

**BUKTI KORESPONDENSI  
ARTIKEL JURNAL INTERNASIONAL BEREPUTASI**

Judul artikel : Abundance and species diversity of predatory arthropods inhabiting rice of refuge habitats and synthetic insecticide application in freshwater swamps in South Sumatra, Indonesia

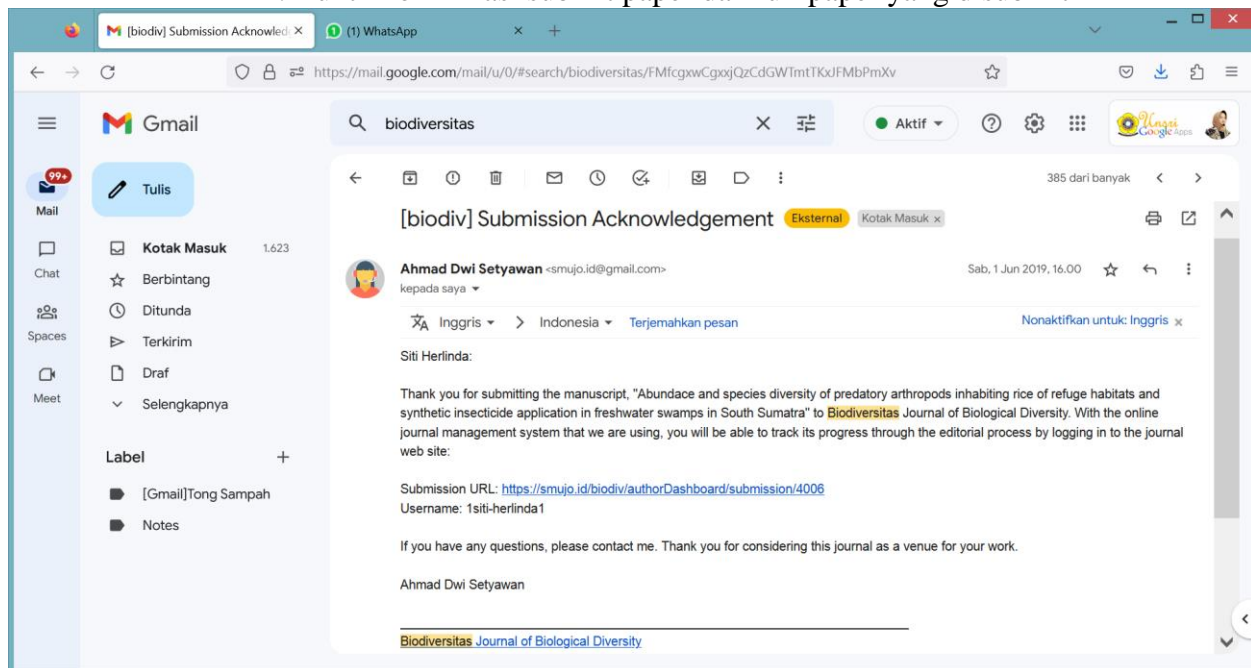
Jurnal : Biodiversitas

Penulis: Tili Karenina, Siti Herlinda, Chandra Irsan, Yulia Pujiastuti

**Bukti korespondensi**

No.	Perihal	Tanggal
1.	Bukti Konfirmasi submit paper dan full paper yang disubmit	1 Juni 2019
2.	Bukti konfirmasi review pertama dan hasil revisi pertama	16 Juli 2019
3.	Bukti konfirmasi paper accepted, uncorrected Proof dan hasil koreksi penulis	4 Agustus 2019
4.	Bukti tagihan untuk penerbitan artikel	2 September 2019

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**COVERING LETTER**

Dear **Editor-in-Chief**,

I herewith enclosed a research article,

**Title:**

Abundance and species diversity of predatory arthropods inhabiting rice of refuge habitats and synthetic insecticide application in freshwater swamps in South Sumatra

**Author(s) name:**

**Tili Karenina<sup>1</sup>, Siti Herlinda<sup>2,3</sup>\*, Chandra Irsan<sup>2,3</sup>, Yulia Pujiastuti<sup>2,3</sup>**

**Address**

<sup>1</sup>Postgraduate Program of Agricultural Sciences, Faculty of Agriculture, Universitas Sriwijaya, Jalan Padang Selasa No. 524, Bukit Besar, Palembang, South Sumatera, Indonesia 30139

<sup>2</sup>Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Sriwijaya, Jalan Raya Palembang-Prabumulih, km 32, Ogan Ilir, Indralaya, South Sumatera, Indonesia 30662

<sup>3</sup>Research Center for Sub-optimal Lands (PUR-PLSO), Universitas Sriwijaya, Jalan Padang Selasa No. 524, Bukit Besar, Palembang, South Sumatera, Indonesia 30139

Tel.: +62711580663, Fax.: +62711580276

✉Corresponding author E-mail: [sitiherlinda@unsri.ac.id](mailto:sitiherlinda@unsri.ac.id)

**For possibility publication on the journal:**

*Biodiversitas*

**Novelty:**

This study highlights several findings, such as abundance and species diversity of predatory arthropods found on paddy surrounded by refugia and vegetables in freshwater swamps in South Sumatra, Indonesia was higher than those on paddy untreated and insecticide application. We also found that species composition (or community) of spiders and predatory insects inhabiting paddy surrounded by the refugia was more similar to those inhabiting paddy surrounded by the vegetables. Therefore, paddy surrounded by the refugia and vegetables was the most appropriate for habitat and niche of predatory arthropods.

**Statements:**

This manuscript has not been published and is not under consideration for publication to any other journal or any other type of publication (including web hosting) either by me or any of my co-authors. Author(s) has been read and agree to the Ethical Guidelines.

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1. Fedai Erler; Akdeniz University, Faculty of Agriculture, Department of Plant Protection 07070 Antalya, Turkey; email: [erler@akdeniz.edu.tr](mailto:erler@akdeniz.edu.tr) Scopus ID: 55908362000
2. Maoye Li; School of Plant Protection, Anhui Agricultural University, Hefei 230036, Anhui Province, China; email: [sj412bq@163.com](mailto:sj412bq@163.com) Scopus ID: 55828064600
3. Novri Nelly; Universitas Andalas, Padang, Indonesia; Email: [novrinelly@agr.unand.ac.id](mailto:novrinelly@agr.unand.ac.id) Scopus ID: 6506527688.
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5. Eka Chandra Lina; Universitas Andalas, Padang, Indonesia; Email: [eka\\_candra@faperta.unand.ac.id](mailto:eka_candra@faperta.unand.ac.id) Scopus ID: 55780641000.

**Place and date:**

Palembang, 1 June 2019

**Sincerely yours,**

Siti Herlinda

# Abundance and species diversity of predatory arthropods inhabiting rice of refuge habitats and synthetic insecticide application in freshwater swamps in South Sumatra

TILI KARENINA<sup>1</sup>, SITI HERLINDA<sup>2,3\*</sup>, CHANDRA IRSAN<sup>2,3</sup>, YULIA PUJIASTUTI<sup>2,3</sup>

<sup>1</sup>Postgraduate Program of Agricultural Sciences, Faculty of Agriculture, Universitas Sriwijaya, Jalan Padang Selasa No. 524, Bukit Besar, Palembang, South Sumatera, Indonesia 30139

<sup>2</sup>Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Sriwijaya, Jalan Raya Palembang-Prabumulih, km 32, Ogan Ilir, Indralaya, South Sumatera, Indonesia 30662

<sup>3</sup>Research Center for Sub-optimal Lands (PUR-PLSO), Universitas Sriwijaya, Jalan Padang Selasa No. 524, Bukit Besar, Palembang, South Sumatera, Indonesia 30139

Tel.: +62711580663, Fax.: +62711580276

\*E-mail: sitiherlinda@unsri.ac.id

Manuscript received: 1 June 2019. Revision accepted: ..... 2019

**Abstract.** Rice cultivation in freshwater swamps is due to no synthetic pesticide spraying and mostly vegetable planted on rice field embankment. The research objective was to compare abundance and species diversity of predatory arthropods inhabiting rice of refuge habitats and synthetic insecticide application in rice field of freshwater swamps. This research used rice plots surrounded by refugia flower (*Zinnia* sp., *Tagetes erecta*, *Cosmo caudatus*, and *Sesamum indicum*); vegetables (*Cucumis sativus*, *Vigna sinensis*, *Luffa acutangula* and *Momordica charantia*); untreated; and synthetic insecticide. Twenty five herbivore species from 12 families, 34 spider species from 8 families, and 24 species of predatory insects from 12 families were found on rice during a planting season. The lowest herbivore population and spider abundance was found on rice synthetic insecticide sprayed and was significantly different than that of refugia-rice plots. The most abundant spiders and predatory insects was found on rice surrounded by refugia and it was not significantly different than that of rice surrounded by vegetables. The highest species diversity for spiders and predatory insects was found on rice surrounded by refugia, whereas the lowest species diversity was found on rice synthetic pesticide sprayed. Therefore, rice surrounded by refugia flowers and vegetables was the most appropriate for habitat and niche of predatory arthropods.

**Key words:** Herbivore, neutral insect, parasitoid, predatory insect, spider

**Running title:** Species diversity of predatory arthropods

## INTRODUCTION

Cultivation of rice (*Oryza sativa*) in freshwater swamps in Indonesia is specific, i.e. only a planting season from April to September in a year. Rice is planted by using transplanting method, i.e. starting from seedling and then transplanted to rice field (Lakitan *et al.*, 2018a,b). Rice seedling can be done with three patterns consisting of floating raft seedling, 'samir' method and digging ('tugal') method (Herlinda *et al.*, 2018a; Lakitan *et al.*, 2018b). Subsequently, seedlings of 7–10 days old were transplanted into rice field. Rice pest control in freshwater swamp generally is not using synthetic insecticide (Herlinda *et al.* 2018b; Safitri *et al.* 2018), whereas weeds control is done without using herbicide but by using manual method through revoked by hand or weeded by using sickle. In addition, rice field embankment usually is planted with flowering seasonal vegetables, such as long beans (*Vigna sinensis*), cucumber (*Cucumis sativus*), bitter melon (*Momordica charantia*) and squash (*Luffa acutangula*).

This specific rice cultivation in freshwater swamps affects arthropod communities. Species richness and abundance of spiders on rice in freshwater swamps are higher than that of rice in tidal lowlands of South Sumatra because farmers in the freshwater swamps do not apply synthetic insecticide (Herlinda *et al.*, 2018a). Application of synthetic insecticide can decrease the abundance and species diversity of predators and parasitoids (Ngin *et al.*, 2017; Svobodová *et al.*, 2017).

In addition to synthetic insecticide application, flora in the vicinity of rice can affects arthropod community (Cao *et al.*, 2004; Lopes *et al.*, 2017; Xu *et al.* 2017; Baba *et al.*, 2018). Wild plants, refugia, and vegetables planted at rice field embankment can provide niche and habitat for arthropods as natural enemies of rice pest insects (Zhu *et al.*, 2014a; Hasan *et al.*, 2016; McCabe *et al.*, 2017). Nectar and pollen on those crops and plants can increase longevity, fecundity, and function of natural enemies (Desai *et al.*, 2017; Foti *et al.*, 2017; Ganai *et al.*, 2017; Lu *et al.*, 2014). Some of refugia had

been utilized for natural enemies conservation on rice, for instance *Zinnia* sp. become niche and habitat for spiders, *Argiope aemula*, *Oxyopes* sp., and *Perenethis* sp. (Desai *et al.*, 2017). *Tagetes erecta* was inhabited by *Oxyopes javanus*, *Coccinella septumpunctata*, *Syrphus* spp., *Geocoris* spp., *Apis dorsata*, *Apis mellifera* and *Vanessa cardui* (Ganai *et al.*, 2017). Refugia species of *Antigonon leptopus*, *Cassia cobanensis*, *Turnera subulata*, and *Antigonon leptopus* had been used for natural enemies conservation of oil palm pests (Dutton *et al.*, 2016; Kamarudin and Arshad, 2016; Saleh and Siregar, 2017). The effort to utilize refugia flower for predatory arthropod conservation in freshwater swamps of rice ecosystems in Indonesia had not yet been done. Therefore, this research objective was to compare abundance and species diversity of predatory arthropods inhabiting rice of refuge habitats and synthetic insecticide application in freshwater swamps.

## MATERIALS AND METHODS

This research was conducted in rice field of freshwater swamps in Pelabuhan Dalam Village, Pemulutan Subdistrict, Ogan Ilir District, South Sumatra Province from May to August 2018. The selected rice field was rice center that had flooding phase within October to March period and dry phase within April to September period.

### Field preparation and treatments

This stage was consisted of land preparation and soil tillage, seedling, planting, and rice maintenance. Land preparation was started with weeds clearing followed by soil tillage and application of manure fertilizer at dose of 1 ton.ha<sup>-1</sup>. Rice seeds used in this research was certified Mekongga variety. Before seedling, seeds were broiled for 1 x 24 hours and then sowed within tray (size of 36 cm x 27 cm x 4,5 cm) for 14 days (Figure 1). The next step was transport of seeds into rice field and transplanted.

Rice was planted by using lined up system ('jajar legowo' 2:1) with planting distance of 50 cm x 25 cm x 12.5 cm. All of rice plot treatments were fertilized with liquid compost extract once in two weeks at dose of 2 L.ha<sup>-1</sup> and manure fertilizer at dose of 1 ton.ha<sup>-1</sup>. Compost extract was produced according to the method of Suwandi *et al.* (2012).

Treatment plots were designed into four treatments (four plots) which consisted of rice plots surrounded by 1) refugia, 2) vegetables, 3) untreated (without refugia, vegetable or insecticide), and 4) control sprayed with synthetic insecticide, respectively. Every plot had an area of 800 m<sup>2</sup>, and was divided into five sub-plots as replications.



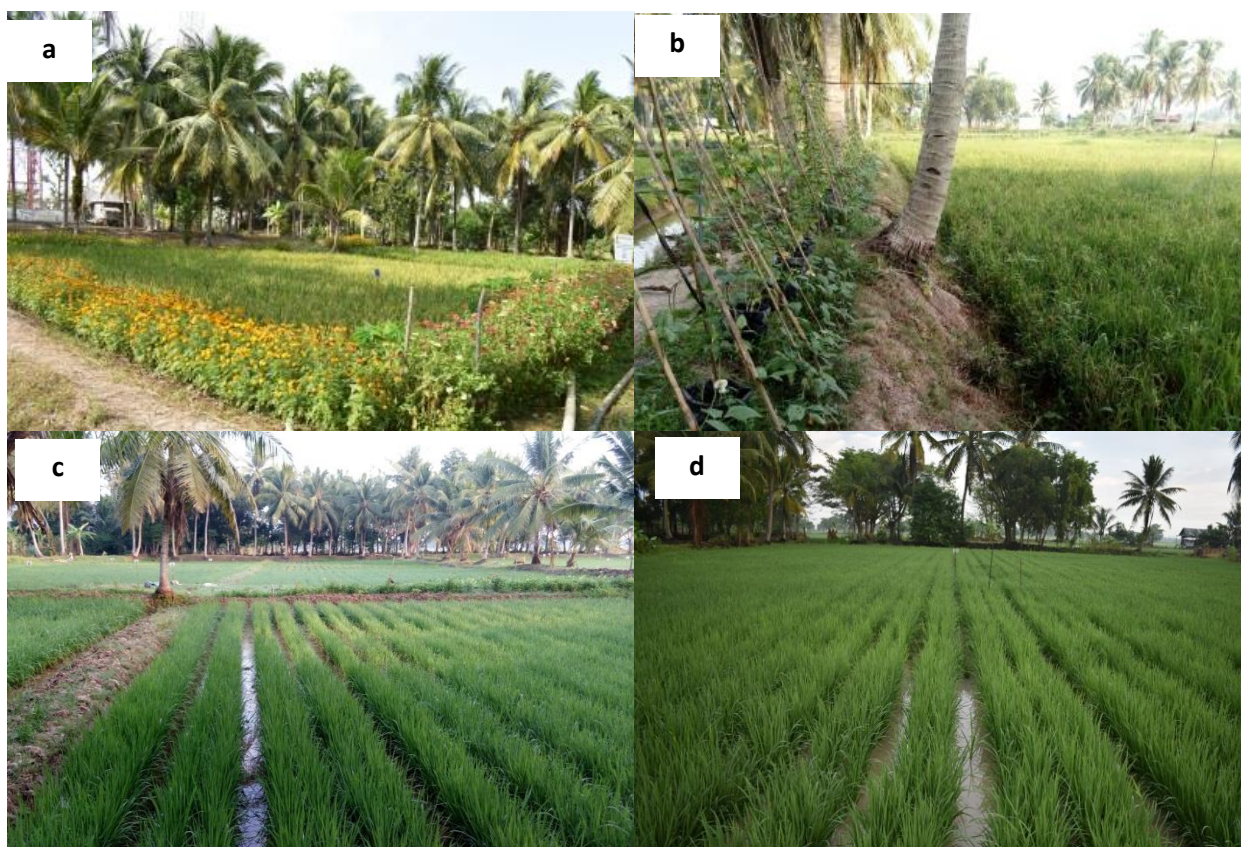
**Figure 1.** Field preparation: seeds broiled for 1 x 24 hours (a), seeds sowed within trays (b), rice transplanted by using 'jajar legowo' 2:1 (c, d)

Refugia and vegetables planting was conducted 30 days prior to rice planting so that refugia already flowering when rice enters vegetative phase at 14 days after transplanting (dat). Rice plots surrounded by refugia used four species of refugia flower consisting of zinnia or paper flower (*Zinnia* sp.), tagetes (*Tagetes erecta*), thinkin (*Cosmo caudatus*), and sesame (*Sesamum*) (Figure 2). Rice plots surrounded by vegetables used four seasonal vegetable species which consisted of long beans (*V. sinensis*), cucumber (*C. sativus*), bitter melon (*M. charantia*), and squash (*L. acutangula*) planted at rice field embankment. Vegetable planting distance (distance between planting holes) was as follows: 30 cm, 60 cm, 30 cm, and 40 cm for long beans, bitter melon, squash, and cucumber, respectively. Refugia planting distance (distance between planting holes) was 15 cm, but refugia had two rows planting at rice field embankment. Rice untreated plots (without refugia, vegetables, and insecticide application) was rice plot having no plants in the vicinity of rice field embankment, whereas rice plots sprayed with synthetic insecticide was also not surrounded by refugia or vegetables (Figure 2). The synthetic insecticide used in this research had abamectine active ingredient according to the recommended dose.

### Arthropods sampling

Arthropod sampling was conducted every week for one planting season and started when rice had age of 14 until 84 days after transplanting (11 observations). Arthropods sampling was done at early morning from 06.00 to 07.00 a.m. The arthropods were collected using sweep nets (net handgrip length of 100 cm, length of 75 cm and diameter of 30 cm) based on the methods from Jayakumar and Sankari (2010) and Janzen (2013). Swinging net was purposively touched on rice stem according to Masika *et al.* (2017) method in order to drag insects that attached on rice stems and leaves at rice lower

canopy. The arthropods were collected by swinging net one time using double swing that form straight line at depth of 30 cm toward rice canopy interior.



**Figure 2.** Plots for treatments: rice surrounded by refugia (a), vegetables (b), untreated (c), and insecticide application (d)

The arthropods caught subsequently were cleaned and put into plastics vial containing 70% alcohol, labelled, and taken to the Entomology Laboratory, Department of Plant Pest and Diseases, College of Agriculture, Universitas Sriwijaya, South Sumatra, Indonesia for identification by Dr. Chandra Irsan, an insect taxonomist. Spider visual identification was conducted by using reference of Barrion and Litsinger (1995) and insect visual identification was conducted by using books reference of Heinrichs (1994), Kalshoven (1981), and McAlpine *et al.* (1987). All the identified arthropods were grouped into guilds and their number of individuals of each species was counted.

### Data analysis

Data of abundance (or number of individuals) of herbivores, spiders, and predatory insects among treatments were analyzed by using analysis of variance (ANOVA). If there were differences among the data of each treatment, they were separated using Tukey's Honestly Significant Different (HSD) test at 5%. The data analysis were calculated using program software of SAS University Edition 2.7 9.4 M5. Data of arthropod abundance were also used to analyze species diversity by using Shannon index ( $H'$ ). The diversity level was also evaluated by the Evenness index ( $J'$ ) derived from the Shannon function, and Berger-Parker dominance biodiversity indices. Data of arthropod abundance was subsequently also grouped according to guild which consisted of herbivore (or phytophagous insects), predator, parasitoid, and neutral insects and reported graphically.

## RESULTS AND DISCUSSION

### Arthropods species

Twenty five herbivore species from 12 families were found during one planting season of rice. The most dominant herbivore found in this research were *Nilaparvata lugens*, *Leptocorisa acuta*, *Valanga nigricornis*, *Oxya chinensis*, and *Acrida turita* (Figure 3). Spider having 34 species from eight families were dominated by *Tetragnatha virescens*, *T. javana*, *T. mandibulata*, *T. maxillosa*, and *Argiope catenulata*. Predatory insect having 24 species from 12 families was also

found in this research. The dominant species of predatory insects found were *Odontoponera transversa*, *Micrapis inops*, *Menochilus sexmaculatus*, *Paederus fuscipes*, and *Conocephalus longipennis*.



