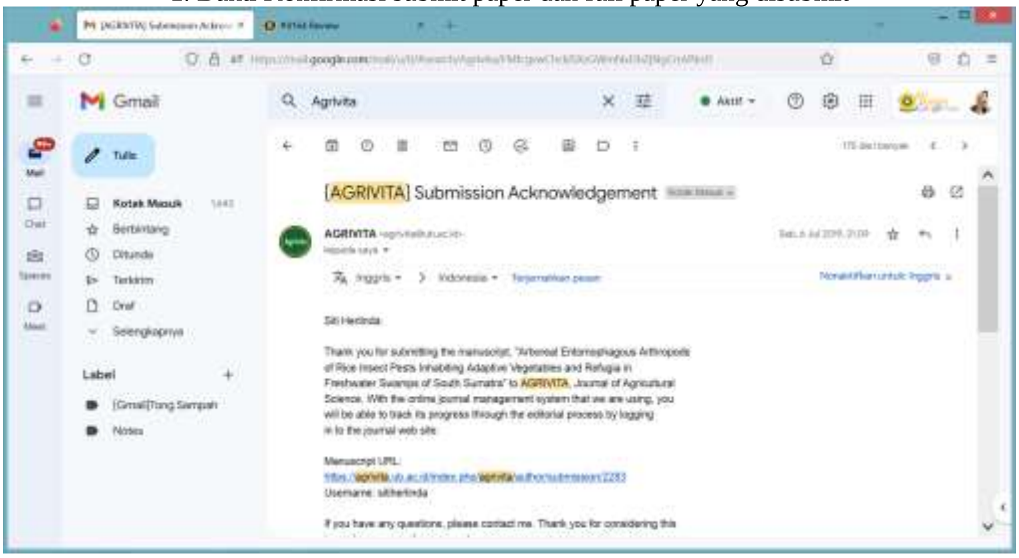
BUKTI KORESPONDENSI
ARTIKEL JURNAL INTERNASIONAL BEREPUTASI

Judul artikel : Arboreal Entomophagous Arthropods of Rice Insect Pests Inhabiting Adaptive Vegetables and Refugia in Freshwater Swamps of South Sumatra
Jurnal : Agrivita
Penulis: Tili Karenina, Siti Herlinda, Chandra Irsan, Yulia Pujiastuti

Bukti korespondensi

No.	Perihal	Tanggal
1.	Bukti Konfirmasi submit paper dan full paper yang disubmit	6 Juli 2019
2.	Bukti konfirmasi review pertama dan hasil revisi pertama	29 April 2020
3.	Bukti konfirmasi review kedua dan hasil revisi kedua	30 April 2020
4.	Bukti konfirmasi paper accepted, uncorrected Proof dan hasil koreksi penulis	6 Mei 2020
5	Bukti tagihan untuk penerbitan artikel	12 Agustus 2020

1. Bukti Konfirmasi submit paper dan full paper yang disubmit



COVER PAGE

Arboreal Entomophagous Arthropods of Rice Insect Pests Inhabiting Adaptive Vegetables and Refugia in Freshwater Swamps of South Sumatra

Tili Karenina[1], Siti Herlinda[1,2,3*], Chandra Irsan[1,23], Yulia Pujiastuti[1,2,3]

[1]Postgraduate Program of Agriculture Sciences, Faculty of Agriculture, Universitas Sriwijaya, Jalan Padang Selasa No. 524, Bukit Besar, Palembang, South Sumatera, Indonesia 30139
[2]Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Sriwijaya, Jalan Raya Palembang-Prabumulih, km 32, Ogan Ilir, Indralaya, South Sumatera, Indonesia 30662
[3]Research Center for Sub-optimal Lands (PUR-PLSO), Universitas Sriwijaya, Jalan Padang Selasa No. 524, Bukit Besar, Palembang, South Sumatera, Indonesia 30139
*Corresponding author: sitiherlinda@unsri.ac.id

II. First author:

1. Name : Tili Karenina
2. Afiliation : Universitas Sriwijaya
3. Orcid ID : Https://orcid.org/0000-0001-9175-899X
4. Contribution to this Manuscript: Focused on survey and assiting insect identification

III. Corresponding author:

1. Name : Siti Herlinda
2. Afiliation : Universitas Sriwijaya
3. E-mail : sitiherlinda@unsri.ac.id
4. Orcid ID : https://orcid.org/0000-0003-1460-7199
5. Contribution to this Manuscript: made the whole research design, managed the whole research, drafted and finalized the manuscript

IV. Third author:

1. Name : Chandra Irsan
2. Afiliation : Universitas Sriwijaya
3. E-mail : chandrairsan@fp.unsri.ac.id
4. Orcid ID : https://orcid.org/0000-0002-3474-9517
5. Contribution to this Manuscript: focused on insect identification

V. Fourth author:

1. Name : Yulia Pujiastuti
2. Afiliation : Universitas Sriwijaya
3. E-mail : ypujiastuti@unsri.ac.id
4. Orcid ID : https://orcid.org/0000-0003-3204-9039
5. Contribution to this Manuscript: focused on conduting data analysis.

