary habitat for diverse insect populations (Norela et al. 2013). The dominance of Libellulidae, commonly known as dragonflies, is unsurprising due to their widespread occurrence and high abundance of individuals and species (Triplehorn & Johnson 2005). According to Vatandoost (2021), adult dragonflies act as efficient predators, capturing and consuming flying insects such as gnats, mosquitoes, mayflies, moths, bees, ants, and termites during flight. These predatory activities are often observed on warm, sunny days near freshwater sources. In this study, the abundant insects attracted to *T. trioniflora* provide a rich food source for dragonflies, supporting their role as natural pest regulators.

The beneficial insects identified in this study, including Libellulidae, Apidae (bees), and Formicidae (ants), contribute significantly to the paddy ecosystem. Libellulidae have been recorded as natural enemies (predators) of various paddy pests, preying on small flying insects that may include pest species such as rice leafhoppers and planthoppers. For example, studies have demonstrated that dragonflies can reduce populations of these pests, thereby indirectly benefiting paddy growers by minimizing crop damage (Franca et al. 2024). Apidae, primarily represented by bees, play a critical role as pollinators. While paddy is a wind-pollinated crop, the presence of bees enhances biodiversity and supports the pollination of other plants in mixed agricultural ecosystems (Katumo et al 2022). Similarly, Formicidae contribute by preying on soft-bodied insects, scavenging, and helping to aerate soil, which improves the overall health of the paddy field ecosystem (Sumah & Kusumadinata 2023). In contrast, Ectobidae, which is made up of species of cockroaches, is considered a minor order because its species richness is lower than that of other main orders (Gullan & Cranston 2014). Ectobidae inhabit a range of environments, including under bark, in decaying wood, and beneath leaf litter. They are primarily omnivores or detritivores and also nocturnal which are active at night especially in search of food (Bell et al. 2007). Nonetheless, the cultivation of *T. trioniflora* is justified even if certain beneficial insects do not directly target major paddy pests. By attracting and supporting diverse beneficial insect populations, this plant promotes ecological balance, reduces the need for chemical pest control, and enhances the sustainability of paddy cultivation. For instance, a study by Jamian and Nur Azura (2018) revealed that the predator *Sycanus dichotomous* preferred the presence of the beneficial plant *T. subulata*. They believe that planting *T. subulata* is the best practice because it can improve buffer strips as habitats for predatory insects. Additionally, the presence of dragonflies and other predators ensures indirect pest suppression, while the ecosystem services provided by bees and ants contribute to overall agricultural productivity and environmental health.

The greater abundance of insects observed in the morning compared to the afternoon is likely influenced by the flowering pattern of *T. trioniflora*, which blooms exclusively during the morning. *Turnera* sp. plants, characterized by their distinctive blooming behavior, usually start the opening of flowers at 8.00 am, attracting the attention of insects. As the day progresses, the flowers gradually close, starting around 12.00 noon and closing completely in the evening (Amzah et al. 2018). This unique flower pattern has made *Turnera* also known as 'Bunga Pukul Lapan' or 'Flowers at Eight'.

Studying the temporal patterns of insect activity is crucial for understanding the dynamics of plant-insect interactions and optimizing the ecological benefits provided by these interactions. Different times of the day may influence insect behaviour due to factors such as temperature, light intensity, and floral resource availability (Karbassioon & Stanley 2023). By identifying periods of peak insect activity, researchers can better understand which species are actively foraging or predating, helping to evaluate their role in ecosystem services, such as pest control and pollination. For example, the peak hour for foraging activities by stingless bees, *Heterotrigona itama* was in the morning, from 10.00 am to 11.00 am (Siti Asma et al. 2024). Additionally, this knowledge is vital for designing targeted pest management strategies that leverage the natural activities of beneficial insects.