**Figure 3.** Dominant arthropod species found on rice: *Nilaparvata lugens* (a), *Leptocoris acuta* (b), *Valanga nigricornis* (c), *Oxya chinensis* (d), *Acrida turita* (e), *Spodoptera* sp. (f), *Cnaphalocrosis medinalis* (g), *Amata nigriceps* (h), *Pelopidas* sp. (i), *Tetrix subulata* (j), *Tetragnatha virescens* (k), *T. mandibulata* (l), *T. javana* (m), *T. maxillosa* (n), *Argiope catenulata* (o), Araneidae (p), *Oxyopes mattienseis* (q), *O. javanus* (r), Salticidae (s), *Pardosa pseudoannulata* (t), *Odontoponera transversa* (u), *Micrapis inops* (v), *Menochilus sexmaculatus* (w), *Paederus fuscipes* (x), *Conocephalus longipennis* (y), *Ophionea nigrofasciata* (z), *Agriocnemis* sp. (aa), *Argia* sp. (ab), *Pantala* sp. (ac), and *Volucella* sp. (ad)



### Herbivore abundance

The highest abundance or population of *N. lugens*, *S. furcifera*, *L. acuta*, *S. litura* and *A. turruta* during one planting season was found on rice surrounded by refugia and significantly different than population of those on rice sprayed with synthetic insecticide (Table 1). The highest population from families of *Delphacidae*, *Alydidae*, *Noctuidae*, and *Acrididae* was found on rice surrounded by refugia, whereas the lowest population was found on rice sprayed with synthetic insecticide. Application of synthetic insecticide during vegetative stage of rice significantly decreased herbivore population.

When rice age was 14–28 days after transplanting, herbivore population was still lower on rice sprayed with synthetic insecticide than that of other treatment plots (Figure 4). After this period, herbivore population tended to increase on rice sprayed with synthetic insecticide. Whereas on other plots (refugia, vegetables, and untreated), population of herbivore tended to decrease continuously and even when rice age was 49–56 days after transplanting on rice surrounded by refugia and vegetables, the abundance of predatory arthropods was higher than herbivore population.

### Spider and predatory insect abundance

The highest abundance of *T. mandibulata*, *T. vermiformis*, and *Bathyphantes tagalogensis* was found on rice surrounded by refugia and vegetables and it was significantly different than those on rice sprayed with synthetic insecticide and untreated rice (Table 2). Total of spider abundance was also higher on rice surrounded by refugia and vegetables. Abundance of predatory insect of *Coccinelidae*, especially *Micraspis inops* was higher on rice surrounded by refugia and untreated rice, and significantly different than abundance of rice plots sprayed with synthetic insecticide and rice plots surrounded by refugia and vegetables (Table 3), but total of predatory insect abundance was higher on rice surrounded by refugia, vegetables, and untreated rice as well as was significantly different than rice plots sprayed with synthetic insecticide.

### Species diversity of predatory arthropods

At 14 up to 84 days after transplanting, spider species diversity on rice surrounded by refugia was tend to be higher than that of other rice plots (Table 4). Total magnitude since initial to final observation showed that the highest spider abundance was found on rice surrounded by refugia, whereas the lowest one was found on rice sprayed with synthetic insecticide. The similar trend was also found on species diversity of predatory insects which tend to be high on rice surrounded by refugia, whereas lower species diversity was found on rice sprayed with synthetic insecticide (Table 5).

### Comparison of arthropod abundance according to guilds

At 14 days after transplanting, the lowest herbivore abundance was found on rice sprayed with synthetic insecticide, whereas higher herbivore abundance was found on other plots (Figure 4). At 21 up to 28 days after transplanting, abundance of predatory arthropods was higher than that of parasitoids and herbivores. The peak increase of herbivore abundance and the decrease of predatory insects abundance were occurred during rice at 35 to 42 days after transplanting and subsequently predatory arthropod abundance started to increase and was higher than herbivore abundance. Prior to harvest at 75 to 84 days after transplanting, abundance of predatory arthropods had sharply increase and herbivore abundance had drastically decrease. Arthropod abundance (herbivores, predators, parasitoids, and neutral insects) on rice surrounded by refugia was tend to be higher than that of other treatment plots, whereas the lowest abundance tended to be found on rice plots sprayed with synthetic insecticide.

The initial observation period at 14 to 21 days after transplanting showed that herbivore proportion on rice sprayed with synthetic insecticide was lower than proportion of predators, parasitoids and neutral insects, whereas the highest herbivore proportion was found on rice surrounded by refugia (Figure 5). Subsequently, herbivore proportion on rice sprayed with synthetic insecticide was continually increase and higher than predator proportion. However, predator and parasitoid proportion on rice surrounded by refugia and vegetable was continually increase higher than herbivore proportion up to before harvest.

### Discussion

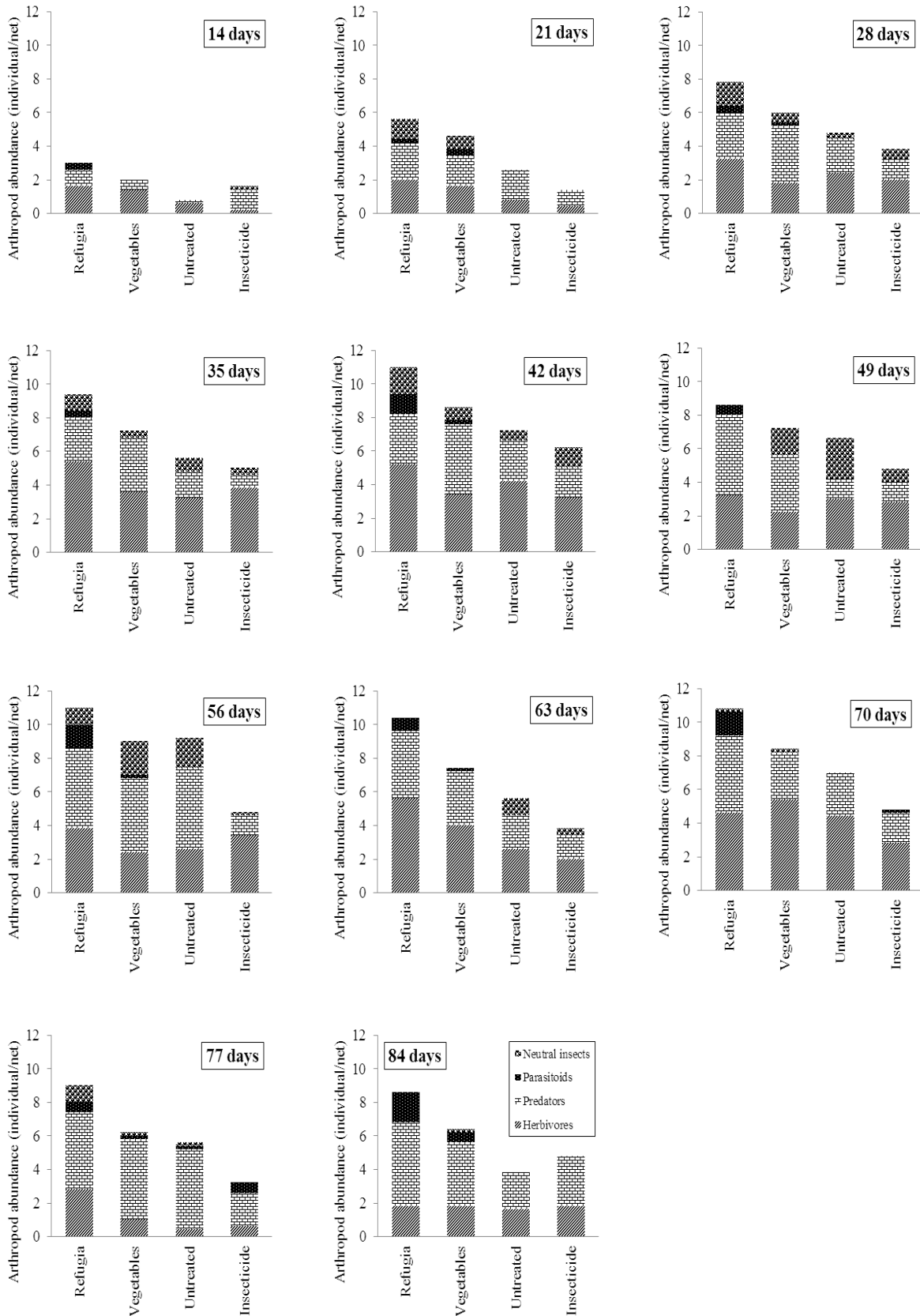
This research showed that refugia and vegetables planted on rice field embankment surround by rice were capable to increase the abundance and species diversity of predatory arthropods (spider and predatory insects) on rice, whereas synthetic insecticide application was not only suppress herbivore population, but also decrease the abundance of natural enemies of pest insects and other useful arthropods, such as spiders, predatory insects, parasitoids, neutral insects or pollinating insects.



**Table 1.** Population or abundance of herbivores inhabiting rice surrounded by refugia, vegetables, untreated, and insecticide application

No.	Ordo/ Family/Species	Mean of population (individual/nets)				F-value	P value (0.05)	Tukey's HSD test
		Rice-Refugia	Rice-Vegetable	Rice-Untreated	Rice-Insecticide			
	HEMIPTERA	1.58 <sup>b</sup>	1.16 <sup>ab</sup>	0.75 <sup>a</sup>	0.78 <sup>a</sup>	5.84	0.01	0.27
	Delphacidae	0.95 <sup>b</sup>	0.69 <sup>ab</sup>	0.51 <sup>ab</sup>	0.25 <sup>a</sup>	5.01	0.02	0.26
1	<i>Nilavarpata lugens</i>	0.8 <sup>b</sup>	0.62 <sup>ab</sup>	0.47 <sup>ab</sup>	0.18 <sup>a</sup>	3.61	0.05	0.29
2	<i>Sogatella furcifera</i>	0.15 <sup>a</sup>	0.07 <sup>a</sup>	0.04 <sup>a</sup>	0.07 <sup>a</sup>	1.08	0.39	
	Cicadellidae	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
3	<i>Cicadulina bipunctata</i>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Coreidae	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.62	0.62	
4	<i>Cletus trigonus</i>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.62	0.62	
	Alydidae	0.64 <sup>b</sup>	0.44 <sup>ab</sup>	0.22 <sup>a</sup>	0.49 <sup>ab</sup>	5.50	0.01	0.17
5	<i>Leptocorisa acuta</i>	0.64 <sup>b</sup>	0.44 <sup>ab</sup>	0.22 <sup>a</sup>	0.49 <sup>ab</sup>	5.50	0.01	0.17
	LEPIDOPTERA	0.22 <sup>a</sup>	0.27 <sup>a</sup>	0.27 <sup>a</sup>	0.11 <sup>a</sup>	1.05	0.41	
	Noctuidae	0.05 <sup>a</sup>	0.18 <sup>b</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	6.66	0.01	0.08
6	<i>Spodoptera sp.</i>	0.05 <sup>ab</sup>	0.15 <sup>b</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	5.97	0.01	0.06
7	<i>Naranga sp.</i>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.68	0.58	
	Pyralidae	0.07 <sup>a</sup>	0.05 <sup>a</sup>	0.09 <sup>a</sup>	0.09 <sup>a</sup>	0.26	0.85	
8	<i>Cnaphalocrosis medinalis</i>	0.05 <sup>a</sup>	0.05 <sup>a</sup>	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0.11	0.95	
9	<i>Scirpophaga incertulas</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.05 <sup>a</sup>	0.05 <sup>a</sup>	1.62	0.24	
	Erebidae	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0.13 <sup>a</sup>	0 <sup>a</sup>	1.21	0.35	
10	<i>Amata nigriceps</i>	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0.13 <sup>a</sup>	0 <sup>a</sup>	1.21	0.35	
	Hesperiidae	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
11	<i>Pelopidas sp.</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Nymphalidae	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	
12	<i>Melanitis leda</i>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	
	COLEOPTERA	0.09 <sup>a</sup>	0.11 <sup>a</sup>	0.07 <sup>a</sup>	0.05 <sup>a</sup>	0.17	0.92	
	Chrysomelidae	0.09 <sup>a</sup>	0.11 <sup>a</sup>	0.07 <sup>a</sup>	0.05 <sup>a</sup>	0.17	0.92	
13	<i>Chrysolina coeruleans</i>	0.07 <sup>a</sup>	0.04 <sup>a</sup>	0.07 <sup>a</sup>	0.00 <sup>a</sup>	0.63	0.61	
14	<i>Dactylispa bayoni</i>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
15	<i>Chaetocnema sp.</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
16	<i>Di cladispa armigera</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
17	<i>Aulacophora frontalis</i>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.88	0.48	
18	<i>Charidotella sp.</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	ORTHOPTERA	1.51 <sup>b</sup>	0.89 <sup>a</sup>	1.24 <sup>ab</sup>	1.04 <sup>ab</sup>	3.63	0.05	0.22
	Tettigonidae	0 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
19	<i>Tetrix subulata</i>	0 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Acrididae	1.49 <sup>b</sup>	0.89 <sup>a</sup>	1.16 <sup>ab</sup>	1.04 <sup>ab</sup>	3.64	0.04	0.21
20	<i>Valanga nigricornis</i>	1.18 <sup>a</sup>	0.69 <sup>a</sup>	1.15 <sup>a</sup>	0.87 <sup>a</sup>	2.29	0.13	
21	<i>Oxya chinensis</i>	0.2 <sup>a</sup>	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.11 <sup>a</sup>	1.67	0.23	
22	<i>Acrida turrata</i>	0.11 <sup>b</sup>	0.13 <sup>b</sup>	0.00 <sup>a</sup>	0.05 <sup>ab</sup>	6.11	0.01	0.06
	Gryllidae	0.02 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	
23	<i>Gryllus sp.</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.681	0.58	
	Diptera	0.11 <sup>a</sup>	0.16 <sup>a</sup>	0.02 <sup>a</sup>	0.11 <sup>a</sup>	1.93	0.18	
	Cecidomyiidae	0.11 <sup>a</sup>	0.16 <sup>a</sup>	0.02 <sup>a</sup>	0.11 <sup>a</sup>	1.93	0.18	
24	<i>Orselia sp.</i>	0.11 <sup>a</sup>	0.16 <sup>a</sup>	0.02 <sup>a</sup>	0.11 <sup>a</sup>	1.93	0.18	
	THYSANOPTERA	0.05 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	2.29	0.13	
	Thripidae	0.05 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	2.29	0.13	
25	<i>Thrips sp.</i>	0.05 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	2.29	0.13	
	Total Abundance (N)	3.56 <sup>b</sup>	2.6 <sup>ab</sup>	2.35 <sup>a</sup>	2.09 <sup>a</sup>	5.14	0.02	0.34

Note: Value within a row followed by the same letters were not significantly different at  $P < 0.05$  according to Tukey's HSD test



**Figure 4.** Arthropod abundance on paddy surrounded by refugia, vegetables, untreated, and insecticide application

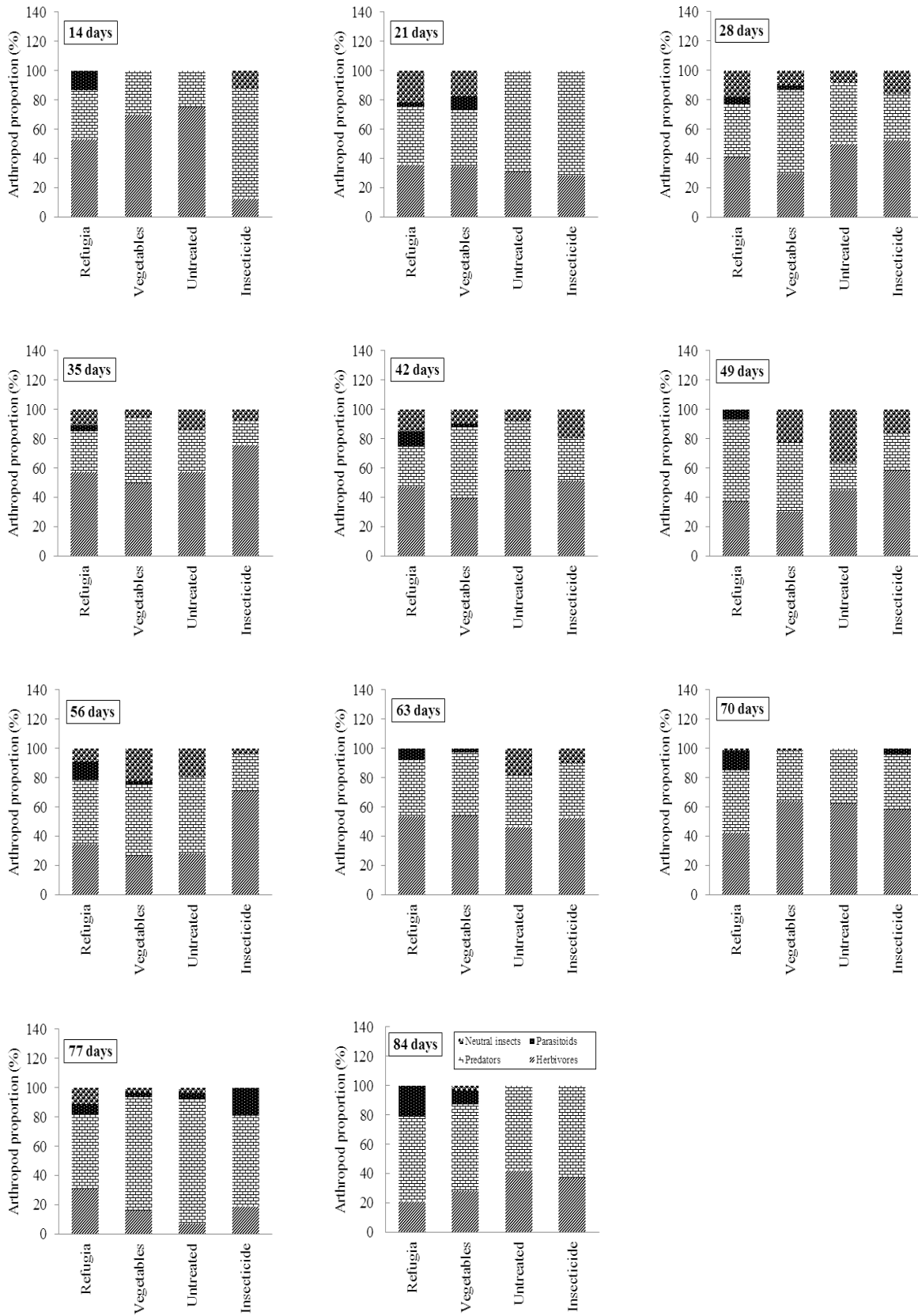


Figure 5. Proportion of arthropods grouped into guilds (herbivore, predator, parasitoid, and neutral insects) on paddy surrounded by refugia, vegetables, untreated, and insecticide application

**Table 2.** Abundance of spiders inhabiting rice surrounded by refugia, vegetables, untreated, and insecticide application

No.	Family and Species	Mean of abundance (individual/nets)				F-value	P value (0.05)	Tukey's HSD test
		Rice-Refugia	Rice-Vegetable	Rice-Untreated	Rice-Insecticide			
	Lycosidae	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.89	0.48	
1	<i>Pardosa pseudoannulata</i>	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.89	0.48	
	Araneidae	0.20 <sup>b</sup>	0.15 <sup>ab</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	7.29	0.01	0.08
2	<i>Araneus inustus</i>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
3	<i>Cylosa insulana</i>	0.05 <sup>a</sup>	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	1.12	0.38	
4	<i>Cyrtophora koronadalensis</i>	0.05 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	2.29	0.13	
5	<i>Neoscona theisi</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
6	<i>Argiope catenulata</i>	0.05 <sup>a</sup>	0.05 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1.14	0.38	
	Tetragnathidae	1.55 <sup>c</sup>	1.55 <sup>c</sup>	0.91 <sup>ab</sup>	0.76 <sup>a</sup>	7.72	0	0.24
7	<i>Tetragnatha javana</i>	0.16 <sup>a</sup>	0.2 <sup>a</sup>	0.15 <sup>a</sup>	0.22 <sup>a</sup>	0.38	0.77	
8	<i>Tetragnatha virescens</i>	0.73 <sup>a</sup>	0.82 <sup>a</sup>	0.51 <sup>a</sup>	0.4 <sup>a</sup>	2.38	0.12	
9	<i>Tetragnatha mandibulata</i>	0.35 <sup>b</sup>	0.22 <sup>ab</sup>	0.16 <sup>ab</sup>	0.11 <sup>a</sup>	4.26	0.03	0.12
10	<i>Tetragnatha ilavaca</i>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
11	<i>Tetragnatha maxillosa</i>	0.16 <sup>a</sup>	0.07 <sup>a</sup>	0.05 <sup>a</sup>	0 <sup>a</sup>	2.18	0.14	
12	<i>Tetragnatha vermiformis</i>	0.09 <sup>ab</sup>	0.22 <sup>b</sup>	0.04 <sup>ab</sup>	0.02 <sup>a</sup>	4.09	0.03	0.12
13	<i>Tetragnatha Okumae</i>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.62	0.62	
14	<i>Tetragnatha iwahigensis</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
15	<i>Tetragnatha natans</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Linyphiidae	0.16 <sup>a</sup>	0.15 <sup>a</sup>	0.05 <sup>a</sup>	0.15 <sup>a</sup>	1	0.43	
16	<i>Bathypantes tagalogensis</i>	0.13 <sup>a</sup>	0.09 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	2.97	0.07	
17	<i>Bathypantes</i> sp.	0 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.05 <sup>a</sup>	0.88	0.48	
18	<i>Erigone bifurca</i>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
19	<i>Enoplognatha</i> sp.	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.83	0.5	
20	Unknown	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Oxyopidae	0.15 <sup>a</sup>	0.11 <sup>a</sup>	0.09 <sup>a</sup>	0.04 <sup>a</sup>	0.8	0.52	
21	<i>Oxyopes javanus</i>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.69	0.58	
22	<i>Oxyopes matiensis</i>	0.09 <sup>a</sup>	0.09 <sup>a</sup>	0.09 <sup>a</sup>	0 <sup>a</sup>	0.73	0.56	
23	<i>Oxyopes pingasus</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Theridiidae	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
24	<i>Theridion</i> sp.	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Salticidae	0.11 <sup>a</sup>	0.09 <sup>a</sup>	0.07 <sup>a</sup>	0.09 <sup>a</sup>	0.13	0.94	
25	<i>Myrmarachne bidentata</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
26	<i>Hyllus maskaranus</i>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.05 <sup>a</sup>	0 <sup>a</sup>	2.11	0.15	
27	<i>Cosmophasis parangpilota</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
28	<i>Cosmophasis</i> sp.	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.82	0.51	
29	<i>Flexipus paykulli</i>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	1	0.43	
30	<i>Harmochirus brachiatus</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.62	0.62	
31	<i>Bianor hotingchiehi</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.62	0.62	
32	<i>Emathis</i> sp.	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
33	Unknown	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
	Hahniidae	0 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	
34	<i>Hahnia tuybaana</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	
	Total Abundance (N)	2.25 <sup>b</sup>	2.09 <sup>b</sup>	1.22 <sup>a</sup>	1.09 <sup>a</sup>	27.51	0	0.17

