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# EXPLORING THE ABUNDANCE AND DIVERSITY OF HYMENOPTERAN PARASITOIDS IN PADDY FIELDS CULTIVATED WITH BENEFICIAL PLANT, *Turnera trioniflora* SIMS

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## ABSTRACT

Beneficial insects such as hymenopteran parasitoids play a crucial role in pest population control and reducing the use of pesticides in paddy fields. To maintain sustainable parasitoid populations in the field, a sufficient nectar source is required, which can be provided by beneficial plants such as *Turnera* plants. However, studies on the abundance and diversity of hymenopteran parasitoids in paddy fields cultivated with *Turnera* plants are scarce. Hence, this study aimed to identify the families of hymenopteran parasitoids and determine their abundance and diversity in paddy fields cultivated with beneficial plant, *Turnera trioniflora* in Besut, Terengganu, Malaysia. Two paddy fields of 1 ha/field were selected, where one plot was cultivated with *T. trioniflora* (Plot A) and the other without *T. trioniflora* (Plot B). Three Malaise traps were randomly placed in each plot and insect samples were collected weekly during paddy off-season (Season 1: March-May 2021) and paddy main-season (Season 2: September-November 2021), and all samples were brought to the laboratory for identification. The study successfully identified 120 hymenopteran parasitoids comprising six families, namely Ichneumonidae, Braconidae, Chalcididae, Scelionidae, Torymidae, and Bethylidae, with the most abundant families being Ichneumonidae (72 individuals) and Braconidae (35 individuals). A significant difference (*P<0.05*) of hymenopteran parasitoid abundance was observed between different families in Season 1 but not in Season 2. The hymenopteran parasitoid abundance in Plot A was recorded as 73% higher than that in Plot B for both seasons. The diversity of hymenopteran parasitoids in Plot A was also higher than that in Plot B for both seasons. The study concludes that the abundance and diversity of hymenopteran parasitoids were higher in paddy plots cultivated with *T. trioniflora*, indicating the beneficial effects of *T. trioniflora* on the hymenopteran parasitoid's populations. These findings suggest that the presence of *T. trioniflora* in paddy fields may contribute to a more abundant and diverse family of hymenopteran parasitoids that may help improve paddy field pest management strategies.

**Keywords**: Beneficial plant, Hymenoptera, paddy, parasitoid, *Turnera*.

## ABSTRAK

Serangga bermanfaat seperti parasitoid Hymenoptera memainkan peranan penting dalam kawalan populasi perosak dan mengurangkan penggunaan racun perosak di sawah padi. Untuk mengekalkan populasi parasitoid yang mampan di lapangan, sumber nektar yang mencukupi diperlukan, di mana boleh dipenuhi oleh tumbuhan bermanfaat seperti *Turnera*. Walau bagaimanapun, kajian mengenai kelimpahan dan kepelbagaian parasitoid Hymenoptera di sawah padi yang ditanam dengan tumbuhan *Turnera* adalah kurang. Oleh itu, tinjauan ini bertujuan untuk mengenal pasti famili parasitoid Hymenoptera dan menentukan kelimpahan dan kepelbagaiannya di sawah padi yang ditanam dengan tumbuhan bermanfaat, *Turnera trioniflora* di Besut, Terengganu, Malaysia. Dua plot padi seluas 1 hektar/petak telah dipilih, di mana satu plot ditanam dengan *T. trioniflora* (Plot A) dan yang lain tanpa *T. trioniflora* (Plot B). Tiga perangkap Malaise diletakkan secara rawak di setiap plot dan sampel serangga dikutip setiap minggu selama 12 minggu semasa luar musim padi (Musim 1: Mac-Mei 2021) dan musim utama padi (Musim 2: September-November 2021), dan semua sampel dibawa ke makmal untuk dikenalpasti. Kajian ini telah mengenal pasti 120 parasitoid Hymenoptera yang terdiri daripada enam famili, iaitu Ichneumonidae, Braconidae, Chalcididae, Scelionidae, Torymidae, dan Bethylidae, dengan famili yang paling melimpah adalah Ichneumonidae (72 individu) dan Braconidae (35 individu). Perbezaan yang signifikan (*P<0.05*) dalam kelimpahan parasitoid Hymenoptera diperhatikan antara famili yang berbeza pada Musim 1 tetapi tidak pada Musim 2. Kelimpahan parasitoid Hymenoptera di Plot A direkodkan sebagai 73% lebih tinggi daripada Plot B untuk kedua-dua musim. Kepelbagaian parasitoid Hymenoptera di Plot A juga lebih tinggi daripada Plot B untuk kedua-dua musim. Kajian ini menyimpulkan bahawa kelimpahan dan kepelbagaian parasitoid Hymenoptera lebih tinggi di plot sawah padi yang ditanam dengan *T. trioniflora*, menunjukkan kesan yang bermanfaat *T. trioniflora* terhadap populasi parasitoid Hymenoptera. Penemuan ini menunjukkan bahawa kehadiran *T. trioniflora* di sawah padi boleh menyumbang kepada famili parasitoid Hymenoptera yang lebih banyak dan pelbagai yang boleh membantu meningkatkan strategi pengurusan perosak sawah padi.

