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Assessment of Insect Abundance and Diversity in Paddy Fields Cultivated with Beneficial Plants, *Turnera trioniflora*

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ABSTRACT

Beneficial plants such as *Turnera* can be a good shelter and provide a food source for insects. The presence of insects, especially natural enemies in paddy fields is very important because the insects help in natural pest population control. However, detailed studies on the composition of insects in paddy fields cultivated with *Turnera* plants are still lacking. Therefore, a study was conducted in Besut, Terengganu to determine the population abundance and diversity of insects in paddy fields cultivated with the beneficial plant, *Turnera trioniflora*. Two paddy fields were selected as sampling plots which cultivated with *T. trioniflora* plants (Plot A) and without *T. trioniflora* plants (Plot B). For each plot, three Malaise traps, five yellow pan traps, and five pitfall traps were used to collect insect samples on a weekly basis during the paddy planting season (February-May 2021). Samples collected were brought to the laboratory for identifying processes. Results showed that a total of 3818 individuals of insects consisting of 10 orders (i.e. Diptera, Hymenoptera, Lepidoptera, Coleoptera, Hemiptera, Orthoptera, Thysanoptera, Odonata, Mantodea, and Blattodea) were successfully collected from both plots with a significance different ($p < 0.05$). Among them, ~~the~~ Diptera dominated the number of individuals collected with 52.12% (n=1990), followed by Hymenoptera with 16.87% (n= 644) and Lepidoptera with 12.40% (n=474). Whilst the Blattodea order was the least abundant with 0.07% (n=3). Plot A and Plot B recorded a total of 1995 and 1823 individuals, respectively and no significant difference ($p > 0.05$) of insect abundance was recorded between both plots. However, the diversity of insects in Plot A was slightly higher (H'=1.57) than in Plot B (H'=1.23). In conclusion, the insect's abundance and diversity in the paddy plot cultivated with *T. trioniflora* plants was relatively higher than in the paddy plot cultivated without *T. trioniflora* plants. This study has provided a set of basic data on the abundance and diversity of insects in paddy fields which is very helpful for further studies on the relationship between beneficial plants, *T. trioniflora* and insects.

Keywords: Beneficial plant; insect diversity; paddy; *Turnera*

INTRODUCTION

Rice is a staple food for Asian countries including Malaysia. Currently, Peninsular Malaysia has 10 paddy granary sites, which serve as the country's rice bowl and provide food security (DOA, 2022). One of the granary sites is located in Besut district, Terengganu which covers about 13,000 ha of paddy crop areas (MAMPU, 2022). The areas are managed by the authority of Integrated Agricultural Development Area of North Terengganu (IADA KETARA) (DOA, 2022). Recently, the Malaysian National Agricultural Policy (NAP 2.0) of 2021–2030 estimated the increase in production of rice from 2.98 million metric tons in 2021 to about 3.62 million metric tons in 2030 with the increase in self-sufficiency level (SSL) from 73.4% in 2021 to 80% in 2030 (MAFI, 2021). It can be viewed as a strategic intervention to support the development of paddy and rice industries while ensuring the nation's food security. However, only 7% of rice produced in the country of origin is exported (Firdaus et al., 2020).

One of the major factors contributing to low rice production at the plantation level is pests' infestation (Fahad et al., 2018). Yaakop et al. (2022) stated that the paddy field is a habitat for many kinds of living organisms such as algae, vertebrates, and invertebrates. The relationship between plants, wild animals, and insects causes an increase and decrease in crop yields (Saunders et al., 2016). According to Amzah et al. (2018), yields lost due to pest attacks is one of the main obstacles faced by farmers. Approximately, 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 Peninsular Malaysia, 61% of rice crop area damage was reported in 2015 due to insect infestation (DOA, 2016).

Therefore, the application of pesticides has been widely used to control pest infestation. However, regular use of insecticides reduces the effectiveness of the natural enemies and this leads to outbreaks of the insect pest (Ooi, 2015). Hence, the biological control method is as an alternative way to control pests. Biological control is an important component of Integrated Pest Management (IPM) programs which rely on predation, parasitism, natural mechanisms, and good agricultural practices such as planting beneficial plants around the paddy field. Basically, beneficial plants such as *Turnera trioniflora* or its local name as '*bunga pukul lapan*' attract insects particularly the natural enemies by providing them with nectars as food sources and shelter. This concept is known as ecological engineering which manipulated the environment (Lu et al., 2015) by increasing the population of natural enemies in agricultural habitats (Horgan et al., 2016).