Note: Values within a row followed by the same letters were not significantly different at P < 0.05 according to Tukey's HSD test

**Table 3.** Abundance of predatory insects inhabiting rice surrounded by refugia, vegetables, untreated, and insecticide application for one planting season

No.	Ordo/ Family/Species	Mean of abundance (individual/nets)				F-value	P value (0.05)	Tukey's HSD test
		Rice-Refugia	Rice-Vegetable	Rice-Untreated	Rice-Insecticide			
	HEMIPTERA	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	1.17	0.36	
	Miridae	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	1.17	0.36	
1	<i>Cyrtorhinus lividipennis</i>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1.46	0.28	
2	<i>Orthotylus</i> sp.	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1.29	0.32	
	COLEOPTERA	1.09 <sup>b</sup>	0.35 <sup>a</sup>	0.67 <sup>ab</sup>	0.29 <sup>a</sup>	12.75	0	0.20
	Carabidae	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
3	<i>Ophionea nigrofasciata</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Staphylinidae	0.27 <sup>a</sup>	0.16 <sup>a</sup>	0.09 <sup>a</sup>	0.11 <sup>a</sup>	2.25	0.14	
4	<i>Paederus fuscipes</i>	0.27 <sup>a</sup>	0.16 <sup>a</sup>	0.09 <sup>a</sup>	0.11 <sup>a</sup>	2.25	0.14	
	Coccinellidae	0.78 <sup>b</sup>	0.16 <sup>a</sup>	0.56 <sup>b</sup>	0.18 <sup>a</sup>	11.72	0	0.19
5	<i>Micraspis inops</i>	0.38 <sup>b</sup>	0.07 <sup>a</sup>	0.25 <sup>ab</sup>	0.15 <sup>ab</sup>	4.8	0.02	0.16
6	<i>Verania lineata</i>	0.04 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
7	<i>Micraspis vincta</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
8	<i>Harmonia octomaculata</i>	0 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
9	<i>Coccinella repanda</i>	0.05 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.99	0.43	
10	<i>Brumoides suturalis</i>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.88	0.48	
11	<i>Menochilus sexmaculatus</i>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
12	Unknown	0.25 <sup>b</sup>	0.07 <sup>ab</sup>	0.16 <sup>ab</sup>	0.04 <sup>a</sup>	3.77	0.04	0.13
	Elateridae	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
13	Unknown	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Anthicidae	0 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.62	0.62	
14	<i>Formicomus</i> sp.	0 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.62	0.62	
	ODONATA	0.04 <sup>a</sup>	0.09 <sup>a</sup>	0.04 <sup>a</sup>	0.05 <sup>a</sup>	0.66	0.59	
	Coenagrionidae	0.04 <sup>a</sup>	0.07 <sup>a</sup>	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0.52	0.68	
15	<i>Agriocnemis</i> sp.	0.02 <sup>a</sup>	0.05 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.47	0.71	
16	<i>Pyrrhosoma</i> sp.	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.38	0.77	
17	<i>Argia</i> sp.	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Libellulidae	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.62	0.62	
18	<i>Pantala</i> sp.	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.00 <sup>a</sup>	1	0.43	
19	Unknown	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
	ORTHOPTERA	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Tettigonidae	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
20	<i>Conocephalus longipennis</i>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	HYMENOPTERA	0.11 <sup>a</sup>	0.65 <sup>b</sup>	0.35 <sup>ab</sup>	0.05 <sup>a</sup>	7.83	0	0.22
	Formicidae	0.11 <sup>a</sup>	0.64 <sup>b</sup>	0.35 <sup>ab</sup>	0.05 <sup>a</sup>	6.48	0.01	0.24
21	<i>Odontoponera transversa</i>	0.09 <sup>a</sup>	0.64 <sup>b</sup>	0.35 <sup>ab</sup>	0.05 <sup>a</sup>	6.71	0.01	0.24
22	<i>Solenopsis</i> sp.	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Syrphidae	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
23	<i>Volucella</i> sp.	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	MANTODEA	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	MANTIDAE	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
24	Unknown	1.33 <sup>b</sup>	1.15 <sup>b</sup>	1.11 <sup>b</sup>	0.42 <sup>a</sup>	15.14	0	0.19
Total Abundance (N)		14.6 <sup>b</sup>	12.7 <sup>b</sup>	12.2 <sup>b</sup>	4.6 <sup>a</sup>	17.00	0.00	0.74

Note: Values within a row followed by the same letters were not significantly different at  $P < 0.05$  according to Tukey's HSD test

Refugia as habitat was capable to provide micro-climate in form of high relative humidity and shady condition that appropriate for natural enemies habitat either predatory arthropods or parasitoids (McCabe *et al.*, 2017). Refugia as habitat was not only required during rice growth in rice field, but also had function as sink for arthropods during rice harvest and would become arthropods source during initial rice planting in rice field (Baba *et al.*, 2018). It was evident that *Zinnia* sp. as habitat was inhabited by spider from families of *Araneidae*, *Oxyopidae* and *Pisauridae* (Desai *et al.*, 2017). Spider (*Oxyopidae*), predatory insects (*Coccinellidae*, *Syrphidae* and *Geocoridae*), parasitoid and pollinating insects from *Hymenoptera* and *Lepidoptera* were found in large numbers which inhabit *T. erecta* as niche (Ganai *et al.*, 2017).

Refugia as niche was capable to provide nectar and pollen as well as preys in form of herbivore or neutral insects. *S. indicum* was capable to provide nectar for parasitoid of rice stem borer (Zhu, 2014a) and natural enemies (Coleoptera, Hymenoptera, Neuroptera and Dictyoptera) (Mahmoud, 2012). *S. indicum* was capable to increase predator capability to prey on herbivores because its nectar and pollen can increase fitness and prey ability of this predator (Zhu, 2014b). Feed in form of nectar and pollen was capable to prolong the longevity of predatory arthropods and parasitoid, even synovigenic-type parasitoid urgently require this feed in order to increase its egg production (Lu *et al.*, 2014; Zhu, 2014a). In addition, refugia existence on rice field embankment that surrounds rice also capable to increase flora species diversity in rice field. The higher the flora species, the higher the fauna species diversity (arthropods) as flora inhabitant (Zhu, 2014b).

**Table 4.** Community characteristics of spiders inhabiting rice surrounded by refugia, vegetables, untreated, and insecticide application for one planting season

Rice age (days)	Community characteristics	Rice-Refugia	Rice-Vegetable	Rice-Untreated	Rice-Insecticide
14	Number of individual (individuals/net)	0.4	0.2	0	1
	Diversity ( $H'$ )	0.69	0	0	0.67
	Dominance (D)	0.5	1	0	0.6
	Evenness (E)	1	0	0	0.97
21	Number of individual (individuals/net)	1.2	1.2	0.8	0.8
	Diversity ( $H'$ )	1.24	0.87	1.04	1.04
	Dominance (D)	0.5	0.67	0.5	0.5
	Evenness (E)	0.90	0.79	1.50	0.95
28	Number of individual (individuals/net)	2	1.8	2	0.8
	Diversity ( $H'$ )	1.64	1.68	1.33	1.04
	Dominance (D)	0.3	0.33	0.4	0.5
	Evenness (E)	0.92	0.94	0.96	0.95
35	Number of individual (individuals/net)	2.4	3	1	0.8
	Diversity ( $H'$ )	1.13	0.88	0.67	1.04
	Dominance (D)	0.5	0.53	0.6	0.5
	Evenness (E)	0.81	0.80	0.97	0.95
42	Number of individual (individuals/net)	2.2	2.6	2.4	1.6
	Diversity ( $H'$ )	1.04	1.31	0.82	1.04
	Dominance (D)	0.45	0.38	0.67	0.5
	Evenness (E)	0.94	0.94	0.75	0.95
49	Number of individual (individuals/net)	3.6	3	1.2	0.2
	Diversity ( $H'$ )	1.57	1.04	0	0
	Dominance (D)	0.39	0.47	1	1
	Evenness (E)	0.87	0.95	0	0
56	Number of individual (individuals/net)	2.6	2	1.2	0.4
	Diversity ( $H'$ )	1.18	0.64	0.69	0
	Dominance (D)	0.62	0.8	0.5	1
	Evenness (E)	0.73	0.58	1	0
63	Number of individual (individuals/net)	2.2	2.4	1	1.4
	Diversity ( $H'$ )	1.64	1.20	1.33	0.96
	Dominance (D)	0.36	0.5	0.4	0.57
	Evenness (E)	1.02	0.86	0.96	0.87
70	Number of individual (individuals/net)	3.2	2.2	1.2	1.2
	Diversity ( $H'$ )	1.72	1.47	0.64	1.56
	Dominance (D)	0.31	0.36	0.67	0.33
	Evenness (E)	0.88	0.91	0.92	0.97
77	Number of individual (individuals/net)	1.85	1.8	1.2	1
	Diversity ( $H'$ )	0.98	0.89	0.97	0.96
	Dominance (D)	0.22	0.44	0.33	0.4
	Evenness (E)	0.98	0.89	0.97	0.96
84	Number of individual (individuals/net)	3.2	2.8	1.4	2.85
	Diversity ( $H'$ )	2.06	1.77	0.80	1.58
	Dominance (D)	0.31	0.36	0.71	0.49
	Evenness (E)	0.90	0.91	0.72	0.81
Total	Number of individual (individuals/net)	24.85	23	13.4	12.05
	Diversity ( $H'$ )	2.47	2.22	1.99	2.05
	Dominance (D)	0.32	0.39	0.42	0.37
	Evenness (E)	0.77	0.73	0.75	0.76

**Table 5.** Community characteristics of predatory insects inhabiting rice surrounded by refugia, vegetables, untreated, and insecticide application for one planting season

Rice age (days)	Community characteristics	Rice-Refugia	Rice-Vegetable	Rice-Untreated	Rice-Insecticide
14	Number of individual (individuals/net)	0.6	0.5	0.2	0.2
	Diversity ( $H'$ )	0.64	0	0	0
	Dominance (D)	0.7	1	1	1
	Evenness (E)	0.92	0	0	0
21	Number of individual (individuals/net)	1	0.6	1	0.2
	Diversity ( $H'$ )	0.50	0.6	1.05	0
	Dominance (D)	0.8	0.67	0.40	1
	Evenness (E)	0.72	0.92	0.96	0
28	Number of individual (individuals/net)	0.8	1.6	0	0.4
	Diversity ( $H'$ )	0.56	0.74	0	0.69
	Dominance (D)	0.81	0.67	0	1
	Evenness (E)	0.75	0.75	0	0.50
35	Number of individual (individuals/net)	0.2	0.2	0.6	0
	Diversity ( $H'$ )	0	0	0	0
	Dominance (D)	1	1	1	0
	Evenness (E)	0	0	0	0
42	Number of individual (individuals/net)	0.8	1.6	0	0.2
	Diversity ( $H'$ )	0.56	1.26	0	0
	Dominance (D)	0.75	0.38	0	1
	Evenness (E)	0.81	0.91	0	0
49	Number of individual (individuals/net)	1.2	0.4	0	1
	Diversity ( $H'$ )	0	0	0	0
	Dominance (D)	1	1	0	1
	Evenness (E)	0	0	0	0
56	Number of individual (individuals/net)	2.2	2.4	3.6	0.8
	Diversity ( $H'$ )	1.34	0.57	1.38	0
	Dominance (D)	0.36	0.83	0.56	1
	Evenness (E)	0.97	0.52	0.77	0
63	Number of individual (individuals/net)	1.8	0.8	1	0
	Diversity ( $H'$ )	1.74	0.56	0	0
	Dominance (D)	0.22	0.75	1	0
	Evenness (E)	0.97	0.81	0	0
70	Number of individual (individuals/net)	1.4	0.6	1.4	0.6
	Diversity ( $H'$ )	0.96	0.64	0.6	0.64
	Dominance (D)	0.57	0.67	0.71	0.67
	Evenness (E)	0.87	0.92	0.86	0.92
77	Number of individual (individuals/net)	2.8	3	3.6	1
	Diversity ( $H'$ )	0.76	0	1.04	1.33
	Dominance (D)	0.71	1	0.5	0.4
	Evenness (E)	0.69	0	0.75	0.96
84	Number of individual (individuals/net)	1.8	1	0.8	0.2
	Diversity ( $H'$ )	1.89	1.33	1.39	0
	Dominance (D)	0.22	0.4	0.25	1
	Evenness (E)	0.97	0.96	1	0
Total	Number of individual (individuals/net)	14.6	12.7	12.2	4.6
	Diversity ( $H'$ )	2.12	1.61	2.06	1.74
	Dominance (D)	0.29	0.55	0.31	0.35
	Evenness (E)	0.76	0.65	0.76	0.84

This research showed that abundance and species diversity of spider and predatory insects on rice surrounded by refugia and vegetables were high and tend to have higher community similarity for spiders and predatory insects than that of other plots. Vegetables (*C. sativus*, *V. sinensis*, *L. acutangula* and *M. charantia*) have flowers that capable to provide nectar and pollen, but information related to arthropods that associate with flower on vegetables is not much. Lami *et al.* (2016) reported that predatory insects, such as ladybird beetles occurred during maize flowering in Northern and Central Italy. During this research period, flowers from the four vegetables were frequently alight by community of pollinating insects, spiders, predatory insects and parasitoids of herbivores. Arthropods inhabiting those vegetables generally were *M. sexmaculatus*, *P. fuscipes*, *Tetragnatha* spp., and *A. catenulata* which found on rice field in this research.

Abundance and species diversity of spiders and predatory insects on rice sprayed with synthetic insecticide were the lowest because toxic from the insecticide can kill several arthropods species. This toxic not only kill herbivore, but also

spider, predatory insects (Ngin *et al.*, 2017), parasitoid (Svobodová *et al.*, 2017), and pollinating insects (Sgolastra *et al.*, 2016). Synthetic insecticide spraying can also slow down colonization of spider and predatory insects on those plots and can cause these natural enemies migration to other plots that are not sprayed with synthetic insecticide (Lopes *et al.*, 2017).

Finally, the results of this study indicate that the most abundant predatory arthropods (spiders and predatory insects) was found on rice surrounded by refugia flower and vegetables. The highest species diversity for spiders and predatory insects was also found on rice surrounded by the refugia and vegetables. Therefore, rice surrounded by the refugia and vegetables was the most appropriate for habitat and niche of predatory arthropods. Thus, the refugia and vegetables should be planted along rice field embankment to conserve those useful arthropods.

## ACKNOWLEDGEMENTS

This research was supported financially by Program of Professor Research Grant of Universitas Sriwijaya, Ministry of Research, Technology and Higher Education, Republic of Indonesia with budget year of 2018, Contract Number: 0006/UN9/SK.LP2M.PT/2018, 5 June 2018 chaired by Siti Herlinda.

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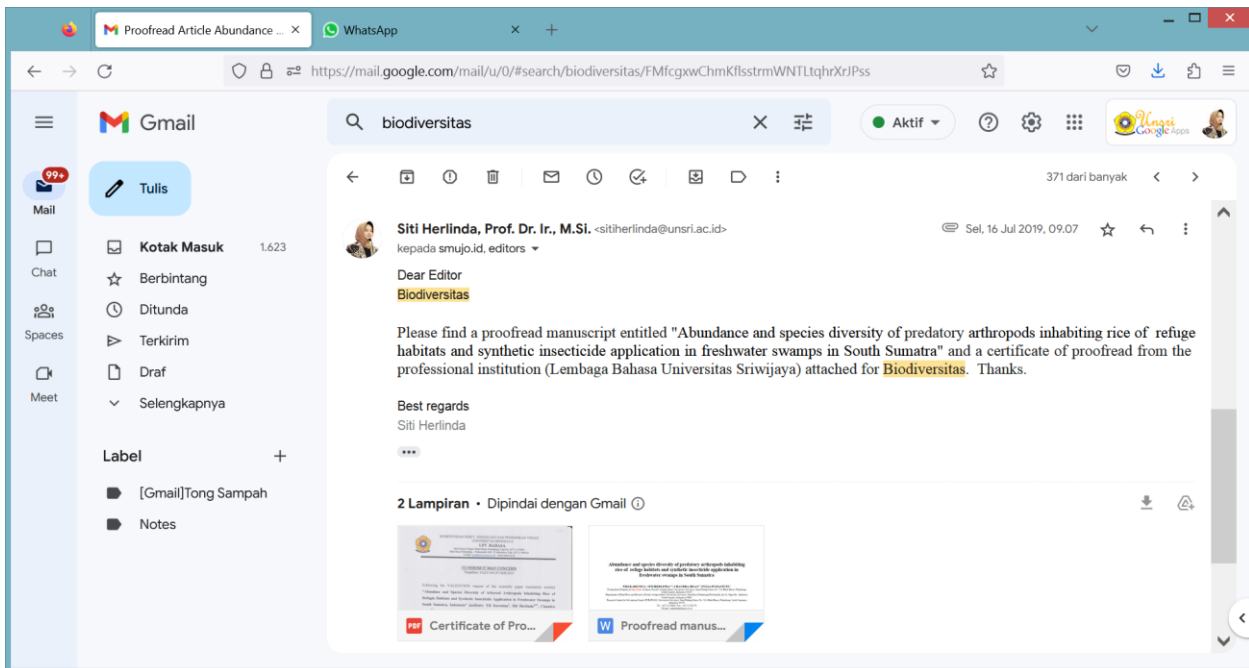
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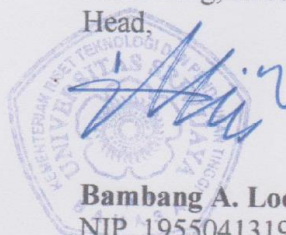
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Following the VALIDATION request of the scientific paper translation entitled “**Abundance and Species Diversity of Arboreal Arthropods Inhabiting Rice of Refugia Habitats and Synthetic Insecticide Application in Freshwater Swamps in South Sumatra, Indonesia**” (authors: Tili Karenina<sup>1</sup>, Siti Herlinda<sup>2,3\*</sup>, Chandra Irsan<sup>2,3</sup>, and Yulia Pujiastuti<sup>2,3</sup>) from the original version of Indonesian to English, UPT Bahasa Universitas Sriwijaya, hereby verifies that after comparing and examining both papers (Indonesian and English versions), and by providing some input, states that the translation has a similar meaning and is in accordance with the original version, so it can be used.

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**Abundance and species diversity of predatory arthropods inhabiting rice of refuge habitats and synthetic insecticide application in freshwater swamps in South Sumatra**

TILI KARENINA<sup>1</sup>, SITI HERLINDA<sup>2,3\*</sup>, CHANDRA IRSAN<sup>2,3</sup>, YULIA PUJIASTUTI<sup>2,3</sup>

<sup>1</sup>Postgraduate Program of Agriculture Sciences, Faculty of Agriculture, Universitas Sriwijaya, Jalan Padang Selasa No. 524, Bukit Besar, Palembang, South Sumatra, Indonesia 30139

<sup>2</sup>Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Sriwijaya, Jalan Raya Palembang-Prabumulih, km 32, Ogan Ilir, Indralaya, South Sumatra, Indonesia 30662

<sup>3</sup>Research Center for Sub-optimal Lands (PUR-PLSO), Universitas Sriwijaya, Jalan Padang Selasa No. 524, Bukit Besar, Palembang, South Sumatra, Indonesia 30139

Tel.: +62711580663, Fax.: +62711580276

\*E-mail: sitiherlinda@unsri.ac.id

Manuscript received: 1 June 2019. Revision accepted: ..... 2019

**Abstract.** Rice cultivation in freshwater swamps in Indonesia is specific, among other things, there is no synthetic pesticide spraying and vegetable growing on rice field embankments. This specific cultivation technique can affect the abundance and diversity of rice-dwelling arthropods species. The study aimed to compare the abundance and species diversity of predatory arthropods inhabiting rice surrounded both by refugia and vegetables and by those being applied with synthetic insecticide in rice field of freshwater swamps. This study used rice plots surrounded by refugia flower (*Zinnia* sp., *Tagetes erecta*, *Cosmo caudatus*, and *Sesamum indicum*); vegetables (*Cucumis sativus*, *Vigna sinensis*, *Luffa acutangula* and *Momordica charantia*); untreated; and synthetic insecticide. Twenty five herbivore species of 12 families, 34 spider species of 8 families, and 24 species of predatory insects of 12 families were found on rice during a planting season. The lowest herbivore population and spider abundance were found on synthetic insecticide sprayed rice and they were significantly different from those of refugia-rice plots. The most abundant spiders and predatory insects were found on rice surrounded by refugia and were not significantly different from those of rice surrounded by vegetables. The highest species diversity for spiders and predatory insects was found on rice surrounded by refugia, whereas the lowest species diversity was found on synthetic pesticide sprayed rice. Therefore, rice surrounded by refugia flowers and vegetables was the most appropriate for habitat and niche of predatory arthropods.