**Katakunci**: Tumbuhan bermanfaat, Hymenoptera, padi, parasitoid, *Turnera*.

## INTRODUCTION

Insects use the paddy plant as a food source from sowing to harvesting, thus paddy is the most important habitat for them with a series of growth stages in a short period of time. The major insect pests in paddy field are divided into six order which are Lepidoptera, Hemiptera, Orthoptera, Thysanoptera, Coleoptera and Diptera (Oo et al. 2020; Ooi 2015). Among the main insect pest of paddy are such as mole cricket, thrips, rice caseworm, rice leaffolder, stem borer, rice black bug, rice ear bug, brown planthopper, and green leafhopper (Maisarah et al. 2018;

Marina et al. 2021; Saad et al. 2018). Consequently, the application of pesticides has been widely used to control pest infestation. However, regular use of insecticides reduces the effectiveness of the natural enemies such as parasitoids and this leads to outbreaks of the insect pest (Sánchez-Bayo 2021).

Therefore, the use of biological control as a component of Integrated Pest Management (IPM) has been proposed to reduce reliance on pesticides (Baker 2019). One of them is the planting of beneficial plants ecological engineering concept which manipulates the environment (Lu et al. 2015) by increasing the population of natural enemies in agricultural habitats (Horgan et al 2016). It has been reported that planting beneficial plants will improve the number of beneficial insects like parasitoids and predators as biological control of paddy pests (Sugiharti et al. 2018). For example, *Turnera* sp. or its local name as *Bunga Pukul Lapan* is capable of attracting various types of insects to the paddy fields (Amzah et al. 2018). *Turnera* plants are also reported to have allelopathic inhibitory properties that has the potential to be integrated into weed management systems (Wan Abdul Halim et al. 2021; Yaakob et al. 2020).

Order Hymenoptera composed of more than 153,000 species which grouped into 132 families and 8,432 genera throughout the world (Sheikh et al. 2019). Among them, 75% are categorized as parasitoids that play an important role in the natural management of insect pests (Rasplus et al. 2010). Their presence in fields is of great importance and affects yield production and ecosystem sustainability (Aman-Zuki et al. 2019). Hymenopteran parasitoids are widely used as biological control agents in Integrated Pest Management (IPM) programs in agriculture, forestry, and horticulture, reducing the reliance on chemical pesticides and promoting sustainable pest control practices. According to Gangwar (2017), 26 families of hymenopteran parasitoids have been used in biological control which the most frequently used families are Braconidae, Ichneumonidae, Eulophidae, Pteromalidae, Encrytidae and Aphelinidae.

Paddy fields in Besut, Terengganu located in East Coast of Peninsular Malaysia is one of the 10 granary sites of Malaysia which serve as the country's rice bowl and provide food security (DOA 2022). The site covers about 13,000 ha of paddy crop areas (MAMPU 2018) and managed by the authority of Integrated Agricultural Development Area of North Terengganu (IADA KETARA) (DOA 2022). In 2019, IADA KETARA started a beneficial plant planting program using *Turnera trioniflora* (yellow coloured flower) in selected paddy fields in Besut (Wan 2021 pers. comm.). However, no specific study has been conducted here to evaluate the effect of planting *T. trioniflora* in paddy fields on the population of beneficial insects such as hymenopteran parasitoids. Therefore, this study aims to identify the families of hymenopteran parasitoids as well as to determine their abundance and diversity in paddy fields cultivated with *T. trioniflora* in different paddy seasons. The data obtained can be used as guidelines and basic information for further ecological studies on beneficial plants for better and sustainable paddy pest management strategies.