Many researches showed that beneficial plant is proven to help in controlling pests of paddy at an acceptable level in China, Vietnam, and Thailand (Lu et al., 2015; Thakur, 2015) but less study was done in paddy areas in Malaysia, thus give difficulties to agriculture authorities to convince the paddy farmers in Malaysia to apply this biological control technique. Therefore, this study was conducted to determine the population abundance and diversity of insects in paddy plots cultivated with the beneficial plant, *T. trioniflora* in Besut, Terengganu.

MATERIALS AND METHODS

Study area and sampling period

The study was carried out in IADA KETARA paddy fields at Kampung Apal, Besut, Terengganu. The study area consists of two plots of paddy fields which are 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") (Fig. 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. The insect sampling was conducted in 2021 during the off-season (February-May). This season is the dry season with average monthly temperatures ranging from 29ºC to 34ºC (Malaysian Department of Meteorological, 2021). Each plot consists of several sampling points and a random selection of trap points is made at each sampling point.

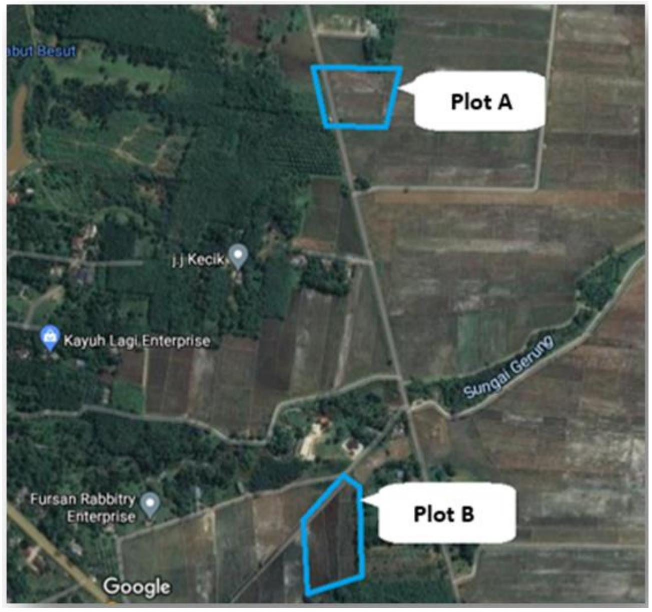

Fig. 1. Paddy sampling plots in Kampung Apal Besut. Plot A is paddy cultivated with *Turnera trioniflora* plants; Plot B is paddy fields cultivated without *T. trioniflora* plants. (Source: Google Maps)

Both sampling plots were planted with MR297 rice variety using a direct seeding method with the same conventional practice control treatment. About 50 plants of 12 months-old of *Turnera trioniflora* shrubs (yellow coloured flower) were cultivated along the paddy roadside that is closer to the paddy field of Plot A (Fig. 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.

A

B

Fig 2. A: *Turnera trioniflora* shrubs cultivated along the paddy bund (Plot A); B: A yellow coloured flower of *T. trioniflora* in full bloom.

Insect sampling

Three different types of insect trapping techniques were used for sampling; Malaise traps, yellow pan traps, and pitfall traps. Malaise and yellow pan traps were used to trap flying insects while pitfall trap was used to trap ground-dwelling insects. For each plot, three Malaise traps were installed at three different points with 20-50 m intervals between each trap point while five yellow pan traps and five pitfall traps were installed at five different points side-by-side with 20-50 m intervals (Fig. 3). The Malaise trap bottle was filled with 70% ethanol while the detergent liquid was filled in the yellow pan and pitfall trap. Ethanol and detergent liquid were replaced weekly. The traps were left for 12 weeks and the insect samples were collected weekly starting from 30 days after planting (DAP) until the rice harvesting time. The collected insects were placed in the collecting bottles containing 70% ethanol for preservation purposes before being brought to the laboratory for sorting, enumeration, and identification process.

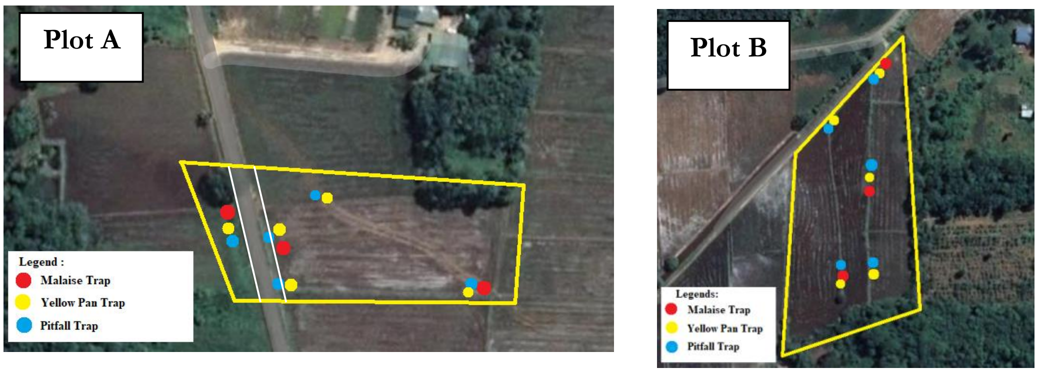

Fig 3. The layout of insect traps in Plot A and Plot B. The two white lines in Plot A indicate the line of *Turnera trioniflora* shrubs.