**Key words:** Herbivore, neutral insect, parasitoid, predatory insect, spider

**Running title:** Species diversity of predatory arthropods

## INTRODUCTION

Cultivation of rice (*Oryza sativa*) in freshwater swamps in Indonesia is specific, i.e. the planting season is from April to September in a year. Rice is planted by using transplanting method, i.e. starting from seedling and then transplanted to rice field (Lakitan *et al.*, 2018a,b). Rice seedling can be carried out with three patterns consisting of floating raft seedling, 'samir' method and digging ('tugal') method (Herlinda *et al.*, 2018a; Lakitan *et al.*, 2018b). Subsequently, seedlings of 7–10 days old are transplanted into rice field. Rice pest control in freshwater swamp generally does not use synthetic insecticide (Herlinda *et al.* 2018b; Safitri *et al.* 2018), whereas weeds control is carried out without using herbicide but by using manual method through pulling out by hand or weeding by using sickle. In addition, rice field embankments are usually planted with flowering seasonal vegetables, such as long beans (*Vigna sinensis*), cucumber (*Cucumis sativus*), bitter melon (*Momordica charantia*) and squash (*Luffa acutangula*).

This specific rice cultivation in freshwater swamps affects arthropod communities. Species richness and abundance of spiders on rice in freshwater swamps are higher than those of rice in tidal lowlands of South Sumatra because farmers in the freshwater swamps do not apply synthetic insecticide (Herlinda *et al.*, 2018a). Application of synthetic insecticide can decrease the abundance and species diversity of predators and parasitoids (Ngin *et al.*, 2017; Svobodová *et al.*, 2017).

In addition to synthetic insecticide application, flora in the vicinity of rice can affect arthropod community (Cao *et al.*, 2004; Lopes *et al.*, 2017; Xu *et al.* 2017; Baba *et al.*, 2018). Wild plants, refugia, and vegetables planted at rice field embankment can provide niche and habitat for arthropods as natural enemies of rice pest insects (Zhu *et al.*, 2014a; Hasan *et al.*, 2016; McCabe *et al.*, 2017). Nectar and pollen on those crops and plants can increase longevity, fecundity, and function of natural enemies (Desai *et al.*, 2017; Foti *et al.*, 2017; Ganai *et al.*, 2017; Lu *et al.*, 2014). Some of refugia were utilized for natural enemy conservation on rice, for instance *Zinnia* sp. becomes niche and habitat for spiders, *Argiope aemula*, *Oxyopes* sp., and *Perenethis* sp. (Desai *et al.*, 2017). *Tagetes erecta* was inhabited by *Oxyopes javanus*, *Coccinella septempunctata*, *Syrphus* spp., *Geocoris* spp., *Apis dorsata*, *Apis mellifera* and *Vanessa cardui* (Ganai *et al.*, 2017). Refugia species of *Antigonon leptopus*, *Cassia cobanensis*, *Turnera subulata*, and *Antigonon leptopus* were used for natural enemies conservation of oil palm pests (Dutton *et al.*, 2016; Kamarudin and Arshad, 2016; Saleh and Siregar, 2017). The effort to utilize refugia flower for predatory arthropod conservation in freshwater swamps of rice ecosystems in Indonesia has not yet been done. Therefore, this research aimed to compare the abundance and species diversity of predatory arthropods inhabiting rice of refuge habitats and synthetic insecticide application in freshwater swamps.

## MATERIALS AND METHODS

This research was conducted in rice field of freshwater swamps in Pelabuhan Dalam Village, Pemulutan Subdistrict, Ogan Ilir District, South Sumatra Province from May to August 2018. The selected rice field is rice center and its area is around 7.1 Mha that had flooding season from October to March and dry season from April to September.

### Field preparation and treatments

This stage consisted of land preparation and soil tillage, seedling, planting, and rice maintenance. Land preparation started with weeds clearance followed by soil tillage and application of manure fertilizer at a dose of 1 ton.ha<sup>-1</sup>. Rice seeds used in this research were certified Mekongga variety. Before seedling, seeds were broiled for 1 x 24 hours and then sowed within tray (size of 36 cm x 27 cm x 4,5 cm) for 14 days (Figure 1). The next step was that the seedlings were transported to the rice field and transplanted.

The rice was planted by using lined up system ('*jajar legowo*' 2:1) with planting distance of 50 cm x 25 cm x 12.5 cm. All of rice plot treatments were fertilized with liquid compost extract once in two weeks at a dose of 2 L.ha<sup>-1</sup> and the manure fertilizer at a dose of 1 ton.ha<sup>-1</sup>. Compost extract was produced according to the method of Suwandi *et al.* (2012).

Treatment plots were designed into four treatments (four plots) which consisted of rice plots surrounded by 1) refugia, 2) vegetables, 3) untreated (without refugia, vegetable or insecticide), and 4) control sprayed with synthetic insecticide, respectively. Every plot had an area of 800 m<sup>2</sup>, and was divided into five sub-plots as replications.

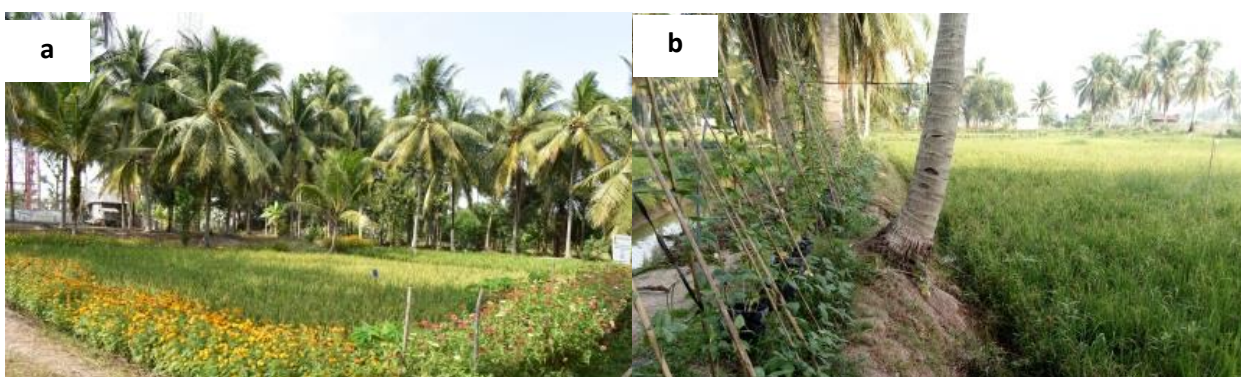


**Figure 1.** Field preparation: seeds broiled for 1 x 24 hours (a), seeds sowed within trays (b), rice transplanted by using '*jajar legowo*' 2:1 (c, d)

Refugia and vegetable planting was conducted 30 days prior to rice planting so that refugia got bloomed when rice entered a vegetative stage at 14 days after transplanting (dat). The rice plots surrounded by refugia used four species of refugia flower consisting of zinnia or paper flower (*Zinnia sp.*), tagetes (*Tagetes erecta*), thinkin (*Cosmo caudatus*), and sesame (*Sesamum*) (Figure 2). The rice plots surrounded by vegetables used four seasonal vegetable species consisting of long beans (*V. sinensis*), cucumber (*C. sativus*), bitter melon (*M. charantia*), and squash (*L. acutangula*) planted at the rice field embankment. The vegetable planting distance (distance between planting holes) was as follows: 30 cm, 60 cm, 30 cm, and 40 cm for long beans, bitter melon, squash, and cucumber respectively. The refugia planting distance (distance between planting holes) was 15 cm, but refugia had two rows planting at rice field embankments. The rice untreated plots (without refugia, vegetables, and insecticide application) was the one having no plants in the vicinity of rice field embankments, whereas the rice plots sprayed with synthetic insecticide were also not surrounded by refugia or vegetables (Figure 2). The synthetic insecticide used in this research had abamectine active ingredient according to the recommended dose.

### Arthropods sampling

Arthropod sampling was conducted every week for one planting season and started when rice reached the age of 14 until 84 days after transplanting (11 observations). The arthropods sampling was carried out at early morning from 06.00 to 07.00 a.m. The arthropods were collected using sweep nets (net handgrip length of 100 cm, length of 75 cm and diameter of 30 cm) based on the methods of Jayakumar and Sankari (2010) and Janzen (2013). Swinging net was purposively touched on rice stem according to the method of Masika *et al.* (2017) in order to drag insects that attached on the rice stems and leaves at rice lower canopy. The arthropods were collected by swinging net once by using double swings that form a straight line at depth of 30 cm toward the rice canopy interior.



**Figure 2.** Plots for treatments: rice surrounded by refugia (a), vegetables (b), untreated (c), and insecticide application (d)

The caught arthropods were subsequently cleaned and put into plastic vials containing 70% alcohol, labelled, and taken to the Entomology Laboratory, Department of Plant Pest and Diseases, Faculty of Agriculture, Universitas Sriwijaya, South Sumatra, Indonesia for identification by Dr. Chandra Irsan, an insect taxonomist. The spider visual identification was conducted by using reference of Barrion and Litsinger (1995) and insect visual identification was conducted by using the references of Heinrichs (1994), Kalshoven (1981), and McAlpine *et al.* (1987). All the identified arthropods were grouped into guilds and their number of individuals of each species was counted.

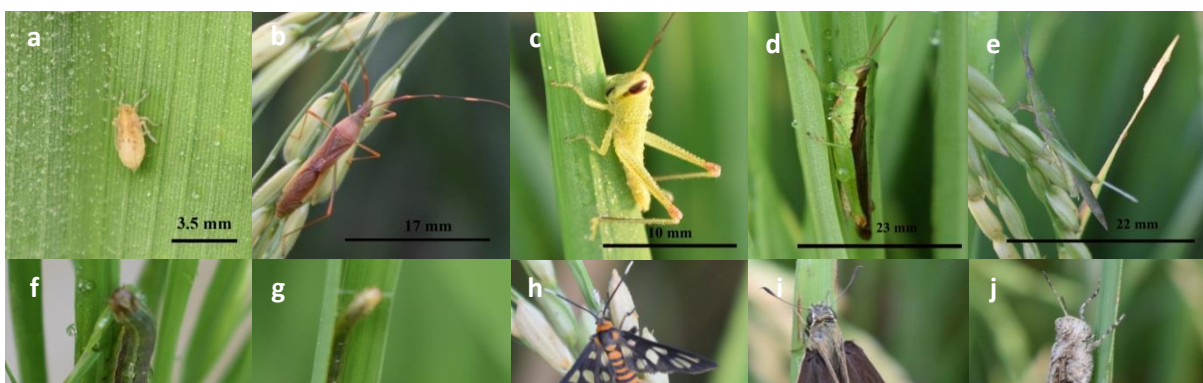
#### Data analysis

Data of abundance (or number of individuals) of herbivores, spiders, and predatory insects among the treatments were analyzed by using analysis of variance (ANOVA). If there were differences among the data of each treatment, they were separated using Tukey's Honestly Significant Different (HSD) test at 5%. The data analysis was calculated using program software of SAS University Edition 2.7 9.4 M5. The data of arthropod abundance were also used to analyze the species diversity by using Shannon index ( $H'$ ). The diversity level was also evaluated by the Evenness index ( $J'$ ) derived from the Shannon function, and Berger-Parker dominance biodiversity indices. Data of arthropod abundance were also subsequently grouped according to guild consisting of herbivore (or phytophagous insects), predator, parasitoid, and neutral insects, and reported graphically.

## RESULTS AND DISCUSSION

#### Arthropods species

Twenty five herbivore species of 12 families were found during one planting season of rice. The most dominant herbivore found in this research were *Nilaparvata lugens*, *Leptocorisa acuta*, *Valanga nigricornis*, *Oxya chinensis*, and *Acrida turita* (Figure 3). Spiders having 34 species of eight families were dominated by *Tetragnatha virescens*, *T. javana*, *T. mandibulata*, *T. maxillosa*, and *Argiope catenulata*. Predatory insects having 24 species of 12 families were also found in this research and the dominant species of predatory insects were *Odontoponera transversa*, *Micrapis inops*, *Menochilus sexmaculatus*, *Paederus fuscipes*, and *Conocephalus longipennis*.



**Figure 3.** Dominant arthropod species found on the rice field: *Nilaparvata lugens* (a), *Leptocorisa acuta* (b), *Valanga nigricornis* (c), *Oxya chinensis* (d), *Acrida turita* (e), *Spodoptera* sp. (f), *Cnaphalocrosis medinalis* (g), *Amata nigriceps* (h), *Pelopidas* sp. (i), *Tetrix subulata* (j), *Tetragnatha virescens* (k), *T. mandibulata* (l), *T. javana* (m), *T. maxillosa* (n), *Argiope catenulata* (o), Araneidae (p), *Oxyopes matiensis* (q), *O. javanus* (r), Salticidae (s), *Pardosa pseudoannulata* (t), *Odontoponera transversa* (u), *Micrapis inops* (v), *Menochilus sexmaculatus* (w), *Paederus fuscipes* (x), *Conocephalus longipennis* (y), *Ophionea nigrofasciata* (z), *Agriocnemis* sp. (aa), *Argia* sp. (ab), *Pantala* sp. (ac), and *Volucella* sp. (ad)

### Herbivore abundance

The highest abundance or population of *N. lugens*, *S. furcifera*, *L. acuta*, *S. litura* and *A. turruta* during one planting season was found on rice surrounded by refugia and significantly different from the population of those on rice sprayed with synthetic insecticide (Table 1). The highest population of the families of *Delphacidae*, *Alydidae*, *Noctuidae*, and *Acrididae* was found on rice surrounded by refugia, whereas the lowest population was found on rice sprayed with synthetic insecticide. The application of synthetic insecticide during vegetative stage of rice significantly decreased the herbivore population.

When the rice reached the age of 14–28 days after transplanting, the herbivore population was still lower on the rice sprayed with synthetic insecticide than that of other treatment plots (Figure 4). After this period, the herbivore population tended to increase on the rice sprayed with synthetic insecticide. Whereas on the other plots (refugia, vegetables, and untreated), the population of herbivore tended to decrease continuously and even when the rice reached the age of 49–56 days after transplanting the rice surrounded by refugia and vegetables, the abundance of predatory arthropods was higher than that of herbivore population.

### Abundance of spider and predatory insects

The highest abundance of *T. mandibulata*, *T. vermiformis*, and *Bathyphantes tagalogensis* was found on the rice surrounded by refugia and vegetables and it was significantly different from those on the rice sprayed with synthetic insecticide and untreated rice (Table 2). The total number of spider abundance was also higher on the rice surrounded by refugia and vegetables. The abundance of predatory insects of *Coccinelidae*, especially *Micraspis inops*, was higher on the rice surrounded by refugia and untreated rice, and it was significantly different from the abundance of rice plots sprayed with synthetic insecticide and the ones surrounded by refugia and vegetables (Table 3). However, the total number of predatory insect abundance was higher on the rice surrounded by refugia, vegetables, and untreated rice, and it was significantly different from those sprayed with synthetic insecticide.

### Species diversity of predatory arthropods

At 14 up to 84 days after transplanting, the spider species diversity on the rice surrounded by refugia tended to be higher than that of other rice plots (Table 4). From the initial to final observation, the total magnitude showed that the highest spider abundance was found on the rice surrounded by refugia, whereas the lowest one was found on the one sprayed with synthetic insecticide. The similar trend was also found on a species diversity of predatory insects which tended to be high on the rice surrounded by refugia, whereas a lower species diversity was found on that sprayed with synthetic insecticide (Table 5).

### Comparison of arthropod abundance according to guilds

At 14 days after transplanting, the lowest herbivore abundance was found on the rice sprayed with synthetic insecticide, whereas a higher herbivore abundance was found on other plots (Figure 4). At 21 up to 28 days after transplanting, the abundance of predatory arthropods was higher than that of parasitoids and herbivores. The peak increase of herbivore abundance and the decrease of predatory insects abundance occurred to the rice from 35 to 42 days after transplanting and subsequently predatory arthropod abundance started to increase and it was higher than herbivore abundance. Prior to the harvest at 75 to 84 days after transplanting, the abundance of predatory arthropods sharply increased and the herbivore abundance drastically decreased. The arthropod abundance (herbivores, predators, parasitoids, and neutral insects) on the rice surrounded by refugia tended to be higher than that of other treatment plots, whereas the lowest abundance tended to be found on the rice plots sprayed with synthetic insecticide.

The initial observation period at 14 to 21 days after transplanting showed that the herbivore proportion on the rice sprayed with synthetic insecticide was lower than the proportion of predators, parasitoids and neutral insects. Whereas the highest herbivore proportion was found on the rice surrounded by refugia (Figure 5). Subsequently, herbivore proportion on the rice sprayed with synthetic insecticide continually increased and got higher than the predator proportion. However, the predator and parasitoid proportion on the rice surrounded by refugia and vegetable continually increased and got higher than the herbivore proportion up to before the harvest.

### Discussion

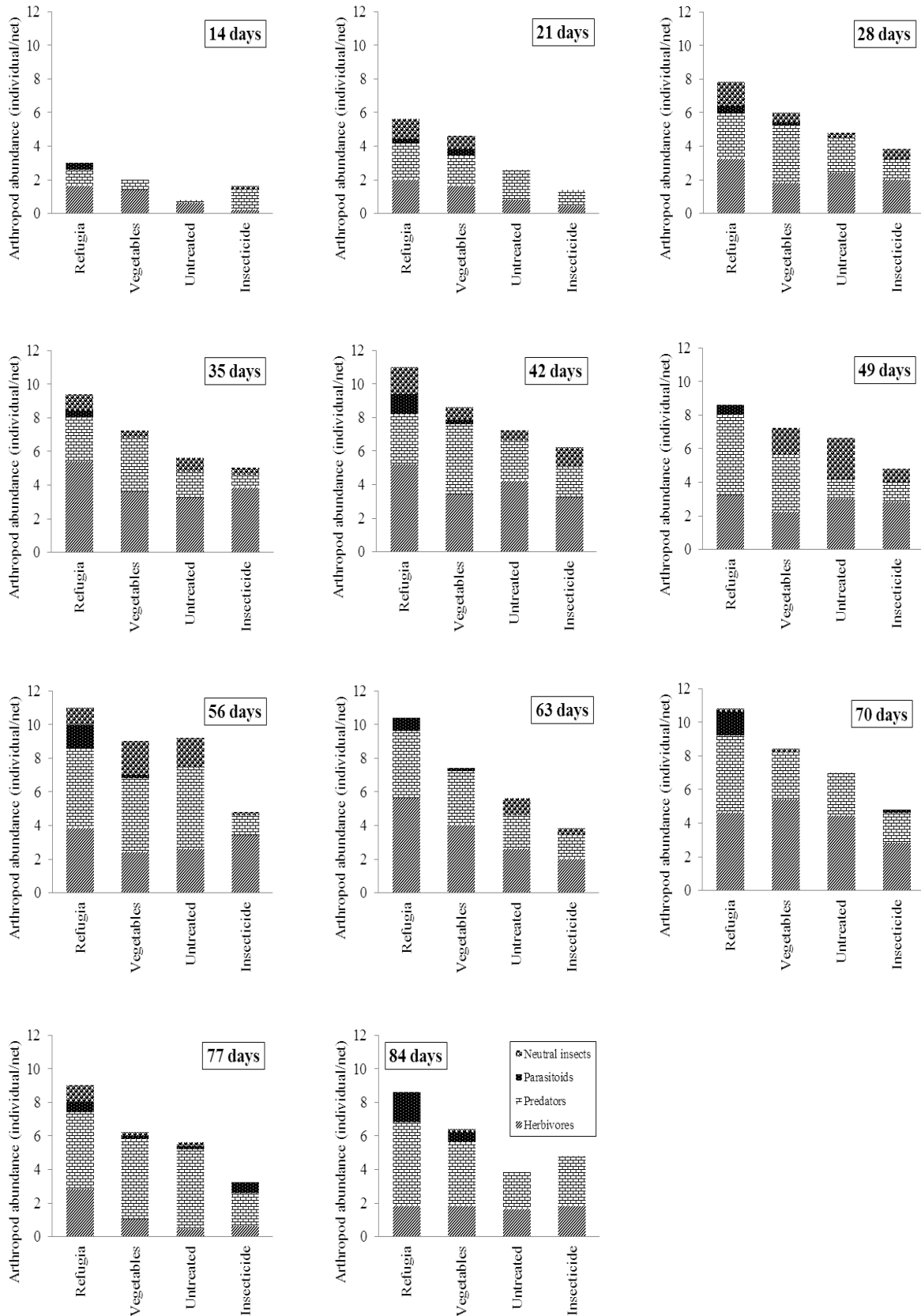
This research results showed that refugia and vegetables planted on rice field embankments surrounded by the rice were capable of increasing the abundance and species diversity of predatory arthropods (spiders and predatory insects) on the rice plot, whereas synthetic insecticide application did not only suppress herbivore population, but also decreased the abundance of natural enemies of pest insects and other useful arthropods, such as spiders, predatory insects, parasitoids, neutral insects or pollinating insects.