## MATERIALS AND METHODS

### Study Area and Sampling Periods

The study was carried out in IADA KETARA rice granary at Kampung Apal, Besut, Terengganu, Malaysia (5°42'00.2"N 102°33'01.5"E). The study area comprises of two plots of paddy fields (i.e. Plot A and Plot B) planted with the MR297 rice variety using the direct seeding method, and both plots were subjected to the same conventional control treatment. The rice variety takes between 105-110 days to mature (Hashim et al. 2022). Plot A is a paddy field cultivated with *Turnera trioniflora* plants (N05° 42' 0.2088" E102° 33' 1.5192") and Plot B is a paddy field cultivated without *T. trioniflora* plants (N05° 41'33.45" E102° 33' 0.324") (Figure 1). The area of both plots is approximately 1 ha each and the distance between these two plots is approximately 800 m to ensure no interference of data effects (Figure 1). In Plot A, about 50 plants of 18 months-old of *T. trioniflora* shrubs (yellow coloured flower) were cultivated along the paddy roadside that is closer to the paddy field (Figure 2). The plants were well maintained and fertilized with organic fertilizer by farmers in every two to three months to ensure the beneficial plants grow healthy and encourage flowering.

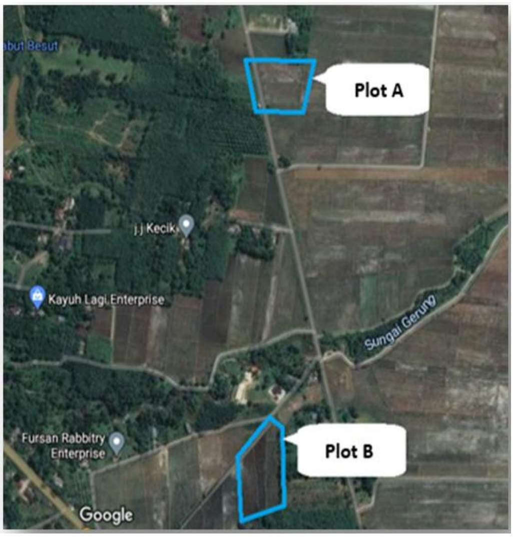


Figure 1. Paddy sampling plots in Kampung Apal Besut. Plot A is paddy cultivated with *T. triniflora*; Plot B is cultivated without *T. trionifora*

(Source: Google Map 2021)

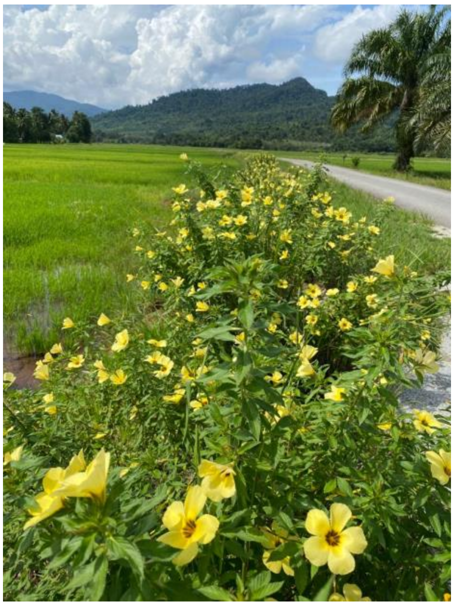

Figure 2. *Turnera trioniflora* shrubs cultivated along the paddy roadside (Plot A)

In IADA KETARA, paddy is typically cultivated in two seasons which known as the main season and the off-season (Hashim et al. 2022). The main season occurs from August to February of the following year and experiences a high amount of rain, while the off-season occurs from March to July and typically depends on irrigation for paddy planting due to a lack of rain in the area (DOA 2019). In this study, insect sampling was conducted from March to May (Season 1) and from September to November 2021 (Season 2). Meteorological data was obtained from the nearest station of the Malaysian Meteorological Department.