In addition, similar studies by Abdullah and Rahim (2018) found that *T. ulmifolia* attracted different insect communities depending on the time of the day but its effectiveness is limited to a short period. Moreover, the diversity of insects was also more diverse in the morning than afternoon. However, the number of insect populations abundance was decreased gradually after a few weeks. It might be due to excessive use of pesticides to control paddy pests that might also killed the beneficial insects (Muniruddin et al. 2023). According to the paddy plot owner (Yusof 2023 pers. comm.), pesticides have been used frequently at the age of paddy on the 27th, 41st and 55th days after sowing because that stage of paddy is most often attacked by insect pests. According to Rahaman et al. (2018), pesticides reduce beneficial insects. In addition, Badrulhadza et al. (2013) emphasized that farmers often use insecticide spraying to eliminate pests, resulting in a heavy reliance on chemical pesticides. This reliance not only escalates input expenses but also poses considerable adverse effects on the environment. Nonetheless, the diversity of insects attracted to *T. trioniflora* was also higher in the morning than in the afternoon. But, overall, the diversity of insects collected was considered low. As stated by Magurran (2004), low species diversity has H' value between 1.0 to 2.4.

Furthermore, we found that abiotic factors, especially rainfall, had a significant effect on the insect population collected, compared to humidity and temperature factors. Chen et al. (2019) reported that heavy rainfalls can affect the growth and survival of small organisms such as insects, thus rainfall is a crucial environmental factor that can influence plant-insect interactions. Lawson and Rands (2019) found that rain can directly affect both flowers and their visitors such as pollinators and may interfere with the timing of insect visitations. Hence, the population of insects becomes low when rainfall happens in that area because increases in rainfall patterns may significantly affect plant–pollinator interactions in multiple ways. However, the temperature still affects the number of insects attracted to *T. trioniflora.* Cuartas-Hernández and Gómez-Murillo (2015) observed that at the same temperature, certain insects, such as bees, tend to exhibit a higher metabolic rate in dry air compared to moist air. Their theory suggests that an increased metabolic rate allows insects to generate more metabolic water, helping to counteract body water loss due to evaporation and maintain a stable water-to-dry matter ratio across varying levels of atmospheric humidity. Since insects are cold-blooded, their body temperature is largely influenced by the surrounding environment, which in turn significantly affects their metabolism and activity levels. An animal's activity is typically inhibited by low temperatures and stimulated by higher ones (Damos & Savopoulou-Soultani 2012). Thus, flowering plants may only be pollinated in a restricted time at a certain level of temperature and production of nectar (Bradbar 2009).

CONCLUSIONS

In conclusion, this study highlights the ecological importance of *Turnera trioniflora* in attracting a diverse range of insects, particularly beneficial species, to paddy fields in Besut, Terengganu, Malaysia. With 12 of the 17 identified species classified as beneficial insects, including dominant families like Libellulidae, Apidae, and Formicidae, the findings underscore the potential of *T. trioniflora* to enhance pest regulation and support ecosystem balance. The significantly higher abundance and diversity of insects observed in the morning align with the flowering behavior of *T. trioniflora*, further emphasizing its role as a critical resource during this time. Additionally, the correlation between abiotic factors and insect activity reinforces the importance of environmental conditions in influencing insect populations. These results provide a foundational understanding of the role of *T. trioniflora* in Integrated Pest Management, offering valuable insights for sustainable paddy cultivation and future research in Malaysia. Moreover, data obtained from this study can be used as basic data for further research particularly about the factors that attract insects in paddy field cultivated with beneficial plants like *Turnera* sp. Thus, the effect of this beneficial plant in reducing the pest population in rice fields can also be studied further.

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AUTHORS DECLARATIONS

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Conflict of Interest
All authors declare that they have no conflicts of interest to influence the findings reported in this paper.

Ethics Declarations
Ethics declarations are not applicable for this research.

Data Availability Statement
This manuscript has no associated data.

Authors' Contributions
Mohammad Syariman Hashim was the principal researcher, collected and identified the specimens, and discussed the findings, and wrote the first draft of the manuscript. Muniruddin Hambali Hamdan and Norhayati Ngah provided materials and references, and Salmah Mohamed and Nur Azura Adam revised and refined the final of the manuscript.

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