**Table 1.** Population or abundance of herbivores inhabiting the rice plot surrounded by refugia, vegetables, untreated, and insecticide application

No.	Ordo/ Family/Species	Mean of population (individual/nets)				F-value	P value (0.05)	Tukey's HSD test
		Rice-Refugia	Rice-Vegetable	Rice-Untreated	Rice-Insecticide			
	HEMIPTERA	1.58 <sup>b</sup>	1.16 <sup>ab</sup>	0.75 <sup>a</sup>	0.78 <sup>a</sup>	5.84	0.01	0.27
	Delphacidae	0.95 <sup>b</sup>	0.69 <sup>ab</sup>	0.51 <sup>ab</sup>	0.25 <sup>a</sup>	5.01	0.02	0.26
1	<i>Nilavarpata lugens</i>	0.8 <sup>b</sup>	0.62 <sup>ab</sup>	0.47 <sup>ab</sup>	0.18 <sup>a</sup>	3.61	0.05	0.29
2	<i>Sogatella furcifera</i>	0.15 <sup>a</sup>	0.07 <sup>a</sup>	0.04 <sup>a</sup>	0.07 <sup>a</sup>	1.08	0.39	
	Cicadellidae	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
3	<i>Cicadulina bipunctata</i>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Coreidae	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.62	0.62	
4	<i>Cletus trigonus</i>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.62	0.62	
	Alydidae	0.64 <sup>b</sup>	0.44 <sup>ab</sup>	0.22 <sup>a</sup>	0.49 <sup>ab</sup>	5.50	0.01	0.17
5	<i>Leptocoris acuta</i>	0.64 <sup>b</sup>	0.44 <sup>ab</sup>	0.22 <sup>a</sup>	0.49 <sup>ab</sup>	5.50	0.01	0.17
	LEPIDOPTERA	0.22 <sup>a</sup>	0.27 <sup>a</sup>	0.27 <sup>a</sup>	0.11 <sup>a</sup>	1.05	0.41	
	Noctuidae	0.05 <sup>a</sup>	0.18 <sup>b</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	6.66	0.01	0.08
6	<i>Spodoptera sp.</i>	0.05 <sup>ab</sup>	0.15 <sup>b</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	5.97	0.01	0.06
7	<i>Naranga sp.</i>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.68	0.58	
	Pyralidae	0.07 <sup>a</sup>	0.05 <sup>a</sup>	0.09 <sup>a</sup>	0.09 <sup>a</sup>	0.26	0.85	
8	<i>Cnaphalocrosis medinalis</i>	0.05 <sup>a</sup>	0.05 <sup>a</sup>	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0.11	0.95	
9	<i>Scirpophaga incertulas</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.05 <sup>a</sup>	0.05 <sup>a</sup>	1.62	0.24	
	Erebidae	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0.13 <sup>a</sup>	0 <sup>a</sup>	1.21	0.35	
10	<i>Amata nigriceps</i>	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0.13 <sup>a</sup>	0 <sup>a</sup>	1.21	0.35	
	Hesperiidae	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
11	<i>Pelopidas sp.</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Nymphalidae	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	
12	<i>Melanitis leda</i>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	
	COLEOPTERA	0.09 <sup>a</sup>	0.11 <sup>a</sup>	0.07 <sup>a</sup>	0.05 <sup>a</sup>	0.17	0.92	
	Chrysomelidae	0.09 <sup>a</sup>	0.11 <sup>a</sup>	0.07 <sup>a</sup>	0.05 <sup>a</sup>	0.17	0.92	
13	<i>Chrysolina coeruleans</i>	0.07 <sup>a</sup>	0.04 <sup>a</sup>	0.07 <sup>a</sup>	0.00 <sup>a</sup>	0.63	0.61	
14	<i>Dactylispa bayoni</i>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
15	<i>Chaetocnema sp.</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
16	<i>Di cladispa armigera</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
17	<i>Aulacophora frontalis</i>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.88	0.48	
18	<i>Charidotella sp.</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	ORTHOPTERA	1.51 <sup>b</sup>	0.89 <sup>a</sup>	1.24 <sup>ab</sup>	1.04 <sup>ab</sup>	3.63	0.05	0.22
	Tettigonidae	0 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
19	<i>Tetrix subulata</i>	0 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Acrididae	1.49 <sup>b</sup>	0.89 <sup>a</sup>	1.16 <sup>ab</sup>	1.04 <sup>ab</sup>	3.64	0.04	0.21
20	<i>Valanga nigricornis</i>	1.18 <sup>a</sup>	0.69 <sup>a</sup>	1.15 <sup>a</sup>	0.87 <sup>a</sup>	2.29	0.13	
21	<i>Oxya chinensis</i>	0.2 <sup>a</sup>	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.11 <sup>a</sup>	1.67	0.23	
22	<i>Acrida turrata</i>	0.11 <sup>b</sup>	0.13 <sup>b</sup>	0.00 <sup>a</sup>	0.05 <sup>ab</sup>	6.11	0.01	0.06
	Gryllidae	0.02 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	
23	<i>Gryllus sp.</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.681	0.58	
	Diptera	0.11 <sup>a</sup>	0.16 <sup>a</sup>	0.02 <sup>a</sup>	0.11 <sup>a</sup>	1.93	0.18	
	Cecidomyiidae	0.11 <sup>a</sup>	0.16 <sup>a</sup>	0.02 <sup>a</sup>	0.11 <sup>a</sup>	1.93	0.18	
24	<i>Orselia sp.</i>	0.11 <sup>a</sup>	0.16 <sup>a</sup>	0.02 <sup>a</sup>	0.11 <sup>a</sup>	1.93	0.18	
	THYSANOPTERA	0.05 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	2.29	0.13	
	Thripidae	0.05 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	2.29	0.13	
25	<i>Thrips sp.</i>	0.05 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	2.29	0.13	
	Total Abundance (N)	3.56 <sup>b</sup>	2.6 <sup>ab</sup>	2.35 <sup>a</sup>	2.09 <sup>a</sup>	5.14	0.02	0.34

Note: Values within a row followed by the same letters were not significantly different at  $P < 0.05$  according to Tukey's HSD test



**Figure 4.** Arthropod abundance on the rice plot surrounded by refugia, vegetables, untreated, and insecticide application

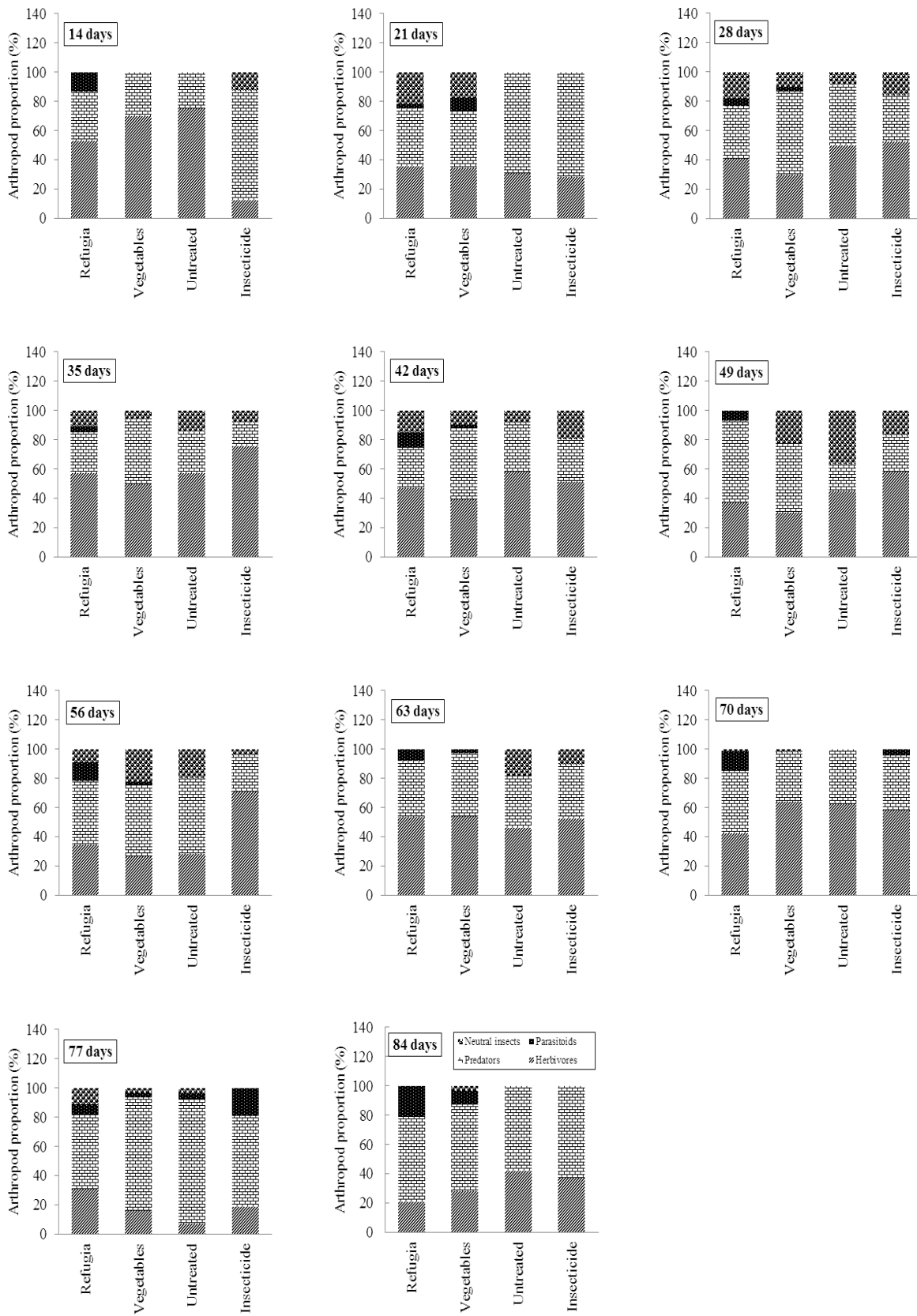


Figure 5. Proportion of arthropods grouped into guilds (herbivore, predator, parasitoid, and neutral insects) on the rice plot surrounded by refugia, vegetables, untreated, and insecticide application

**Table 2.** Abundance of spiders inhabiting the rice plot surrounded by refugia, vegetables, untreated, and insecticide application

No.	Family and Species	Mean of abundance (individual/nets)				F-value	P value (0.05)	Tukey's HSD test
		Rice-Refugia	Rice-Vegetable	Rice-Untreated	Rice-Insecticide			
	Lycosidae	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.89	0.48	
1	<i>Pardosa pseudoannulata</i>	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.89	0.48	
	Araneidae	0.20 <sup>b</sup>	0.15 <sup>ab</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	7.29	0.01	0.08
2	<i>Araneus inustus</i>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
3	<i>Cylosa insulana</i>	0.05 <sup>a</sup>	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	1.12	0.38	
4	<i>Cyrtophora koronadalensis</i>	0.05 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	2.29	0.13	
5	<i>Neoscona theisi</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
6	<i>Argiope catenulata</i>	0.05 <sup>a</sup>	0.05 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1.14	0.38	
	Tetragnathidae	1.55 <sup>c</sup>	1.55 <sup>c</sup>	0.91 <sup>ab</sup>	0.76 <sup>a</sup>	7.72	0	0.24
7	<i>Tetragnatha javana</i>	0.16 <sup>a</sup>	0.2 <sup>a</sup>	0.15 <sup>a</sup>	0.22 <sup>a</sup>	0.38	0.77	
8	<i>Tetragnatha virescens</i>	0.73 <sup>a</sup>	0.82 <sup>a</sup>	0.51 <sup>a</sup>	0.4 <sup>a</sup>	2.38	0.12	
9	<i>Tetragnatha mandibulata</i>	0.35 <sup>b</sup>	0.22 <sup>ab</sup>	0.16 <sup>ab</sup>	0.11 <sup>a</sup>	4.26	0.03	0.12
10	<i>Tetragnatha ilavaca</i>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
11	<i>Tetragnatha maxillosa</i>	0.16 <sup>a</sup>	0.07 <sup>a</sup>	0.05 <sup>a</sup>	0 <sup>a</sup>	2.18	0.14	
12	<i>Tetragnatha vermiformis</i>	0.09 <sup>ab</sup>	0.22 <sup>b</sup>	0.04 <sup>ab</sup>	0.02 <sup>a</sup>	4.09	0.03	0.12
13	<i>Tetragnatha Okumae</i>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.62	0.62	
14	<i>Tetragnatha iwahigensis</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
15	<i>Tetragnatha natans</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Linyphiidae	0.16 <sup>a</sup>	0.15 <sup>a</sup>	0.05 <sup>a</sup>	0.15 <sup>a</sup>	1	0.43	
16	<i>Bathypantes tagalogensis</i>	0.13 <sup>a</sup>	0.09 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	2.97	0.07	
17	<i>Bathypantes</i> sp.	0 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.05 <sup>a</sup>	0.88	0.48	
18	<i>Erigone bifurca</i>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
19	<i>Enoplognatha</i> sp.	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.83	0.5	
20	Unknown	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Oxyopidae	0.15 <sup>a</sup>	0.11 <sup>a</sup>	0.09 <sup>a</sup>	0.04 <sup>a</sup>	0.8	0.52	
21	<i>Oxyopes javanus</i>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.69	0.58	
22	<i>Oxyopes matiensis</i>	0.09 <sup>a</sup>	0.09 <sup>a</sup>	0.09 <sup>a</sup>	0 <sup>a</sup>	0.73	0.56	
23	<i>Oxyopes pingasus</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Theridiidae	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
24	<i>Theridion</i> sp.	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Salticidae	0.11 <sup>a</sup>	0.09 <sup>a</sup>	0.07 <sup>a</sup>	0.09 <sup>a</sup>	0.13	0.94	
25	<i>Myrmarachne bidentata</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
26	<i>Hyllus maskaranus</i>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.05 <sup>a</sup>	0 <sup>a</sup>	2.11	0.15	
27	<i>Cosmophasis parangpilota</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
28	<i>Cosmophasis</i> sp.	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.82	0.51	
29	<i>Flexipus paykulli</i>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	1	0.43	
30	<i>Harmochirus brachiatus</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.62	0.62	
31	<i>Bianor hotingchiehi</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.62	0.62	
32	<i>Emathis</i> sp.	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
33	Unknown	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
	Hahniidae	0 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	
34	<i>Hahnia tuybaana</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	
	Total Abundance (N)	2.25 <sup>b</sup>	2.09 <sup>b</sup>	1.22 <sup>a</sup>	1.09 <sup>a</sup>	27.51	0	0.17

Note: Values within a row followed by the same letters were not significantly different at P < 0.05 according to Tukey's HSD test

**Table 3.** Abundance of predatory insects inhabiting the rice plot surrounded by refugia, vegetables, untreated, and insecticide application for one planting season

No.	Ordo/ Family/Species	Mean of abundance (individual/nets)				F-value	P value (0.05)	Tukey's HSD test
		Rice-Refugia	Rice-Vegetable	Rice-Untreated	Rice-Insecticide			
	HEMIPTERA	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	1.17	0.36	
	Miridae	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	1.17	0.36	
1	<i>Cyrtorhinus lividipennis</i>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1.46	0.28	
2	<i>Orthotylus</i> sp.	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1.29	0.32	
	COLEOPTERA	1.09 <sup>b</sup>	0.35 <sup>a</sup>	0.67 <sup>ab</sup>	0.29 <sup>a</sup>	12.75	0	0.20
	Carabidae	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
3	<i>Ophionea nigrofasciata</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Staphylinidae	0.27 <sup>a</sup>	0.16 <sup>a</sup>	0.09 <sup>a</sup>	0.11 <sup>a</sup>	2.25	0.14	
4	<i>Paederus fuscipes</i>	0.27 <sup>a</sup>	0.16 <sup>a</sup>	0.09 <sup>a</sup>	0.11 <sup>a</sup>	2.25	0.14	
	Coccinellidae	0.78 <sup>b</sup>	0.16 <sup>a</sup>	0.56 <sup>b</sup>	0.18 <sup>a</sup>	11.72	0	0.19
5	<i>Micraspis inops</i>	0.38 <sup>b</sup>	0.07 <sup>a</sup>	0.25 <sup>ab</sup>	0.15 <sup>ab</sup>	4.8	0.02	0.16
6	<i>Verania lineata</i>	0.04 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
7	<i>Micraspis vincta</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
8	<i>Harmonia octomaculata</i>	0 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
9	<i>Coccinella repanda</i>	0.05 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.99	0.43	
10	<i>Brumoides suturalis</i>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.88	0.48	
11	<i>Menochilus sexmaculatus</i>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
12	Unknown	0.25 <sup>b</sup>	0.07 <sup>ab</sup>	0.16 <sup>ab</sup>	0.04 <sup>a</sup>	3.77	0.04	0.13
	Elateridae	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
13	Unknown	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Anthicidae	0 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.62	0.62	
14	<i>Formicomus</i> sp.	0 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.62	0.62	
	ODONATA	0.04 <sup>a</sup>	0.09 <sup>a</sup>	0.04 <sup>a</sup>	0.05 <sup>a</sup>	0.66	0.59	
	Coenagrionidae	0.04 <sup>a</sup>	0.07 <sup>a</sup>	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0.52	0.68	
15	<i>Agriocnemis</i> sp.	0.02 <sup>a</sup>	0.05 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.47	0.71	
16	<i>Pyrrhosoma</i> sp.	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.38	0.77	
17	<i>Argia</i> sp.	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Libellulidae	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.62	0.62	
18	<i>Pantala</i> sp.	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.00 <sup>a</sup>	1	0.43	
19	Unknown	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
	ORTHOPTERA	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Tettigonidae	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
20	<i>Conocephalus longipennis</i>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	HYMENOPTERA	0.11 <sup>a</sup>	0.65 <sup>b</sup>	0.35 <sup>ab</sup>	0.05 <sup>a</sup>	7.83	0	0.22
	Formicidae	0.11 <sup>a</sup>	0.64 <sup>b</sup>	0.35 <sup>ab</sup>	0.05 <sup>a</sup>	6.48	0.01	0.24
21	<i>Odontoponera transversa</i>	0.09 <sup>a</sup>	0.64 <sup>b</sup>	0.35 <sup>ab</sup>	0.05 <sup>a</sup>	6.71	0.01	0.24
22	<i>Solenopsis</i> sp.	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	Syrphidae	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
23	<i>Volucella</i> sp.	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	MANTODEA	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
	MANTIDAE	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
24	Unknown	1.33 <sup>b</sup>	1.15 <sup>b</sup>	1.11 <sup>b</sup>	0.42 <sup>a</sup>	15.14	0	0.19
Total Abundance (N)		14.6 <sup>b</sup>	12.7 <sup>b</sup>	12.2 <sup>b</sup>	4.6 <sup>a</sup>	17.00	0.00	0.74

Note: Values within a row followed by the same letters were not significantly different at  $P < 0.05$  according to Tukey's HSD test

Refugia as habitat were capable of providing micro-climate in form of high relative humidity and shady condition that appropriate for natural enemies habitat either predatory arthropods or parasitoids (McCabe *et al.*, 2017). Refugia as habitat were not only required during rice growth in a rice field, but also had function as a sink for arthropods during a rice harvest and would become arthropod source during the initial rice planting in rice fields (Baba *et al.*, 2018). It was evident that *Zinnia* sp. as habitat was inhabited by spiders of the families of *Araneidae*, *Oxyopidae* and *Pisauridae* (Desai *et al.*, 2017). The spider (*Oxyopidae*), predatory insects (*Coccinellidae*, *Syrphidae* and *Geocoridae*), parasitoid and pollinating insects of *Hymenoptera* and *Lepidoptera* were found in large numbers inhabiting *T. erecta* as niche (Ganai *et al.*, 2017).

Refugia as niche were capable of providing nectar and pollen as well as preys in form of herbivore or neutral insects. *S. indicum* was capable of providing nectar for parasitoid of rice stem borer (Zhu, 2014a) and natural enemies (Coleoptera, Hymenoptera, Neuroptera and Dictyoptera) (Mahmoud, 2012). *S. indicum* was capable of increasing predator capability to prey on herbivores because its nectar and pollen can increase fitness and prey ability of this predator (Zhu, 2014b). Feed in form of nectar and pollen could prolong the longevity of predatory arthropods and parasitoid, even synovigenic-type parasitoid urgently requires this feed in order to increase its egg production (Lu *et al.*, 2014; Zhu, 2014a). In addition, refugia existence on rice field embankments surrounding the rice could increase flora species diversity in rice fields. The higher the flora species is, the higher the fauna species diversity (arthropods) will be as flora inhabitant (Zhu, 2014b).