**Sampling Method**

Insect sampling and collection was done three times for each season using Malaise traps as they are suitable for trapping low-flying insects such as hymenopteran parasitoids that receive significant numerical captures (Fraser et al. 2007). Each plot consists of three sampling points and a random selection of trap points is made at each sampling point. Three Malaise traps (2 x 1.7 x 1.2 m) were installed at three different points with an interval of 20-50 m between each trap point in each sampling plot. The traps were left for three months and the insect samples were collected weekly starting from 35 days after sowing (DAS) or mid vegetative stage until the paddy early ripening stage (85 DAS) (Hashim et al. 2022). Each Malaise trap bottle was filled with 70% ethanol and replaced after each time insects were collected. Collected insects were brought to the laboratory for isolation, counting and identification. Sampling bottles are labelled according to plot, date, and sampling point.

**Insect Identification**

The insect samples collected were brought to the Laboratory of Entomology, Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin (UniSZA), Besut Campus for the identification process. Insects (i.e. hymenopteran parasitoids) were calculated and identified by sorting and enumeration from order up to the family level. All specimens were examined and identified under a stereomicroscope (Olympus SZ51 Japan) based on their morphological characteristics and family's keys according to Goulet and Huber (1993) and other related references. The number of individuals per family from different plots and seasons were recorded.

**Data Analysis**

One-Way Analysis of Variance (ANOVA) was used to compare different numbers of hymenopteran families collected from different plots and run on Minitab 17 software version 2019. Means were separated with Tukey's Range (HSD) Test at 0.05 level of significance. Species diversity was calculated using Shannon Index and carried out using Paleontological Statistics (PAST) 4.0 software.

## RESULTS

**Abundance of Hymenopteran Parasitoids Between Different Families**

Overall, a total of 120 individuals of hymenopteran parasitoids consisting of six hymenopteran families were collected from both paddy seasons (Table 1). Among the identified families, Ichneumonidae had the highest number of individuals collected, accounting for 60% (72 individuals) of the total number of parasitoids collected. Braconidae was the second most common family, with 29.2% (35 individuals) of the total individuals collected. Chalcididae and Scelionidae had lower numbers, with 7.5% (9 individuals) and 1.7% (2 individuals) of samples collected, respectively. The families Torymidae and Bethylidae had the lowest number of individuals collected, with only one individual or 0.8% each.

Table 1. Total number of hymenopterans parasitoids collected in all seasons

| Family | Number of Individuals | Percentage (%) |
|---|---|---|
| Ichneumonidae | 72 | 60.0 |
| Braconidae | 35 | 29.2 |
| Chalcididae | 9 | 7.5 |
| Scelionidae | 2 | 1.7 |
| Torymidae | 1 | 0.8 |
| Bethylidae | 1 | 0.8 |
| **Total** | **120** | **100** |

The abundance of different hymenopteran families at different seasons were displayed in Table 2 and Table 3. A total of 101 individuals of parasitoids were collected for both plots across four families in paddy Season 1 with a significant difference (*P<0.05*) (Table 2). The family Ichneumonidae was found to have significantly the highest number of individuals, with 63 individuals, followed by Braconidae with 35 individuals. The families Chalcididae and Bethylidae were not significantly different (*P>0.05*) and represented by two and one individuals, respectively. Meanwhile, there were four families consisted of 19 number of individuals hymenopteran parasitoids recorded for both plots in Season 2 with no significant difference (*P>0.05*) (Table 3). Among the families, Ichneumonidae was recorded the highest number of individuals with nine individuals and followed by seven individuals of Chalcididae. Whilst family of Scelionidae recorded with two individuals and Torymidae with one individual.

Table 2. Total of different hymenopteran parasitoids families collected in Season 1.

| Family | No. of Hymenopteran Parasitoids | |
|---|---|---|
| | **Mean±SE** | **Individuals** |
| Ichneumonidae | 21.00±3.00[a] | 63 |
| Braconidae | 11.67±2.85[a] | 35 |
| Chalcididae | 0.67±0.33[b] | 2 |
| Bethylidae | 0.33±0.33[b] | 1 |
| | **Total** | **101** |

Means with the different letters in different columns are significantly different (*P<0.05*)

Table 3. Total of different hymenopteran parasitoids families collected in Season 2.

| Family | No. of Parasitoids | |
|---|---|---|
| | **Mean±SE** | **Individuals** |
| Ichneumonidae | 3.00±0.47[a] | 9 |
| Chalcididae | 2.33±0.98[a] | 7 |
| Sclionidae | 0.67±0.54[a] | 2 |
| Torymidae | 0.33±0.27[a] | 1 |
| | **Total** | **19** |