Insect identification

The insect samples were brought for identification and enumeration to the Laboratory of Entomology, Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin (UniSZA), Besut, Terengganu. All samples collected were sorted using forceps according to their order. The identification of insect orders was examined under a stereo microscope (Olympus SZ51, Japan) based on their main external morphological characteristics such as the type of legs, wings, mouth, and antenna. The specimens were identified based on Triplehorn and Johnson (2005).

Data analysis

T-test analysis was conducted to compare the insect abundance between two paddy plots while One-way ANOVA was used to compare the insect abundance between orders. Both T-test and one-way ANOVA were analysed using Minitab 17 software version 2019. Shannon-Weiner Diversity Index was used to determine the diversity of the insect using the Paleontological Statistics (PAST) Version 3.15.

RESULTS AND DISCUSSION

Determination of insect abundance

A total of 3818 individuals from 10 insect orders were successfully collected from the sampling plots and arranged in order from the highest number to the lowest number of individuals collected as shown in Table 1. The orders consist of Diptera, Hymenoptera, Lepidoptera, Coleoptera, Hemiptera, Orthoptera, Thysanoptera, Odonata, Mantodea, and Blattodea. There was a significant difference (F=30.39, df=9, $p < 0.05$) of insect abundance between different orders.

Table 1. Total insect abundance of different orders in paddy plots of Besut, Terengganu.

Order	Mean ± SE Mean	Total	Percentage (%)
Diptera	995.00 ± 157.00[a]	1990	52.12
Hymenoptera	322.00 ± 169.00[b]	644	16.87
Lepidoptera	237.00 ± 0.00[bc]	474	12.40
Coleoptera	191.50 ± 13.50[c]	383	10.03
Hemiptera	72.00 ± 35.00[c]	144	3.77
Orthoptera	67.50 ± 22.50[c]	135	3.54
Thysanoptera	11.00 ± 2.00[c]	22	0.58
Odonata	8.50 ± 0.50[c]	17	0.45
Mantodea	3.00 ± 0.00[c]	6	0.16
Blattodea	1.50 ± 0.50[c]	3	0.08
	Total	**3818**	**100**

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

Among them, the Diptera showed significantly the highest individuals compared to other orders, with 1990 individuals (52.12 %) and followed by Hymenoptera with 644 individuals (16.87 %), but it was not significantly different with Lepidoptera (474 individuals, 12.40%). The remaining 18.53 % of the total number of individuals collected were Coleoptera (383 individuals), Hemiptera (144 individuals), Orthoptera (135 individuals), Thysanoptera (22 individuals), Odonata (17 individuals), and Mantodea (6 individuals). Whilst the Blattodea recorded the lowest number of individuals collected with only 3 individuals (0.08 %).

The findings of this study show that various orders of insects are abundant in paddy fields with the order Diptera dominating the number of insects because the paddy ecosystem is the main habitat for many insect species (Norela et al., 2013). The dominance of Diptera in this study is not surprising as it is one of the largest insect orders and is often found almost everywhere due to its high abundance in terms of number of individuals and species (Triplehorn & Johnson (2005). Scherber et al. (2014) stated that the dipteran an act as predators, parasitoids, plant eaters, detritivores and pollinators. Moreover, Diptera together with Hymenoptera, Lepidoptera, Coleoptera and Hemiptera belong to the category of the major orders which stands out for their high species richness (Gullan & Cranston, 2014). In contrast, Blattodea, which consists of cockroach species, is categorized as a minor order due to its low species richness compared to other major orders (Gullan & Cranston 2014). Blattodea are mostly omnivores or detritivores and live in a variety of habitats such as under leaf litter, in decaying wood, and under bark. This group is also nocturnal which is active at night especially in search of food (Bell et al. 2007).

Furthermore, when compared between both plots, the paddy plot cultivated with *T. trioniflora* showed a slightly higher total insect individuals collected (1995 individuals) (Table 2) compared to total individuals of insects collected from the paddy plot without *T. trioniflora* (1823 individuals) (Table 3). However, no significant difference (F=0.11, df=1, $p > 0.05$) of insect abundance was recorded between both plots. Nonetheless, both plots had equivalent number of insect orders (i.e. 10 orders). Diptera and Hymenoptera were recorded significantly the highest abundance in plot cultivated with *T. trioniflora*, accounting for 838 individuals (42.01%) and 491 individuals (24.61%), respectively compared to other insect orders (Table 2). While the plot cultivated without *T. trioniflora* showed that Diptera was significantly the highest abundance in the plot comprising for 1152 individuals (63.19%) and followed by Lepidoptera with 237 individuals (13.02%) (Table 3).