**Table 4.** Community characteristics of spiders inhabiting the rice plot surrounded by refugia, vegetables, untreated, and insecticide application for one planting season

Rice age (days)	Community characteristics	Rice-Refugia	Rice-Vegetable	Rice-Untreated	Rice-Insecticide
14	Number of individual (individuals/net)	0.4	0.2	0	1
	Diversity ( $H'$ )	0.69	0	0	0.67
	Dominance (D)	0.5	1	0	0.6
	Evenness (E)	1	0	0	0.97
21	Number of individual (individuals/net)	1.2	1.2	0.8	0.8
	Diversity ( $H'$ )	1.24	0.87	1.04	1.04
	Dominance (D)	0.5	0.67	0.5	0.5
	Evenness (E)	0.90	0.79	1.50	0.95
28	Number of individual (individuals/net)	2	1.8	2	0.8
	Diversity ( $H'$ )	1.64	1.68	1.33	1.04
	Dominance (D)	0.3	0.33	0.4	0.5
	Evenness (E)	0.92	0.94	0.96	0.95
35	Number of individual (individuals/net)	2.4	3	1	0.8
	Diversity ( $H'$ )	1.13	0.88	0.67	1.04
	Dominance (D)	0.5	0.53	0.6	0.5
	Evenness (E)	0.81	0.80	0.97	0.95
42	Number of individual (individuals/net)	2.2	2.6	2.4	1.6
	Diversity ( $H'$ )	1.04	1.31	0.82	1.04
	Dominance (D)	0.45	0.38	0.67	0.5
	Evenness (E)	0.94	0.94	0.75	0.95
49	Number of individual (individuals/net)	3.6	3	1.2	0.2
	Diversity ( $H'$ )	1.57	1.04	0	0
	Dominance (D)	0.39	0.47	1	1
	Evenness (E)	0.87	0.95	0	0
56	Number of individual (individuals/net)	2.6	2	1.2	0.4
	Diversity ( $H'$ )	1.18	0.64	0.69	0
	Dominance (D)	0.62	0.8	0.5	1
	Evenness (E)	0.73	0.58	1	0
63	Number of individual (individuals/net)	2.2	2.4	1	1.4
	Diversity ( $H'$ )	1.64	1.20	1.33	0.96
	Dominance (D)	0.36	0.5	0.4	0.57
	Evenness (E)	1.02	0.86	0.96	0.87
70	Number of individual (individuals/net)	3.2	2.2	1.2	1.2
	Diversity ( $H'$ )	1.72	1.47	0.64	1.56
	Dominance (D)	0.31	0.36	0.67	0.33
	Evenness (E)	0.88	0.91	0.92	0.97
77	Number of individual (individuals/net)	1.85	1.8	1.2	1
	Diversity ( $H'$ )	0.98	0.89	0.97	0.96
	Dominance (D)	0.22	0.44	0.33	0.4
	Evenness (E)	0.98	0.89	0.97	0.96
84	Number of individual (individuals/net)	3.2	2.8	1.4	2.85
	Diversity ( $H'$ )	2.06	1.77	0.80	1.58
	Dominance (D)	0.31	0.36	0.71	0.49
	Evenness (E)	0.90	0.91	0.72	0.81
Total	Number of individual (individuals/net)	24.85	23	13.4	12.05
	Diversity ( $H'$ )	2.47	2.22	1.99	2.05
	Dominance (D)	0.32	0.39	0.42	0.37
	Evenness (E)	0.77	0.73	0.75	0.76

**Table 5.** Community characteristics of predatory insects inhabiting the rice plot surrounded by refugia, vegetables, untreated, and insecticide application for one planting season

Rice age (days)	Community characteristics	Rice-Refugia	Rice-Vegetable	Rice-Untreated	Rice-Insecticide
14	Number of individual (individuals/net)	0.6	0.5	0.2	0.2
	Diversity ( $H'$ )	0.64	0	0	0
	Dominance (D)	0.7	1	1	1
	Evenness (E)	0.92	0	0	0
21	Number of individual (individuals/net)	1	0.6	1	0.2
	Diversity ( $H'$ )	0.50	0.6	1.05	0
	Dominance (D)	0.8	0.67	0.40	1
	Evenness (E)	0.72	0.92	0.96	0
28	Number of individual (individuals/net)	0.8	1.6	0	0.4
	Diversity ( $H'$ )	0.56	0.74	0	0.69
	Dominance (D)	0.81	0.67	0	1
	Evenness (E)	0.75	0.75	0	0.50
35	Number of individual (individuals/net)	0.2	0.2	0.6	0
	Diversity ( $H'$ )	0	0	0	0
	Dominance (D)	1	1	1	0
	Evenness (E)	0	0	0	0
42	Number of individual (individuals/net)	0.8	1.6	0	0.2
	Diversity ( $H'$ )	0.56	1.26	0	0
	Dominance (D)	0.75	0.38	0	1
	Evenness (E)	0.81	0.91	0	0
49	Number of individual (individuals/net)	1.2	0.4	0	1
	Diversity ( $H'$ )	0	0	0	0
	Dominance (D)	1	1	0	1
	Evenness (E)	0	0	0	0
56	Number of individual (individuals/net)	2.2	2.4	3.6	0.8
	Diversity ( $H'$ )	1.34	0.57	1.38	0
	Dominance (D)	0.36	0.83	0.56	1
	Evenness (E)	0.97	0.52	0.77	0
63	Number of individual (individuals/net)	1.8	0.8	1	0
	Diversity ( $H'$ )	1.74	0.56	0	0
	Dominance (D)	0.22	0.75	1	0
	Evenness (E)	0.97	0.81	0	0
70	Number of individual (individuals/net)	1.4	0.6	1.4	0.6
	Diversity ( $H'$ )	0.96	0.64	0.6	0.64
	Dominance (D)	0.57	0.67	0.71	0.67
	Evenness (E)	0.87	0.92	0.86	0.92
77	Number of individual (individuals/net)	2.8	3	3.6	1
	Diversity ( $H'$ )	0.76	0	1.04	1.33
	Dominance (D)	0.71	1	0.5	0.4
	Evenness (E)	0.69	0	0.75	0.96
84	Number of individual (individuals/net)	1.8	1	0.8	0.2
	Diversity ( $H'$ )	1.89	1.33	1.39	0
	Dominance (D)	0.22	0.4	0.25	1
	Evenness (E)	0.97	0.96	1	0
Total	Number of individual (individuals/net)	14.6	12.7	12.2	4.6
	Diversity ( $H'$ )	2.12	1.61	2.06	1.74
	Dominance (D)	0.29	0.55	0.31	0.35
	Evenness (E)	0.76	0.65	0.76	0.84

This research showed that the abundance and species diversity of spider and predatory insects on the rice surrounded by refugia and vegetables were high and tended to have a higher community similarity for spiders and predatory insects than that of other plots. Vegetables (*C. sativus*, *V. sinensis*, *L. acutangula*, and *M. charantia*) have flowers that could provide nectar and pollen, but information related to arthropods associating with flowers on vegetables is not much. Lami et al. (2016) reported that predatory insects, such as ladybird beetles occurred during maize flowering in Northern and Central Italy. During this research period, the flowers of the four vegetables were frequently alight by the community of pollinating insects, spiders, predatory insects and parasitoids of herbivores. The arthropods inhabiting those vegetables generally were *M. sexmaculatus*, *P. fuscipes*, *Tetragnatha* spp., and *A. catenulata* found on rice fields in this research.

The abundance and species diversity of spiders and predatory insects on the rice sprayed with synthetic insecticide were the lowest because the toxic from the insecticide could kill several arthropods species. This toxic kills not only

herbivore, but also spider, predatory insects (Ngin *et al.*, 2017), parasitoid (Svobodová *et al.*, 2017), and pollinating insects (Sgolastra *et al.*, 2016). The synthetic insecticide spraying can also slow down colonization of spider and predatory insects on those plots and can cause these natural enemies migration to other plots that are not sprayed with synthetic insecticide (Lopes *et al.*, 2017).

Finally, the results of this study indicate that the most abundant predatory arthropods (spiders and predatory insects) was found on the rice surrounded by refugia flower and vegetables. The highest species diversity for spiders and predatory insects was also found on the rice surrounded by the refugia and vegetables. Therefore, the rice surrounded by the refugia and vegetables was the most appropriate for habitat and niche of predatory arthropods. Consequently, the refugia and vegetables should be planted along rice field embankments to conserve those useful arthropods.

## ACKNOWLEDGEMENTS

This research was financially supported by Program of Professor Research Grant of Universitas Sriwijaya, Ministry of Research, Technology and Higher Education, Republic of Indonesia with budget year of 2018, Contract Number: 0006/UN9/SK.LP2M.PT/2018, 5 June 2018 chaired by Siti Herlinda. We would like to thank to Program Beasiswa SDM IPTEK, Ministry of Research, Technology, and Higher Education that has given a scholarship for Tili Karenina.

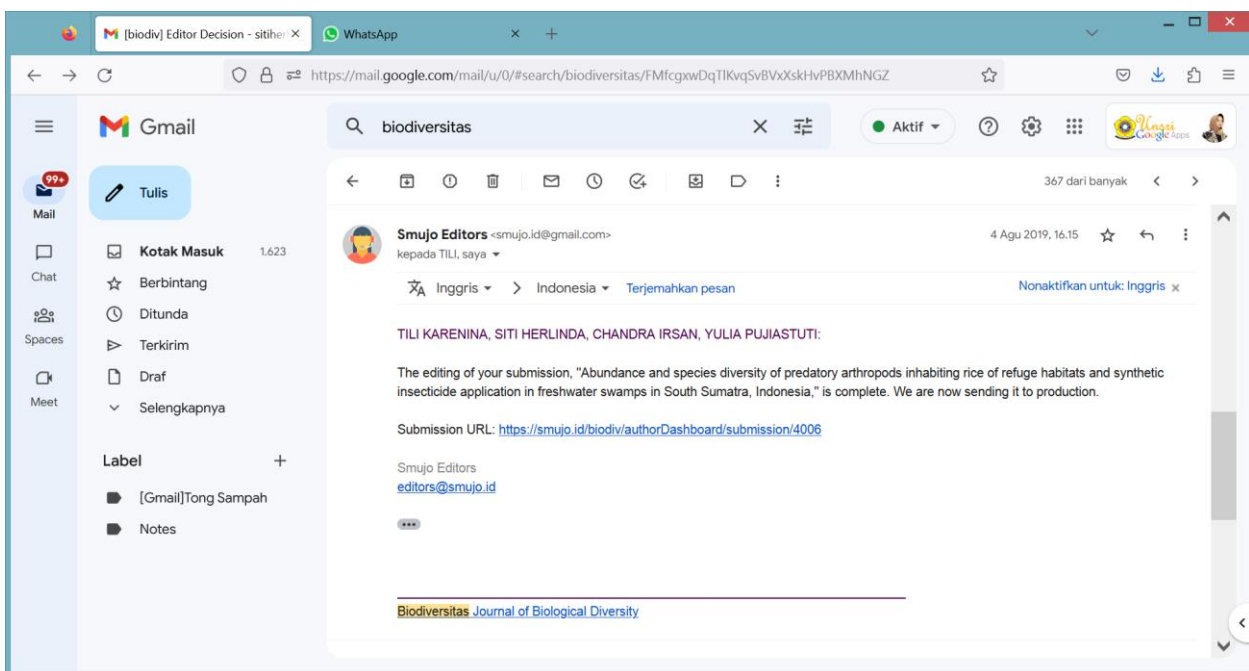
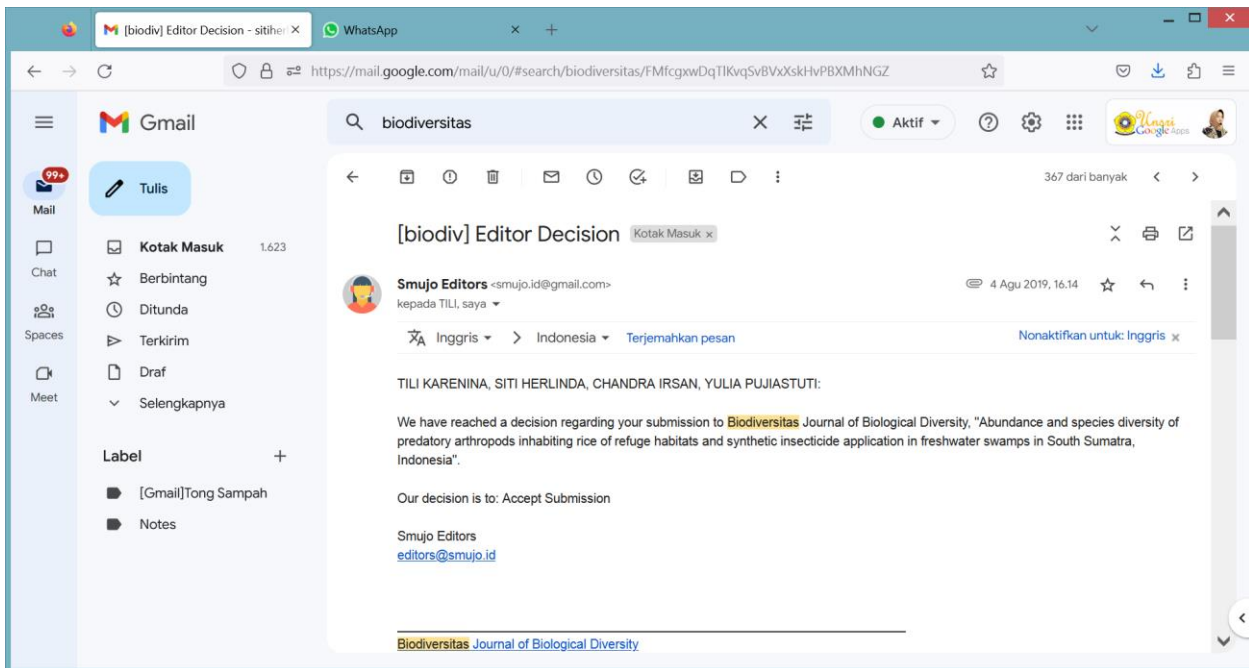
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## 3. Bukti konfirmasi paper accepted, uncorrected Proof dan hasil koreksi penulis



## Abundance and species diversity of predatory arthropods inhabiting rice of refuge habitats and synthetic insecticide application in freshwater swamps in South Sumatra, Indonesia

TILI KARENINA<sup>1</sup>, SITI HERLINDA<sup>2,3,\*</sup>, CHANDRA IRSAN<sup>2,3</sup>, YULIA PUJIASTUTI<sup>2,3</sup>

<sup>1</sup>Program of Agriculture Sciences, Faculty of Agriculture, Universitas Sriwijaya. Jl. Padang Selasa No. 524, Bukit Besar, Palembang 30139, South Sumatra, Indonesia

<sup>2</sup>Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Sriwijaya. Jl. Raya Palembang-Prabumulih, km 32, Indralaya, Ogan Ilir 30662, South Sumatra, Indonesia. Tel.: +62-711-580663, Fax.: +62-711-580276, ✉email: sitiherlinda@unsri.ac.id

<sup>3</sup>Research Center for Sub-optimal Lands, Universitas Sriwijaya. Jl. Padang Selasa No. 524, Bukit Besar, Palembang 30139, South Sumatra, Indonesia

Manuscript received: 1 June 2019. Revision accepted: 28 July 2019.

**Abstract.** Karenina T, Herlinda S, Irsan C, Pujiastuti Y. 2019. Abundance and species diversity of predatory arthropods inhabiting rice of refuge habitats and synthetic insecticide application in freshwater swamps in South Sumatra, Indonesia. *Biodiversitas* 20: 2375-2387. Rice cultivation in freshwater swamps in Indonesia is specific, among other things, there is no synthetic pesticide spraying and vegetable growing on rice field embankments. This specific cultivation technique can affect the abundance and diversity of rice-dwelling arthropods species. The study aimed to compare the abundance and species diversity of predatory arthropods inhabiting rice surrounded both by refugia and vegetables and by those being applied with synthetic insecticide in the rice field of freshwater swamps. This study used rice plots surrounded by refugia flower (*Zinnia* sp., *Tagetes erecta*, *Cosmo caudatus*, and *Sesamum indicum*); vegetables (*Cucumis sativus*, *Vigna sinensis*, *Luffa acutangula*, and *Momordica charantia*); untreated; and synthetic insecticide. Twenty-five herbivore species of 12 families, 34 spider species of 8 families, and 24 species of predatory insects of 12 families were found on rice during a planting season. The lowest herbivore population and spider abundance were found on synthetic insecticide sprayed rice and they were significantly different from those of refugia-rice plots. The most abundant spiders and predatory insects were found on rice surrounded by refugia and were not significantly different from those of rice surrounded by vegetables. The highest species diversity for spiders and predatory insects was found on rice surrounded by refugia, whereas the lowest species diversity was found on synthetic pesticide sprayed rice. Therefore, rice surrounded by refugia flowers and vegetables was the most appropriate for habitat and niche of predatory arthropods.

**Keywords:** Herbivore, neutral insect, parasitoid, predatory insect, spider

## INTRODUCTION

Cultivation of rice (*Oryza sativa*) in freshwater swamps in Indonesia is specific, i.e., the planting season is from April to September in a year. Rice is planted by using transplanting method, i.e., starting from seedling and then transplanted to rice field (Lakitan et al. 2018a,b). Rice seedling can be carried out with three patterns consisting of floating raft seedling, 'samir' method and digging ('tugal') method (Herlinda et al. 2018a; Lakitan et al. 2018b). Subsequently, seedlings of 7–10 days old are transplanted into rice field. Rice pest control in freshwater swamp generally does not use synthetic insecticide (Herlinda et al. 2018b; Safitri et al. 2018), whereas weeds control is carried out without using herbicide but by using manual method through pulling out by hand or weeding by using a sickle. In addition, rice field embankments are usually planted with flowering seasonal vegetables, such as long beans (*Vigna sinensis*), cucumber (*Cucumis sativus*), bitter melon (*Momordica charantia*) and squash (*Luffa acutangula*).

This specific rice cultivation in freshwater swamps affects arthropod communities. Species richness and abundance of spiders on rice in freshwater swamps are higher than those of rice in tidal lowlands of South Sumatra because farmers in the freshwater swamps do not apply synthetic insecticide (Herlinda et al. 2018a). Application of synthetic insecticide can decrease the abundance and species diversity of predators and parasitoids (Ngin et al. 2017; Svobodová et al. 2017).

In addition to synthetic insecticide application, flora in the vicinity of rice can affect arthropod community (Cao et al. 2004; Lopes et al. 2017; Xu et al. 2017; Baba et al. 2018). Wild plants, refugia, and vegetables planted at rice field embankment can provide niche and habitat for arthropods as natural enemies of rice pest insects (Zhu et al. 2014a; Hasan et al. 2016; McCabe et al. 2017). Nectar and pollen on those crops and plants can increase

longevity, fecundity, and function of natural enemies (Desai et al. 2017; Foti et al. 2017; Ganai et al. 2017; Lu et al. 2014). Some of refugia were utilized for natural enemy conservation on rice, for instance *Zinnia* sp. becomes niche and habitat for spiders, *Argiope aemula*, *Oxyopes* sp., and *Perenethis* sp. (Desai et al. 2017). *Tagetes erecta* was inhabited by *Oxyopes javanus*, *Coccinella septempunctata*, *Syrphus* spp., *Geoceris* spp., *Apis dorsata*, *Apis mellifera*, and *Vanessa cardui* (Ganai et al. 2017). Refugia species of *Antigonon leptopus*, *Cassia cobanensis*, *Turnera subulata*, and *Antigonon leptopus* were used for natural enemies conservation of oil palm pests (Dutton et al. 2016; Kamarudin and Arshad 2016; Saleh and Siregar 2017). The effort to utilize refugia flower for predatory arthropod conservation in freshwater swamps of rice ecosystems in Indonesia has not yet been done. Therefore, this research aimed to compare the abundance and species diversity of predatory arthropods inhabiting rice of refuge habitats and synthetic insecticide application in freshwater swamps.

## MATERIALS AND METHODS

This research was conducted in the rice field of freshwater swamps in Pelabuhan Dalam Village, Pemulutan Subdistrict, Ogan Ilir District, South Sumatra Province, Indonesia from May to August 2018. The selected rice field is rice center, and its area is around 7.1 Mha that had flooding season from October to March and a dry season from April to September.

### Field preparation and treatments

This stage consisted of land preparation and soil tillage, seedling, planting, and rice maintenance. Land preparation started with weeds clearance followed by soil tillage and application of manure fertilizer at a dose of 1 ton.ha<sup>-1</sup>. Rice seeds used in this research were certified Mekongga

variety. Before seedling, seeds were broiled for 1 x 24 hours and then sowed within tray (size of 36 cm x 27 cm x 4,5 cm) for 14 days (Figure 1). The next step was that the seedlings were transported to the rice field and transplanted.

The rice was planted by using lined up system ('*jajar legowo*' 2:1) with a planting distance of 50 cm x 25 cm x 12.5 cm. All of the rice plot treatments were fertilized with liquid compost extract once in two weeks at a dose of 2 L.ha<sup>-1</sup> and the manure fertilizer at a dose of 1 ton.ha<sup>-1</sup>. Compost extract was produced according to the method of Suwandi et al. (2012).

Treatment plots were designed into four treatments (four plots) which consisted of rice plots surrounded by (i) refugia, (ii) vegetables, (iii) untreated (without refugia, vegetable or insecticide), and (iv) control sprayed with synthetic insecticide, respectively. Every plot had an area of 800 m<sup>2</sup> and was divided into five sub-plots as replications.

Refugia and vegetable planting was conducted 30 days prior to rice planting so that refugia got bloomed when rice entered a vegetative stage at 14 days after transplanting (dat). The rice plots surrounded by refugia used four species of refugia flower consisting of zinnia or paper flower (*Zinnia sp.*), tagetes (*Tagetes erecta*), thinkin (*Cosmo caudatus*), and sesame (*Sesamum*) (Figure 2). The rice plots surrounded by vegetables used four seasonal vegetable species consisting of long beans (*V. sinensis*), cucumber (*C. sativus*), bitter melon (*M. charantia*), and squash (*L. acutangula*) planted at the rice field embankment. The vegetable planting distance (distance between planting holes) was as follows: 30 cm, 60 cm, 30 cm, and 40 cm for long beans, bitter melon, squash, and cucumber respectively. The refugia planting distance (distance between planting holes) was 15 cm, but refugia had two rows planting at rice field embankments. The untreated rice plots (without refugia, vegetables, and insecticide application) was the one having no plants in the vicinity of rice field embankments, whereas the rice plots sprayed with synthetic insecticide were also not surrounded by refugia or vegetables (Figure 2). The synthetic insecticide used in this research had abamectin active ingredient according to the recommended dose.

#### Arthropods sampling

Arthropod sampling was conducted every week for one planting season and started when rice reached the age of 14 until 84 days after transplanting (11 observations). The arthropods sampling was carried out at early morning from 06.00 to 07.00 a.m. The arthropods were collected using

sweep nets (net handgrip length of 100 cm, length of 75 cm and diameter of 30 cm) based on the methods of Jayakumar and Sankari (2010) and Janzen (2013). The swinging net was purposively touched on rice stem according to the method of Masika et al. (2017) in order to drag insects that attached on the rice stems and leaves at rice lower canopy. The arthropods were collected by swinging net once by using double swings that form a straight line at a depth of 30 cm toward the rice canopy interior.