Means with the same letters in different columns are not significantly different (*P>0.05*)

**Abundance of Hymenopteran Parasitoid in Different Paddy Plots**

Table 4 shows the abundance of hymenopteran parasitoids at different paddy plots in Season 1. The total number of hymenopteran parasitoids collected in Plot A was 74 individuals, which was 73.3% higher than the parasitoids collected in Plot B (27 individuals, 26.7%). Among the families, Ichneumonidae had the highest number of individuals for both plots, with 44 individuals in Plot A and 19 individuals in Plot B, followed by Braconidae with 28 individuals in Plot A and 7 individuals in Plot B. Only one individual of Chalcididae was collected for each plot, while Bethylidae was only found in Plot A with one individual collected.

Table 4. Total abundance of hymenopteran parasitoids collected in different plots in Season 1

| **Family** | **No. of Individuals** | |
|---|---|---|
| | **Plot A** | **Plot B** |
| Ichneumonidae | 44 | 19 |
| Braconidae | 28 | 7 |
| Chalcididae | 1 | 1 |
| Bethylidae | 1 | 0 |
| **Total** | **74** | **27** |

Meanwhile, Table 5 presents the total population abundance of hymenopteran parasitoids per plot in the second paddy season. A total of 14 individuals of parasitoids were collected in Plot A, which 73.7% higher than in Plot B that had only five individuals (26.3%). Ichneumonidae was the most abundant family in both plots with six individuals in Plot A and three individuals in Plot B, followed by Chalcididae with seven individuals collected in Plot A. In Plot B, two individuals of Scelionidae were collected, while one individual of Torymidae was collected in Plot A.

Table 5. Total abundance of hymenopteran parasitoids collected in different plots in Season 2

| **Family** | **No. of Individuals** | |
|---|---|---|
| | **Plot A** | **Plot B** |
| Ichenumonidae | 6 | 3 |
| Chalcididae | 7 | 0 |
| Scelionidae | 0 | 2 |
| Torymidae | 1 | 0 |
| **Total** | **14** | **5** |

**Diversity of Hymenopteran Parasitoids in Different Paddy Plots**

Table 6 shows the diversity, richness and, evenness of overall hymenopteran parasitoids collected in paddy Season 1. The highest diversity of hymenopteran parasitoids recorded was from the Plot A at the value of H'= 0.793 compared to the Plot B at the value of H'=0.719. As for the evenness, the Plot B recorded higher (E'=0.655) hymenopteran parasitoids than the Plot A (E'=0.572). The richness of the parasitoids for the Plot A higher at R'=4.000 than the Plot B at R'=3.000.

Table 6. Shannon-Weiner Diversity Index, Evenness Index and Margalef's Richness Index of hymenopteran parasitoids in Season 1

| Index | Plot A | Plot B |
|---|---|---|
| Diversity (H') | 0.793 | 0.719 |
| Richness (R') | 4.000 | 3.000 |
| Evenness (E') | 0.572 | 0.655 |

In the meantime, the results of diversity index in Season 2 (Table 7) were similar with Season 1, where the diversity of hymenopteran parasitoids was higher in Plot A compared to Plot B, with a value of H'=0.898 and H'=0.673, respectively. However, Plot B had a higher evenness of hymenopteran parasitoids compared to Plot A, with a value of E'=0.818 and E'=0.971, respectively. In terms of richness, Plot A had a higher number of hymenopteran parasitoid compared to Plot B, with a value of R'=3.000 and R'=2.000, respectively.