Table 2. The insect abundance of different orders in Plot A (with *T. trioniflora*)

Order	Mean ± SE Mean	Total	Percentage (%)
Diptera	69.83 ± 9.34^{a}	838	42.01
Hymenoptera	41.67 ± 6.92^{b}	491	24.61
Lepidoptera	19.75 ± 4.30^{c}	237	11.88
Coleoptera	17.08 ± 3.65^{c}	205	10.28
Hemiptera	8.17 ± 4.20^{c}	107	5.36
Orthoptera	7.50 ± 2.20^{c}	90	4.51
Thysanoptera	1.08 ± 0.61^{c}	13	0.65
Odonata	0.75 ± 0.25^{c}	9	0.45
Mantodae	0.25 ± 0.18^{c}	3	0.15
Blattodea	0.17 ± 0.11^{c}	2	0.10
	Total	**1995**	**100**

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

Table 3. The insect abundance of different orders in Plot B (without *T. trioniflora*)

Order	Mean ± SE Mean	Total	Percentage (%)
Diptera	96.0 ± 24.0^{a}	1152	63.19
Lepidoptera	19.67 ± 5.08^{b}	237	13.02
Coleoptera	14.83 ± 3.88^{b}	178	9.76
Hymenoptera	12.75 ± 1.76^{b}	153	8.39
Orthoptera	3.75 ± 1.05^{b}	45	2.47
Hemiptera	3.08 ± 0.87^{b}	37	2.03
Thysanoptera	0.67 ± 0.28^{b}	9	0.49
Odonata	0.83 ± 0.58^{b}	8	0.44
Mantodae	0.25 ± 0.18^{b}	3	0.16
Blattodea	0.17 ± 0.11^{b}	1	0.05
	Total	**1823**	**100**

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

Ooi (2015) stated that most of the paddy pests are from Diptera and Lepidoptera orders. Several species of lepidopteran rice pests that occurred in Malaysian rice fields have been reported by previous researchers (Heinrichs, 1994; Ooi, 2015). While most of the hymenopteran insects and some dipterans are beneficial to the ecosystem as natural enemies and pollinators to flowering plants (Gullan & Cranston, 2014). This explains the higher numbers of Hymenoptera insects in paddy plot cultivated with *T. trioniflora* (n=491) compared to paddy plot without *T. trioniflora* that recorded less hymenopteran insects (n=153). According to Sari (2015), flowering plants such as *Turnera* have the ability to attract insects such as bees, butterflies, predators and parasitoids due to the flowers consist of many nectars and pollen contents attract those insects. Ryan et al. (2018) recorded about 48 species of insects were attracted to *T. subulata* plants (white coloured flower) and mostly they were hymenopteran insects.

Determination of insect diversity

A summary of Shannon-Weiner Index shows that Plot A recorded higher insect diversity at H'=1.57 compared to Plot B at H'=1.23. This result is similar with Amzah et al. (2018) which found that planting *Turnera* flowering plants in the ecological engineering paddy plot can increase the diversity of arthropods specifically the natural enemies in paddy ecosystem compared to conventional paddy plot (without *Turnera* plants). They added that the flowering plants are capable of serving as an alternative food source for arthropods to sustain in the environment. Thus, this study may provide an initial insight into the effectiveness of *Turnera* plants such as *T. trioniflora* as an attraction to diverse insect species particularly from Hymenoptera and Diptera orders. Sari (2015) recorded many insects attracted to *Turnera* sp. because this plant has ~~a~~ bright flower colour, rich in nectar and pollen content. Insect such as bees (*Trigona spinipes*), butterflies (*Nisoniades macarius*) and beetles (*Pristimerus calcaratus*) are recorded as frequent visitors to *Turnera* plants (Schlindwein & Medeiros, 2006; Sari, 2015). According to Agussalim et al. (2017), nectar and pollen from the flowering plants are the main sources of carbohydrates, protein, fats, vitamin, and essential minerals, which essential for insect's growth and development.

CONCLUSION

In conclusion, a total of 3818 individuals of insects consisting of 10 orders were successfully collected from the both paddy plots and among them, Diptera dominates the individual numbers collected followed by Hymenoptera and Lepidoptera. Hence, the insect's abundance and diversity were recorded relatively higher in the paddy plot cultivated with *T. trioniflora* than the paddy plot cultivated without *T. trioniflora*. Therefore, further study of relationship between insects and *T. trioniflora* should be conducted in the future.

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