The caught arthropods were subsequently cleaned and put into plastic vials containing 70% alcohol, labeled, and taken to the Entomology Laboratory, Department of Plant Pest and Diseases, Faculty of Agriculture, Universitas Sriwijaya, South Sumatra, Indonesia for identification by Dr. Chandra Irsan, an insect taxonomist. The spider visual identification was conducted by using the reference of Barrion and Litsinger (1995), and insect visual identification was conducted by using the references of Heinrichs (1994), Kalshoven (1981), and McAlpine et al. (1987). All the identified arthropods were grouped into guilds, and their number of individuals of each species was counted.

#### Data analysis

Data of abundance (or the number of individuals) of herbivores, spiders, and predatory insects among the treatments were analyzed by using analysis of variance (ANOVA). If there were differences among the data of each treatment, they were separated using Tukey's Honestly Significant Different (HSD) test at 5%. The data analysis was calculated using the program software of SAS University Edition 2.7 9.4 M5. The data of arthropod abundance were also used to analyze the species diversity by using the Shannon index (H'). The diversity level was also evaluated by the Evenness index (J') derived from the Shannon function, and Berger-Parker dominance biodiversity indices. Data of arthropod abundance were also subsequently grouped according to guild consisting of herbivore (or phytophagous insects), predator, parasitoid, and neutral insects, and reported graphically.

## RESULTS AND DISCUSSION

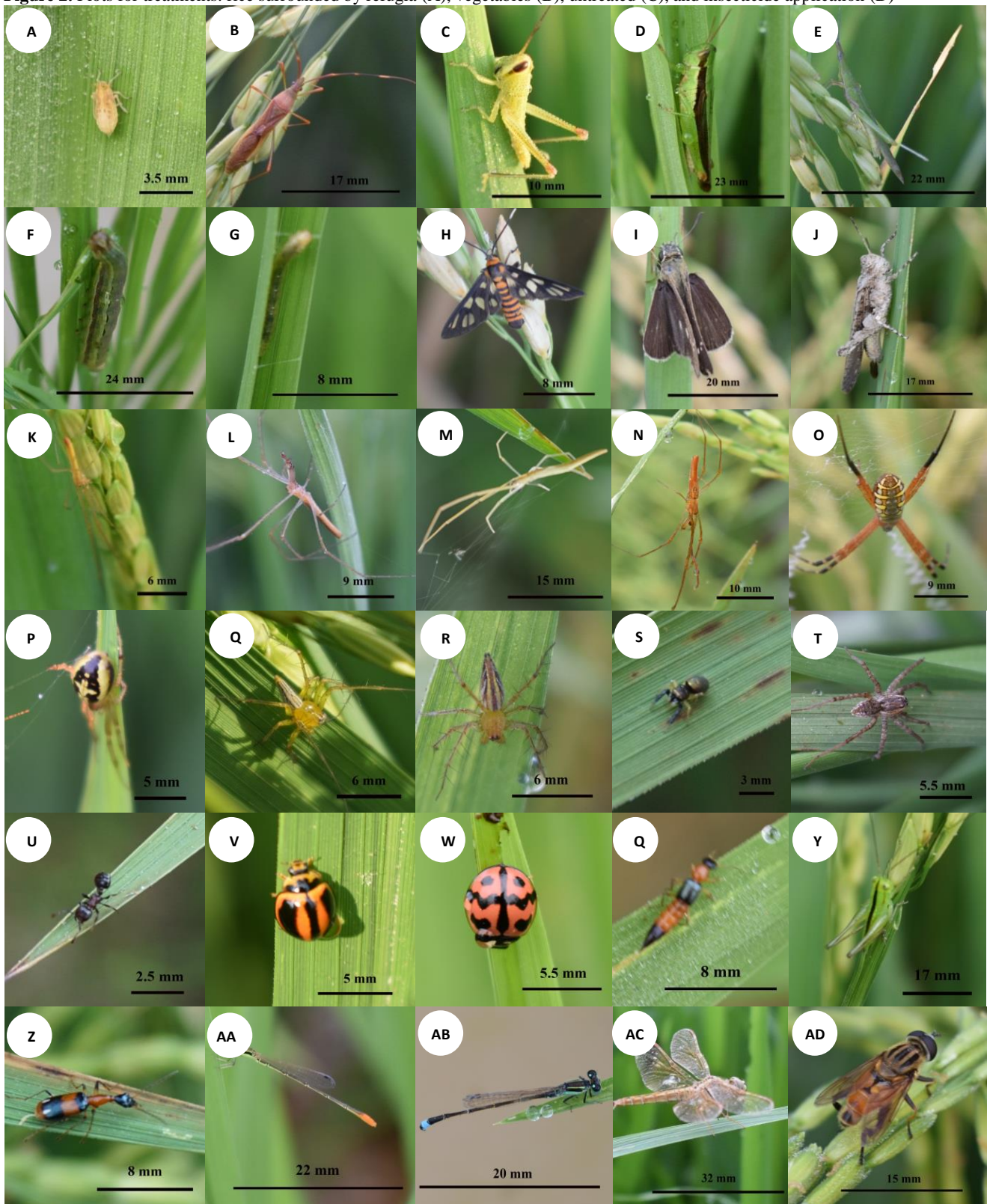
#### Arthropods species

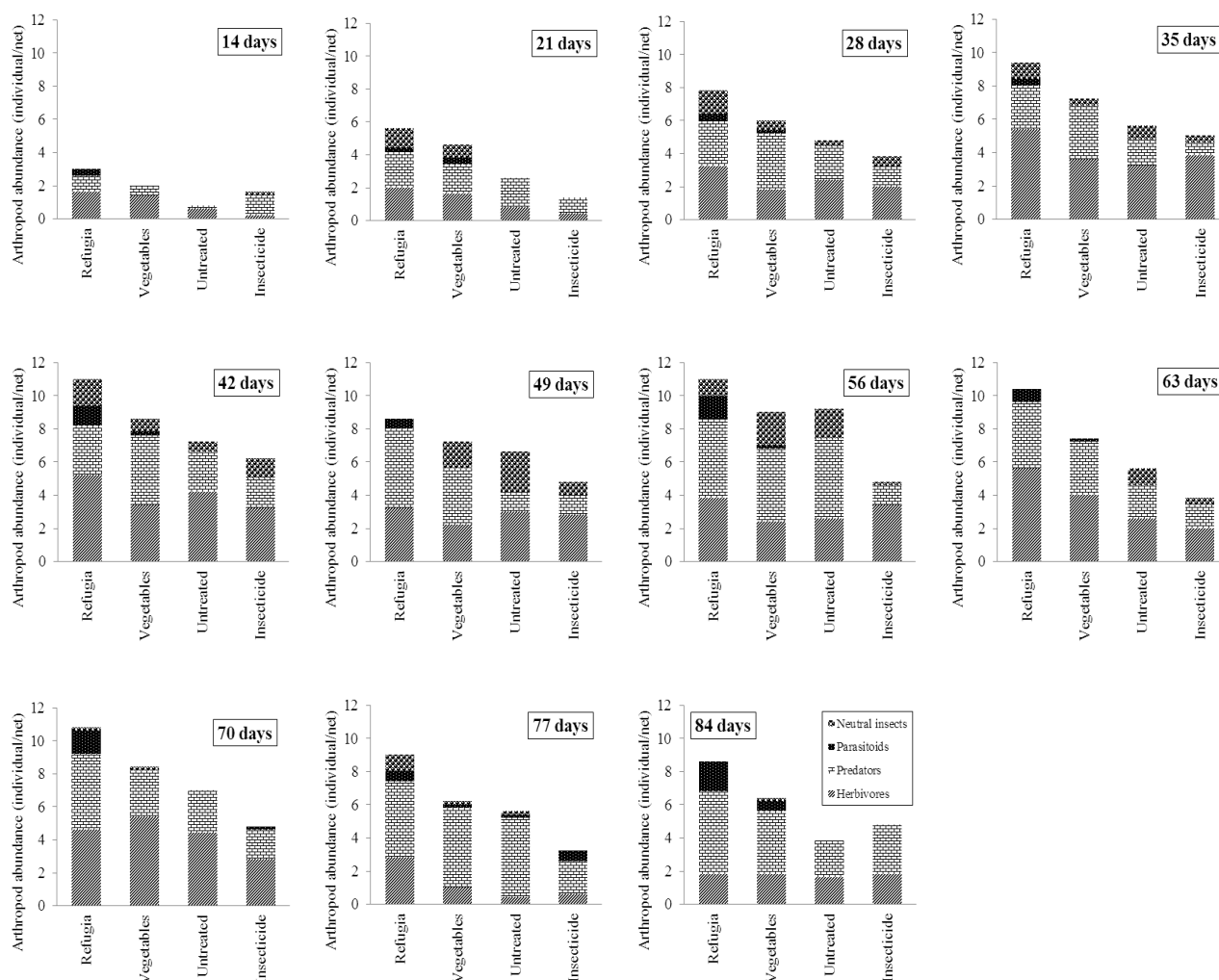
Twenty-five herbivore species of 12 families were found during one planting season of rice. The most dominant herbivore found in this research were *Nilaparvata lugens*, *Leptocorisa acuta*, *Valanga nigricornis*, *Oxya chinensis*, and *Acrida turita* (Figure 3).



**Figure 1.** Field preparation: seeds broiled for 1 x 24 hours (A), seeds sowed within trays (B), rice transplanted by using 'jajar legowo' 2:1 (C, D)



**Figure 2.** Plots for treatments: rice surrounded by refugia (A), vegetables (B), untreated (C), and insecticide application (D)**Figure 3.** Dominant arthropod species found on the rice field: *Nilaparvata lugens* (A), *Leptocorisa acuta* (B), *Valanga nigricornis* (C), *Oxya chinensis* (D), *Acrida turrita* (E), *Spodoptera* sp. (F), *Cnaphalocrosis medinalis* (G), *Amata nigriceps* (H), *Pelopidas* sp. (I), *Tetrax subulata* (J), *Tetragnatha virescens* (K), *T. mandibulata* (L), *T. javana* (M), *T. maxillosa* (N), *Argiope catenulata* (O), *Araneidae* (P), *Oxyopes matiensis* (Q), *O. javanus* (R), *Salticidae* (S), *Pardosa pseudoannulata* (T), *Odontoponera transversa* (U), *Micrapis inops* (V), *Menochilus sexmaculatus* (W), *Paederus fuscipes* (X), *Conocephalus longipennis* (Y), *Ophionea nigrofasciata* (Z), *Agriocnemis* sp. (AA), *Argia* sp. (AB), *Pantala* sp. (AC), and *Volucella* sp. (AD)



**Figure 4.** Arthropod abundance on the rice plot surrounded by refugia, vegetables, untreated, and insecticide application

Spiders having 34 species of eight families were dominated by *Tetragnatha virescens*, *T. javana*, *T. mandibulata*, *T. maxillosa*, and *Argiope catenulata*. Predatory insects having 24 species of 12 families were also found in this research and the dominant species of predatory insects were *Odontoponera transversa*, *Micrapis inops*, *Menochilus sexmaculatus*, *Paederus fuscipes*, and *Conocephalus longipennis*.

#### Herbivore abundance

The highest abundance or population of *N. lugens*, *S. furcifera*, *L. acuta*, *S. litura* and *A. turrita* during one planting season was found on rice surrounded by refugia and significantly different from the population of those on rice sprayed with synthetic insecticide (Table 1). The highest population of the families of *Delphacidae*, *Alydidae*, *Noctuidae*, and *Acrididae* was found on rice surrounded by refugia, whereas the lowest population was found on rice sprayed with synthetic insecticide. The application of synthetic insecticide during the vegetative stage of rice significantly decreased the herbivore population.

When the rice reached the age of 14–28 days after transplanting, the herbivore population was still lower on the rice sprayed with synthetic insecticide than that of other treatment plots (Figure 4). After this period, the herbivore population tended to increase on the rice sprayed with synthetic insecticide. Whereas on the other plots (refugia, vegetables, and untreated), the population of herbivore tended to decrease continuously and even when the rice reached the age of 49–56 days after transplanting the rice surrounded by refugia and vegetables, the abundance of predatory arthropods was higher than that of herbivore population.

#### The abundance of spider and predatory insects

The highest abundance of *T. mandibulata*, *T. vermiformis*, and *Bathyphantes tagalogensis* was found on the rice surrounded by refugia and vegetables, and it was significantly different from those on the rice sprayed with synthetic insecticide and untreated rice (Table 2). The total number of spider abundance was also higher on the rice surrounded by refugia and vegetables. The abundance of

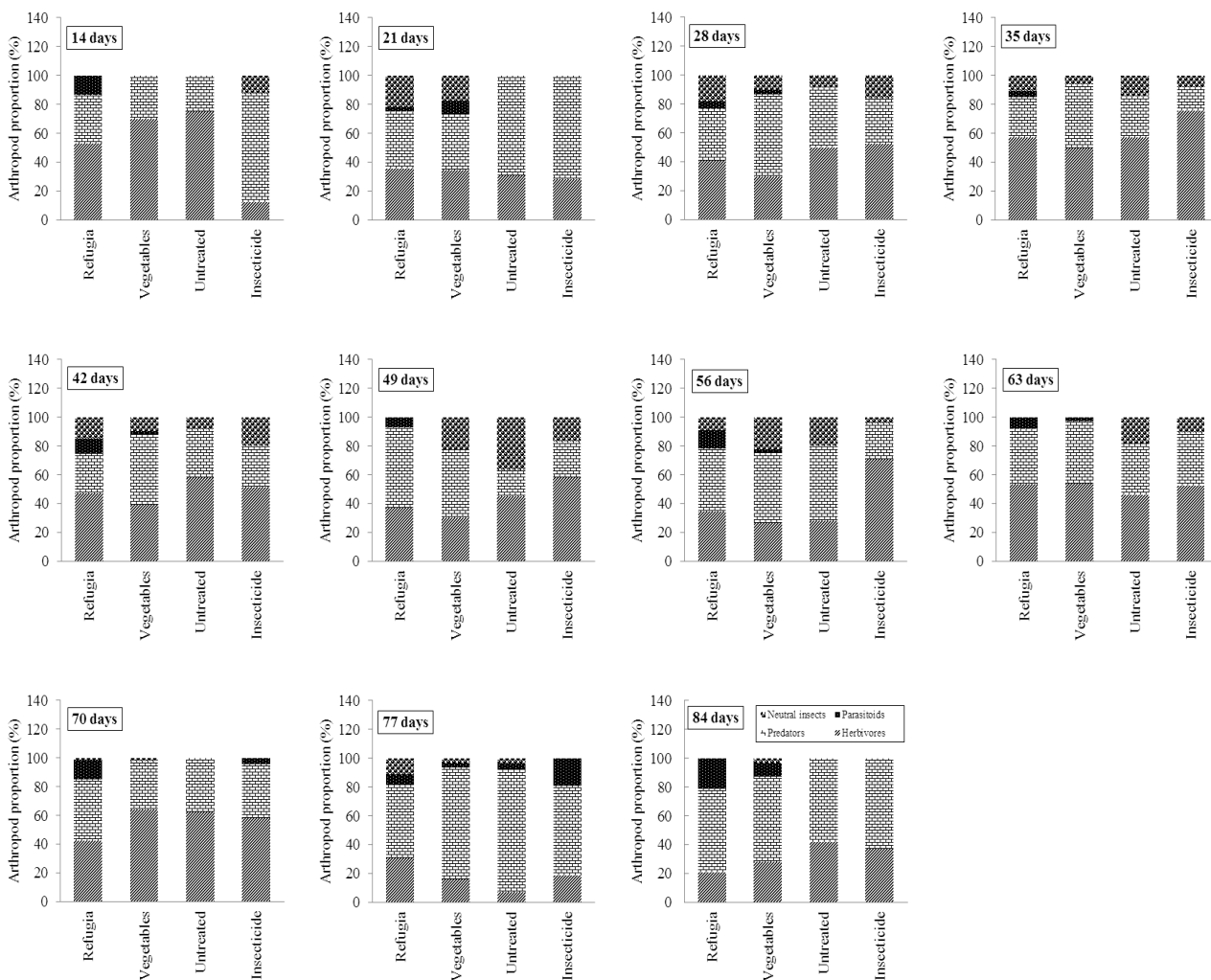
predatory insects of *Coccinellidae*, especially *Micraspis inops*, was higher on the rice surrounded by refugia and untreated rice, and it was significantly different from the abundance of rice plots sprayed with synthetics insecticide and the ones surrounded by refugia and vegetables (Table 3). However, the total number of predatory insect abundance was higher on the rice surrounded by refugia, vegetables, and untreated rice, and it was significantly different from those sprayed with synthetic insecticide.

**Species diversity of predatory arthropods**

At 14 up to 84 days after transplanting, the spider species diversity on the rice surrounded by refugia tended to be higher than that of other rice plots (Table 4). From the initial to final observation, the total magnitude showed that the highest spider abundance was found on the rice surrounded by refugia, whereas the lowest one was found on the one sprayed with synthetic insecticide. The similar trend was also found on species diversity of predatory insects which tended to be high on the rice surrounded by refugia, whereas a lower species diversity was found on that sprayed with synthetic insecticide (Table 5).

**Comparison of arthropod abundance according to guilds**

At 14 days after transplanting, the lowest herbivore abundance was found on the rice sprayed with synthetic insecticide, whereas a higher herbivore abundance was found on other plots (Figure 4). At 21 up to 28 days after transplanting, the abundance of predatory arthropods was higher than that of parasitoids and herbivores. The peak increase of herbivore abundance and the decrease of predatory insects abundance occurred to the rice from 35 to 42 days after transplanting, and subsequently, predatory arthropod abundance started to increase, and it was higher than herbivore abundance. Prior to the harvest at 75 to 84 days after transplanting, the abundance of predatory arthropods sharply increased, and the herbivore abundance drastically decreased. The arthropod abundance (herbivores, predators, parasitoids, and neutral insects) on the rice surrounded by refugia tended to be higher than that of other treatment plots, whereas the lowest abundance tended to be found on the rice plots sprayed with synthetic insecticide.





**Figure 5.** The proportion of arthropods grouped into guilds (herbivore, predator, parasitoid, and neutral insects) on the rice plot surrounded by refugia, vegetables, untreated, and insecticide application**Table 1.** Population or abundance of herbivores inhabiting the rice plot surrounded by refugia, vegetables, untreated, and insecticide application

Ordo/family/species	Mean of population (individual/nets)				F-value	P value (0.05)	Tukey's HSD test
	Rice-refugia	Rice-vegetable	Rice-untreated	Rice-insecticide			
HEMIPTERA	1.58 <sup>b</sup>	1.16 <sup>ab</sup>	0.75 <sup>a</sup>	0.78 <sup>a</sup>	5.84	0.01	0.27
Delphacidae	0.95 <sup>b</sup>	0.69 <sup>ab</sup>	0.51 <sup>ab</sup>	0.25 <sup>a</sup>	5.01	0.02	0.26
<i>Nilavarpata lugens</i>	0.8 <sup>b</sup>	0.62 <sup>ab</sup>	0.47 <sup>ab</sup>	0.18 <sup>a</sup>	3.61	0.05	0.29
<i>Sogatella furcifera</i>	0.15 <sup>a</sup>	0.07 <sup>a</sup>	0.04 <sup>a</sup>	0.07 <sup>a</sup>	1.08	0.39	
Cicadellidae	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Cicadulina bipunctata</i>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Coreidae	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.62	0.62	
<i>Cletus trigonus</i>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.62	0.62	
Alydidae	0.64 <sup>b</sup>	0.44 <sup>ab</sup>	0.22 <sup>a</sup>	0.49 <sup>ab</sup>	5.50	0.01	0.17
<i>Leptocoris acuta</i>	0.64 <sup>b</sup>	0.44 <sup>ab</sup>	0.22 <sup>a</sup>	0.49 <sup>ab</sup>	5.50	0.01	0.17
LEPIDOPTERA	0.22 <sup>a</sup>	0.27 <sup>a</sup>	0.27 <sup>a</sup>	0.11 <sup>a</sup>	1.05	0.41	
Noctuidae	0.05 <sup>a</sup>	0.18 <sup>b</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	6.66	0.01	0.08
<i>Spodoptera sp.</i>	0.05 <sup>ab</sup>	0.15 <sup>b</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	5.97	0.01	0.06
<i>Naranga sp.</i>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.68	0.58	
Pyralidae	0.07 <sup>a</sup>	0.05 <sup>a</sup>	0.09 <sup>a</sup>	0.09 <sup>a</sup>	0.26	0.85	
<i>Cnaphalocrosis medinalis</i>	0.05 <sup>a</sup>	0.05 <sup>a</sup>	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0.11	0.95	
<i>Scirpophaga incertulas</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.05 <sup>a</sup>	0.05 <sup>a</sup>	1.62	0.24	
Erebidae	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0.13 <sup>a</sup>	0 <sup>a</sup>	1.21	0.35	
<i>Amata nigriceps</i>	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0.13 <sup>a</sup>	0 <sup>a</sup>	1.21	0.35	
Hesperiidae	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Pelopidas sp.</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Nymphalidae	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	
<i>Melanitis leda</i>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	
COLEOPTERA	0.09 <sup>a</sup>	0.11 <sup>a</sup>	0.07 <sup>a</sup>	0.05 <sup>a</sup>	0.17	0.92	
Chrysomelidae	0.09 <sup>a</sup>	0.11 <sup>a</sup>	0.07 <sup>a</sup>	0.05 <sup>a</sup>	0.17	0.92	
<i>Chrysolina coerulans</i>	0.07 <sup>a</sup>	0.04 <sup>a</sup>	0.07 <sup>a</sup>	0.00 <sup>a</sup>	0.63	0.61	
<i>Dactylispa bayoni</i>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
<i>Chaetocnema sp.</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Dicladispa armigera</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Aulacophora frontalis</i>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.88	0.48	
<i>Charidotella sp.</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
ORTHOPTERA	1.51 <sup>b</sup>	0.89 <sup>a</sup>	1.24 <sup>ab</sup>	1.04 <sup>ab</sup>	3.63	0.05	0.22
Tettigoniidae	0 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Tetrix subulata</i>	0 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Acrididae	1.49 <sup>b</sup>	0.89 <sup>a</sup>	1.16 <sup>ab</sup>	1.04 <sup>ab</sup>	3.64	0.04	0.21
<i>Valanga nigricornis</i>	1.18 <sup>a</sup>	0.69 <sup>a</sup>	1.15 <sup>a</sup>	0.87 <sup>a</sup>	2.29	0.13	
<i>Oxya chinensis</i>	0.2 <sup>a</sup>	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.11 <sup>a</sup>	1.67	0.23	
<i>Acrida turrata</i>	0.11 <sup>b</sup>	0.13 <sup>b</sup>	0.00 <sup>a</sup>	0.05 <sup>ab</sup>	6.11	0.01	0.06
Gryllidae	0.02 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	
<i>Gryllus sp.</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.681	0.58	
Diptera	0.11 <sup>a</sup>	0.16 <sup>a</sup>	0.02 <sup>a</sup>	0.11 <sup>a</sup>	1.93	0.18	
Cecidomyiidae	0.11 <sup>a</sup>	0.16 <sup>a</sup>	0.02 <sup>a</sup>	0.11 <sup>a</sup>	1.93	0.18	
<i>Orselia sp.</i>	0.11 <sup>a</sup>	0.16 <sup>a</sup>	0.02 <sup>a</sup>	0.11 <sup>a</sup>	1.93	0.18	
THYSANOPTERA	0.05 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	2.29	0.13	
Thripidae	0.05 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	2.29	0.13	
<i>Thrips sp.</i>	0.05 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	2.29	0.13	
Total abundance (N)	3.56 <sup>b</sup>	2.6 <sup>ab</sup>	2.35 <sup>a</sup>	2.09 <sup>a</sup>	5.14	0.02	0.34

Note: Values within a row followed by the same letters were not significantly different at  $P < 0.05$  according to Tukey's HSD test

The initial observation period at 14 to 21 days after transplanting showed that the herbivore proportion on the rice sprayed with synthetic insecticide was lower than the proportion of predators, parasitoids, and neutral insects, whereas the highest herbivore proportion was found in the rice surrounded by refugia (Figure 5). Subsequently,

herbivore proportion on the rice sprayed with synthetic insecticide continually increased and got higher than the predator proportion. However, the predator and parasitoid proportion on the rice surrounded by refugia and vegetable continually increased and got higher than the herbivore proportion up to before the harvest.