Table 7. Shannon-Weiner Diversity Index, Evenness Index and Margalef's Richness Index of hymenopteran parasitoids in Season 2

| Index | Plot A | Plot B |
|---|---|---|
| Diversity (H') | 0.898 | 0.673 |
| Richness (R') | 3.000 | 2.000 |
| Evenness (E') | 0.818 | 0.971 |

## DISCUSSION

### Abundance of Hymenopteran Parasitoids Between Different Families

This study had successfully identified and collected six hymenopteran families. Among the families, Ichneumonidae parasitoids dominant the number of individuals collected for both seasons. Ichneumonidae is one of the largest families of Ichneumonoidea as primary or secondary parasitoids that attack various insect orders at different phases of life, thus plays a critical role in the natural management of insect pests (Alfred Daniel et al. 2020). Usually, length of Ichneumonidae is to about 3.81 cm, not including antennae. The antennae are long, usually with at least 16 segments and at least half the length of the body. This parasitoid typically deposits their eggs in or on the eggs or larvae of other insects, specifically moth and butterfly caterpillars. Bennett et al. (2019) stated that the presence of Ichneumonidae in paddy fields plays a large role in controlling Lepidoptera and Coleoptera, which are the main pest of paddy. According to Gurr et al. (2012), at least 34 species of Ichneumonidae has been reported to attack lepidopteran leaffolder, *Cnaphalocrocis medinalis,* a common serious pest of paddy in Asian countries. Viet (2017) showed that Pimplini, a subfamily of Ichneumonidae is specialist parasitoid of the pupae of caterpillars.

In addition, Braconidae are also common parasitoids of the larvae of Lepidoptera in paddy field (Ranjith et al. 2015). Females of Braconidae are synovigenic, eating additional hosts and laying large eggs and larvae grow as a gregarious or solitary parasitoid (Quicke 2015). Their host selection includes several species with a wide variety of habits, but all victims display a certain degree of concealment in the tissues of annual and biennial plants, including galls, rolled leaves, inflorescences, seeds, stems and, more rarely, leaf mining or hardwood tissues (Quicke 2015). For example, *Apantales* sp. is one the important larval parasitoids of lepidopteran pest. *Apantales* sp. usually larval and pupal parasitoid of paddy leaf folder (Reddy 2017).

Meanwhile, the Chalcididae belong to a medium-sized parasitoid family of 96 genera and 1469 species worldwide (Aguiar et al. 2013). Chacididae often black with yellow, red, or white markings. Sized of this parasitoid about 1.5-15 mm long and their antennae that are bent and very small. Chalcidids is not a category of great economic significance since the extent of parasitism is most often comparatively low; thus, they are not capable of holding the populations of their hosts at a suitable level (Delvare 2017). Some of them are primary parasitoids and sometimes optional hyperparasitoids, while a few other chalcidids are mandatory secondary parasitoids (Delvare 2017). The members of the Chalcididae family parasitize Lepidoptera, Coleoptera, Diptera, Neuroptera, and a portion of Hymenoptera insects. Chalcididae lives solitary and only some of the time in the colony. The distribution of Chalcididae exists throughout the world, but generally, only a few species can live in cold regions (Ikhsan & Oktavia 2021).

Torymidae is one of the mid-sized families of Chalcidoidea that included 69 valid extant genera and about 1100 described species. Their head and mesosoma metallic green, metasoma and legs yellow, partly black (Janšta et al. 2018). Comparatively to other families of Hymenoptera, other character that can be found in Torymidae is they have a body character that is simple to identify, including a sturdy body and partly large, black or red with a mark in the form of yellow strokes, has a femur on the enlarged hind legs, has a part serrated abdomen, arched back tibia to support the femur, prepectus smaller than tegula, propodeum mostly areolate Torymidae is from superfamily Chalcidoidae, so their character also almost like Chalcididae (Ikhsan & Oktavia 2021). Torymidae is also important parasitoids to larvae of Lepidoptera (Ikhsan et al. 2020).

The Scelionidae is a large family of parasitic Hymenoptera whose members specialize in egg parasitism of insects and arachnids. Scelionidae are exclusively egg parasitoids, with a wide host array, with host dependent morphological specialization (Felipe-Victoriano et al. 2019). They have high searching abilities and reproductive rates, synchrony with host populations, positive host-density responsiveness, simple adult diets, can be reared easily, and lack of hyperparasitoids (Samin & Bagriacik 2015). Scelionidae are mostly small (0.5-10 mm), often black. Geniculate (elbowed) antennae that have a 9- or 10-segmented flagellum. They are internal egg parasitoids of Hemiptera, Lepidoptera (Polaszek 2021). Scelionidae such as *Gryon nixoni* is an egg parasitoid to ricebug (Mandanayake & Lanka 2017).