## Discussion

This research results showed that refugia and vegetables planted on rice field embankments surrounded by the rice were capable of increasing the abundance and species diversity of predatory arthropods (spiders and predatory insects) on the rice plot, whereas synthetic insecticide application did not only suppress herbivore population but also decreased the abundance of natural enemies of pest insects and other useful arthropods, such as spiders, predatory insects, parasitoids, neutral insects or pollinating insects.

Refugia as habitat were capable of providing microclimate in the form of high relative humidity and shady condition that appropriate for natural enemies habitat either

predatory arthropods or parasitoids (McCabe et al. 2017). Refugia as habitat were not only required during rice growth in a rice field but also had functioned as a sink for arthropods during a rice harvest and would become arthropod source during the initial rice planting in rice fields (Baba et al. 2018). It was evident that *Zinnia* sp. as habitat was inhabited by spiders of the families of *Araneidae*, *Oxyopidae*, and *Pisauridae* (Desai et al. 2017). The spider (*Oxyopidae*), predatory insects (*Coccinellidae*, *Syrphidae*, and *Geocoridae*), parasitoid and pollinating insects of *Hymenoptera* and *Lepidoptera* were found in large numbers inhabiting *T. erecta* as niche (Ganai et al. 2017).

**Table 2.** Abundance of spiders inhabiting the rice plot surrounded by refugia, vegetables, untreated, and insecticide application

Family and species	Mean of abundance (individual/nets)				F-value	P value (0.05)	Tukey's HSD test
	Rice-refugia	Rice-vegetable	Rice-untreated	Rice-insecticide			
Lycosidae	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.89	0.48	
<i>Pardosa pseudoannulata</i>	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.89	0.48	
Araneidae	0.20 <sup>b</sup>	0.15 <sup>ab</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	7.29	0.01	0.08
<i>Araneus inustus</i>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Cylosa insulana</i>	0.05 <sup>a</sup>	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	1.12	0.38	
<i>Cyrtophora koronadalensis</i>	0.05 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	2.29	0.13	
<i>Neoscona theisi</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Argiope catenulata</i>	0.05 <sup>a</sup>	0.05 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1.14	0.38	
Tetragnathidae	1.55 <sup>c</sup>	1.55 <sup>c</sup>	0.91 <sup>ab</sup>	0.76 <sup>a</sup>	7.72	0	0.24
<i>Tetragnatha javana</i>	0.16 <sup>a</sup>	0.2 <sup>a</sup>	0.15 <sup>a</sup>	0.22 <sup>a</sup>	0.38	0.77	
<i>Tetragnatha virescens</i>	0.73 <sup>a</sup>	0.82 <sup>a</sup>	0.51 <sup>a</sup>	0.4 <sup>a</sup>	2.38	0.12	
<i>Tetragnatha mandibulata</i>	0.35 <sup>b</sup>	0.22 <sup>ab</sup>	0.16 <sup>ab</sup>	0.11 <sup>a</sup>	4.26	0.03	0.12
<i>Tetragnatha ilavaca</i>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
<i>Tetragnatha maxillosa</i>	0.16 <sup>a</sup>	0.07 <sup>a</sup>	0.05 <sup>a</sup>	0 <sup>a</sup>	2.18	0.14	
<i>Tetragnatha vermiformis</i>	0.09 <sup>ab</sup>	0.22 <sup>b</sup>	0.04 <sup>ab</sup>	0.02 <sup>a</sup>	4.09	0.03	0.12
<i>Tetragnatha Okumae</i>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.62	0.62	
<i>Tetragnatha iwahigensis</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Tetragnatha natans</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Linyphiidae	0.16 <sup>a</sup>	0.15 <sup>a</sup>	0.05 <sup>a</sup>	0.15 <sup>a</sup>	1	0.43	
<i>Bathyphantes tagalogensis</i>	0.13 <sup>a</sup>	0.09 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	2.97	0.07	
<i>Bathyphantes</i> sp.	0 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.05 <sup>a</sup>	0.88	0.48	
<i>Erigone bifurca</i>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
<i>Enoplognatha</i> sp.	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.83	0.5	
Unknown	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Oxyopidae	0.15 <sup>a</sup>	0.11 <sup>a</sup>	0.09 <sup>a</sup>	0.04 <sup>a</sup>	0.8	0.52	
<i>Oxyopes javanus</i>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0.69	0.58	
<i>Oxyopes matiensis</i>	0.09 <sup>a</sup>	0.09 <sup>a</sup>	0.09 <sup>a</sup>	0 <sup>a</sup>	0.73	0.56	
<i>Oxyopes pingasus</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Theridiidae	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Theridion</i> sp.	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Salticidae	0.11 <sup>a</sup>	0.09 <sup>a</sup>	0.07 <sup>a</sup>	0.09 <sup>a</sup>	0.13	0.94	
<i>Myrmarachne bidentata</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Hyllus maskaranus</i>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.05 <sup>a</sup>	0 <sup>a</sup>	2.11	0.15	
<i>Cosmophasis parangpilota</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Cosmophasis</i> sp.	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.82	0.51	
<i>Flexipus paykulli</i>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	1	0.43	
<i>Harmochirus brachiatus</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.62	0.62	
<i>Bianor hotingchiehi</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.62	0.62	
<i>Emathis</i> sp.	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Unknown	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
Hahniidae	0 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	
<i>Hahnina tuybaana</i>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.68	0.58	

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Total abundance (N)	2.25 <sup>b</sup>	2.09 <sup>b</sup>	1.22 <sup>a</sup>	1.09 <sup>a</sup>	27.51	0	0.17
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Note: Values within a row followed by the same letters were not significantly different at  $P < 0.05$  according to Tukey's HSD test

**Table 3.** The abundance of predatory insects inhabiting the rice plot surrounded by refugia, vegetables, untreated, and insecticide application for one planting season

Family and species	Mean of abundance (individual/nets)				F-value	P value (0.05)	Tukey's HSD test
	Rice-refugia	Rice-vegetable	Rice-untreated	Rice-insecticide			
HEMIPTERA	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	1.17	0.36	
Miridae	0.07 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	1.17	0.36	
<i>Cyrtorhinus lividipennis</i>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1.46	0.28	
<i>Orthotylus</i> sp.	0.04 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1.29	0.32	
COLEOPTERA	1.09 <sup>b</sup>	0.35 <sup>a</sup>	0.67 <sup>ab</sup>	0.29 <sup>a</sup>	12.75	0	0.20
Carabidae	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Ophionea nigrofasciata</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Staphylinidae	0.27 <sup>a</sup>	0.16 <sup>a</sup>	0.09 <sup>a</sup>	0.11 <sup>a</sup>	2.25	0.14	
<i>Paederus fuscipes</i>	0.27 <sup>a</sup>	0.16 <sup>a</sup>	0.09 <sup>a</sup>	0.11 <sup>a</sup>	2.25	0.14	
Coccinellidae	0.78 <sup>b</sup>	0.16 <sup>a</sup>	0.56 <sup>b</sup>	0.18 <sup>a</sup>	11.72	0	0.19
<i>Micraspis inops</i>	0.38 <sup>b</sup>	0.07 <sup>a</sup>	0.25 <sup>ab</sup>	0.15 <sup>ab</sup>	4.8	0.02	0.16
<i>Verania lineata</i>	0.04 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Micraspis vincta</i>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Harmonia octomaculata</i>	0 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Coccinella repanda</i>	0.05 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.99	0.43	
<i>Brumoides suturalis</i>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.04 <sup>a</sup>	0 <sup>a</sup>	0.88	0.48	
<i>Menochilus sexmaculatus</i>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Unknown	0.25 <sup>b</sup>	0.07 <sup>ab</sup>	0.16 <sup>ab</sup>	0.04 <sup>a</sup>	3.77	0.04	0.13
Elateridae	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Unknown	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Anthicidae	0 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.62	0.62	
<i>Formicomus</i> sp.	0 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.62	0.62	
ODONATA	0.04 <sup>a</sup>	0.09 <sup>a</sup>	0.04 <sup>a</sup>	0.05 <sup>a</sup>	0.66	0.59	
Coenagrionidae	0.04 <sup>a</sup>	0.07 <sup>a</sup>	0.04 <sup>a</sup>	0.04 <sup>a</sup>	0.52	0.68	
<i>Agriocnemis</i> sp.	0.02 <sup>a</sup>	0.05 <sup>a</sup>	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0.47	0.71	
<i>Pyrhosoma</i> sp.	0.02 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.38	0.77	
<i>Argia</i> sp.	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Libellulidae	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0.62	0.62	
<i>Pantala</i> sp.	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0.00 <sup>a</sup>	1	0.43	
Unknown	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	1	0.43	
ORTHOPTERA	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Tettigonidae	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Conocephalus longipennis</i>	0.02 <sup>a</sup>	0.04 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
HYMENOPTERA	0.11 <sup>a</sup>	0.65 <sup>b</sup>	0.35 <sup>ab</sup>	0.05 <sup>a</sup>	7.83	0	0.22
Formicidae	0.11 <sup>a</sup>	0.64 <sup>b</sup>	0.35 <sup>ab</sup>	0.05 <sup>a</sup>	6.48	0.01	0.24
<i>Odontoponera transversa</i>	0.09 <sup>a</sup>	0.64 <sup>b</sup>	0.35 <sup>ab</sup>	0.05 <sup>a</sup>	6.71	0.01	0.24
<i>Solenopsis</i> sp.	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Syrphidae	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
<i>Volucella</i> sp.	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
MANTODEA	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
MANTIDAE	0 <sup>a</sup>	0 <sup>a</sup>	0.02 <sup>a</sup>	0 <sup>a</sup>	1	0.43	
Unknown	1.33 <sup>b</sup>	1.15 <sup>b</sup>	1.11 <sup>b</sup>	0.42 <sup>a</sup>	15.14	0	0.19
Total abundance (N)	14.6 <sup>b</sup>	12.7 <sup>b</sup>	12.2 <sup>b</sup>	4.6 <sup>a</sup>	17.00	0.00	0.74

Note: Values within a row followed by the same letters were not significantly different at  $P < 0.05$  according to Tukey's HSD test

Refugia as niche were capable of providing nectar and pollen as well as preys in form of herbivore or neutral insects. *S. indicum* was capable of providing nectar for parasitoid of rice stem borer (Zhu 2014a) and natural enemies (Coleoptera, Hymenoptera, Neuroptera, and Dictyoptera) (Mahmoud 2012). *S. indicum* was capable of increasing predator capability to prey on herbivores because its nectar and pollen can increase fitness and prey ability of this predator (Zhu 2014b). Feed-in form of nectar

and pollen could prolong the longevity of predatory arthropods and parasitoid, and even synovigenic-type parasitoid urgently requires this feed in order to increase its egg production (Lu et al. 2014; Zhu 2014a). In addition, refugia existence on rice field embankments surrounding the rice could increase flora species diversity in rice fields. The higher the flora species is, the higher the fauna species diversity (arthropods) will be as flora inhabitant (Zhu 2014b).

**Table 4.** Community characteristics of spiders inhabiting the rice plot surrounded by refugia, vegetables, untreated, and insecticide application for one planting season

Rice age (days)	Community characteristics	Rice-refugia	Rice-vegetable	Rice-untreated	Rice-insecticide
14	Number of individual (individuals/net)	0.4	0.2	0	1
	Diversity (H')	0.69	0	0	0.67
	Dominance (D)	0.5	1	0	0.6
	Evenness (E)	1	0	0	0.97
21	Number of individual (individuals/net)	1.2	1.2	0.8	0.8
	Diversity (H')	1.24	0.87	1.04	1.04
	Dominance (D)	0.5	0.67	0.5	0.5
	Evenness (E)	0.90	0.79	1.50	0.95
28	Number of individual (individuals/net)	2	1.8	2	0.8
	Diversity (H')	1.64	1.68	1.33	1.04
	Dominance (D)	0.3	0.33	0.4	0.5
	Evenness (E)	0.92	0.94	0.96	0.95
35	Number of individual (individuals/net)	2.4	3	1	0.8
	Diversity (H')	1.13	0.88	0.67	1.04
	Dominance (D)	0.5	0.53	0.6	0.5
	Evenness (E)	0.81	0.80	0.97	0.95
42	Number of individual (individuals/net)	2.2	2.6	2.4	1.6
	Diversity (H')	1.04	1.31	0.82	1.04
	Dominance (D)	0.45	0.38	0.67	0.5
	Evenness (E)	0.94	0.94	0.75	0.95
49	Number of individual (individuals/net)	3.6	3	1.2	0.2
	Diversity (H')	1.57	1.04	0	0
	Dominance (D)	0.39	0.47	1	1
	Evenness (E)	0.87	0.95	0	0
56	Number of individual (individuals/net)	2.6	2	1.2	0.4
	Diversity (H')	1.18	0.64	0.69	0
	Dominance (D)	0.62	0.8	0.5	1
	Evenness (E)	0.73	0.58	1	0
63	Number of individual (individuals/net)	2.2	2.4	1	1.4
	Diversity (H')	1.64	1.20	1.33	0.96
	Dominance (D)	0.36	0.5	0.4	0.57
	Evenness (E)	1.02	0.86	0.96	0.87
70	Number of individual (individuals/net)	3.2	2.2	1.2	1.2
	Diversity (H')	1.72	1.47	0.64	1.56
	Dominance (D)	0.31	0.36	0.67	0.33
	Evenness (E)	0.88	0.91	0.92	0.97
77	Number of individual (individuals/net)	1.85	1.8	1.2	1
	Diversity (H')	0.98	0.89	0.97	0.96
	Dominance (D)	0.22	0.44	0.33	0.4
	Evenness (E)	0.98	0.89	0.97	0.96
84	Number of individual (individuals/net)	3.2	2.8	1.4	2.85
	Diversity (H')	2.06	1.77	0.80	1.58
	Dominance (D)	0.31	0.36	0.71	0.49
	Evenness (E)	0.90	0.91	0.72	0.81
Total	Number of individual (individuals/net)	24.85	23	13.4	12.05
	Diversity (H')	2.47	2.22	1.99	2.05
	Dominance (D)	0.32	0.39	0.42	0.37
	Evenness (E)	0.77	0.73	0.75	0.76

**Table 5.** Community characteristics of predatory insects inhabiting the rice plot surrounded by refugia, vegetables, untreated, and insecticide application for one planting season

Rice age (days)	Community characteristics	Rice-refugia	Rice-vegetable	Rice-untreated	Rice-insecticide
14	Number of individual (individuals/net)	0.6	0.5	0.2	0.2
	Diversity (H')	0.64	0	0	0
	Dominance (D)	0.7	1	1	1
	Evenness (E)	0.92	0	0	0
21	Number of individual (individuals/net)	1	0.6	1	0.2
	Diversity (H')	0.50	0.6	1.05	0
	Dominance (D)	0.8	0.67	0.40	1
	Evenness (E)	0.72	0.92	0.96	0
28	Number of individual (individuals/net)	0.8	1.6	0	0.4
	Diversity (H')	0.56	0.74	0	0.69
	Dominance (D)	0.81	0.67	0	1
	Evenness (E)	0.75	0.75	0	0.50
35	Number of individual (individuals/net)	0.2	0.2	0.6	0
	Diversity (H')	0	0	0	0
	Dominance (D)	1	1	1	0
	Evenness (E)	0	0	0	0
42	Number of individual (individuals/net)	0.8	1.6	0	0.2
	Diversity (H')	0.56	1.26	0	0
	Dominance (D)	0.75	0.38	0	1
	Evenness (E)	0.81	0.91	0	0
49	Number of individual (individuals/net)	1.2	0.4	0	1
	Diversity (H')	0	0	0	0
	Dominance (D)	1	1	0	1
	Evenness (E)	0	0	0	0
56	Number of individual (individuals/net)	2.2	2.4	3.6	0.8
	Diversity (H')	1.34	0.57	1.38	0
	Dominance (D)	0.36	0.83	0.56	1
	Evenness (E)	0.97	0.52	0.77	0
63	Number of individual (individuals/net)	1.8	0.8	1	0
	Diversity (H')	1.74	0.56	0	0
	Dominance (D)	0.22	0.75	1	0
	Evenness (E)	0.97	0.81	0	0
70	Number of individual (individuals/net)	1.4	0.6	1.4	0.6
	Diversity (H')	0.96	0.64	0.6	0.64
	Dominance (D)	0.57	0.67	0.71	0.67
	Evenness (E)	0.87	0.92	0.86	0.92
77	Number of individual (individuals/net)	2.8	3	3.6	1
	Diversity (H')	0.76	0	1.04	1.33
	Dominance (D)	0.71	1	0.5	0.4
	Evenness (E)	0.69	0	0.75	0.96
84	Number of individual (individuals/net)	1.8	1	0.8	0.2
	Diversity (H')	1.89	1.33	1.39	0
	Dominance (D)	0.22	0.4	0.25	1
	Evenness (E)	0.97	0.96	1	0
Total	Number of individual (individuals/net)	14.6	12.7	12.2	4.6
	Diversity (H')	2.12	1.61	2.06	1.74
	Dominance (D)	0.29	0.55	0.31	0.35
	Evenness (E)	0.76	0.65	0.76	0.84

This research showed that the abundance and species diversity of spider and predatory insects on the rice surrounded by refugia and vegetables were high and tended to have a higher community similarity for spiders and predatory insects than that of other plots. Vegetables (*C. sativus*, *V. sinensis*, *L. acutangula*, and *M. charantia*) have flowers that could provide nectar and pollen, but information related to arthropods associating with flowers on vegetables is not much. Lami et al. (2016) reported that predatory insects, such as ladybird beetles occurred during maize flowering in Northern and Central Italy. During this research period, the flowers of the four vegetables were frequently alight by the community of pollinating insects, spiders, predatory insects, and parasitoids of herbivores. The arthropods inhabiting those vegetables generally were *M. sexmaculatus*, *P. fuscipes*, *Tetragnatha* spp., and *A. catenulata* found on rice fields in this research.

The abundance and species diversity of spiders and predatory insects on the rice sprayed with synthetic insecticide were the lowest because the toxic from the insecticide could kill several arthropods species. This toxic kill not only herbivore, but also spider, predatory insects (Ngin et al. 2017), parasitoid (Svobodová et al. 2017), and pollinating insects (Sgolastra et al. 2016). The synthetic insecticide spraying can also slow down colonization of spider and predatory insects on those plots and can cause these natural enemies migration to other plots that are not sprayed with synthetic insecticide (Lopes et al. 2017).

Finally, the results of this study indicate that the most abundant predatory arthropods (spiders and predatory insects) were found in the rice surrounded by refugia flower and vegetables. The highest species diversity for spiders and predatory insects was also found on the rice surrounded by the refugia and vegetables. Therefore, the rice surrounded by the refugia and vegetables was the most appropriate for habitat and niche of predatory arthropods. Consequently, the refugia and vegetables should be planted along rice field embankments to conserve those useful arthropods.

#### ACKNOWLEDGEMENTS

This research was financially supported by Program of Professor Research Grant of Universitas Sriwijaya, Ministry of Research, Technology and Higher Education, Republic of Indonesia with the budget year of 2018, Contract Number: 0006/UN9/SK.LP2M.PT/2018, 5 June 2018 chaired by Siti Herlinda. We want to thank Program Beasiswa SDM IPTEK, Ministry of Research, Technology, and Higher Education that has given a scholarship for Tili Karenina.

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