Bethylids are small to medium-sized, dark-coloured wasps. The females of many species are apterous and ant-like in appearance. Bethylidae are the parasitoids of Lepidoptera and Coleoptera larvae and several species attack moths or beetles. Usually, these parasitoids attack the larvae of Lepidoptera like *Parsie rola* and *Goniozus* sp. (Hendawy et al. 2016). Bethylidae are of special interest because of their mating and food habits, the maternal care of the brood and a tendency in some species toward community life (Azevedo et al. 2018).

**Abundance and Diversity of Hymenopteran Parasitoids in Different Paddy Plots**

Clearly, it was observed that the abundance and diversity of hymenopteran parasitoids collected were higher in rice plots planted with *T. trioniflora* (Plot A) compared to rice plots without *T. trioniflora* plants (Plot B) in both seasons. This suggests that the presence of *T. trioniflora* in Plot A may have contributed to a more diverse community of hymenopteran parasitoids compared to the control plot. Higher hymenopteran parasitoids abundance and diversity recorded in the Plot A compared in the Plot B is expected as availability of life support resources such as insect hosts and nectar sources from the *Turnera* plants. According to Marina Baez-Parra et al. (2018), many insects attract to *Turnera* due to its bright colour, rich in nectars and pollen contents. It might also be influenced by the availability of the plant that provide shelter to the insects (Nurul et al. 2015).

However, the diversity value is considered low as the value of H' is below 2.4 (H'=0.793 and 0.898). Magurran (2004) stated that low species diversity has H' value within 1.0 to 2.4. Thus, the overall diversity of hymenopteran parasitoids in Besut that was obtained from this study was considered low. It might be due to excessive use of pesticides to control paddy pests that might also killed the beneficial insects. Previous studies recorded that pesticides play an important role in the reduction of beneficial insects such as parasitoids (Rahaman et al. 2018). Farmers typically rely on spraying insecticides to get rid of pests, but this has led to a heavy dependence on chemical pesticides that not only raise input costs but also have significant harmful impacts on the environment (Badrulhadza et al. 2013).

The findings also clearly show that parasitoids obtained during Season 2 were lower in abundance than in Season 1. The reduced number of hymenopteran parasitoids collected in Season 2 could be attributed to abiotic factors. Typically, the state of Terengganu experiences the northeast monsoon season from November to March (Wahab et al. 2018) where heavy rains usually occur in this monsoon season, with an average annual reading of 2,990 mm (Ismail et al. 2020). As per the abiotic data obtained from The Malaysian Meteorological Department (MetMalaysia), the average rainfall recorded during Season 2 of insect sampling was 13.2 mm which is higher than Season 1 (4.05 mm). This indicates that the increased rainfall during Season 2 might had an impact on the number of hymenopteran parasitoids collected, as heavy downpours can affect the growth and survival of small organisms such as insects (Chen et al. 2019). Moreover, rainfall is a crucial environmental factor that can influence plant-insect interactions. Rain can directly affect both flowers and their visitors such as parasitoids and pollinators and may interfere with the timing of insect visitations (Faheem et al. 2004; Lawson & Rands 2019). Moreover, the collection of insects had to be limited to a period of seven weeks during Season 2 due to flooding in the sampling area caused by a high tide phenomenon that started in early November 2021 as reported by MalayMail (2021).

## CONCLUSIONS

In conclusion, a total of six hymenopteran families were successfully identified from this study, which were; Ichneumonidae, Braconidae, Chalcididae, Torymidae, Scelionidae and Bethylidae. Paddy plot cultivated with *Turnera trioniflora* showed a higher abundance and diversity of hymenopteran parasitoids than in the paddy plot without *T. turnera* for both paddy seasons. This suggests that the presence of *Turnera trioniflora* in paddy fields can have a positive impact on the abundance and diversity of hymenopteran parasitoids, which can help to control pests in paddy fields. Further studies may be needed to confirm the effectiveness of using beneficial plants such as *T. trioniflora* in pest management strategies for paddy fields as well as the factors that attract beneficial insects to *Turnera* plants.

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

**Ethics Declarations**
Ethics declarations are not applicable for this research.

**Data Availability Statement**
This manuscript has no associated data.

**Authors' Contributions**
MHH was the principal researcher, collected and identified the specimens, and discussed the findings, and wrote the first draft of the manuscript. SM, NASM and MR provided materials and references, revised the manuscript, and NAA refined the final draft.

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