VI. Acknowledgement

This research was supported financially by Program of Professor Research Grant (Penelitian Unggulan Profesi) of Universitas Sriwijaya, Ministry of Research, Technology and Higher Education, Republic of Indonesia with budget year of 2019, Contract Number: SP DIPA-042.01.2.400953/2019 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, a postgraduate student.

VI. Reviewers Candidate :

1. Eka Chandra Lina, Scopus ID: 55780641000, E-mail: eka_candra@faperta.unand.ac.id
2. Novri Nelly, Orcid ID: https://orcid.org/0000-0003-3830-3763. E-mail: novrinelly@yahoo.com
3. Shahabuddin Saleh, Scopus ID: 35335106500, Email: shahabsaleh@gmail.com
4. Maoye Li, Scopus ID: 55828064600, E-mail: sj412bq@163.com
5. Jae Su Kim, Scopus ID: 55161782900, E-mail: jskim10@jbnu.ac.kr

Arboreal Entomophagous Arthropods of Rice Insect Pests Inhabiting Adaptive Vegetables and Refugia in Freshwater Swamps of South Sumatra

Running Title: Entomophagous Arthropods of Rice Pests

ABSTRACT

Plants growing around rice fields are habitats and niches for entomophagous arthropods. This study aimed to identify species of entomophagous arthropods of rice insect pests and to analyze their abundance and community in adaptive vegetables and refugia in freshwater swamps. The rice was surrounded by 4 species of refugia (*Zinnia* sp., *Tagetes erecta, Cosmos caudatus, Sesamum indicum*) and 4 species of vegetables (*Vigna unguiculata, Momordica charantia, Cucumis sativus, Luffa acutangula*) and arthropods were sampled using nets. The results showed that all predatory arthropods and parasitoids found were 67 and 22 species, respectively. The predatory arthropod species were mostly found in rice (51 species), refugia of *Zinnia* sp. (15 species), and vegetables of *M. charantia* (9 species). Most parasitoid species were found in rice (19 species), *Zinnia* (7 species), and *M. charantia* (6 species). The predatory arthropods that were dominantly found were *Tetragnatha javana, Tetragnatha virescens,* and *Paederus fuscipes*, while the dominant parasitoid were *Cardiochiles* sp., *Elasmus* sp., and *Snellenius* sp. *Zinnia* sp. and *M. charantia* were most chosen by the entomophagous arthropods as an habitat besides rice; however, economically *M. charantia* is more beneficial than *Zinnia* sp. because it has double function for land productivity and conservation of natural enemies.

KEYWORDS

Habitats, herbivores, natural enemies, niches, parasitoid, and predator

INTRODUCTION

Wetlands are land saturated with water, both year-round and seasonal. Wetlands in Indonesia generally consist of freshwater (non-tidal) swamps and tidal lowlands. Freshwater swamps are wetlands which are flooded due to the influence of river water or rain, while the lowland tidal is inundated due to the influence of tides. According to Margono et al. (2014) the wetland area in Indonesia is around 39.6 Mha, 77% of which is spread on Sumatra Island (11.9 Mha), Kalimantan (12.2 Mha), and Papua (11.8 Mha), while the remaining 23% are spread in Java (1.9 Mha), Sulawesi (1.2 Mha), Maluku (0.5 Mha), and Bali-Nusa Tenggara (0.2 Mha).

Freshwater swamps in South Sumatra are generally inundated from November to April or May depending on the lowland typology, and in dry season the land often undergoes drought (based on direct observation in the center of freshwater swamps, Ogan Ilir District, South Sumatra from 2012 to March 2019). In freshwater swamps of South Sumatra, when they are inundated, some local farmers raise swamp fish or local "pegagan" ducks, while in the dry season they grow rice (Lakitan et al. 2018) or vegetables adaptive to freshwater swamps (Lakitan et al., 2019). Another local hereditary habit is when they grow rice, they also grow adaptive vegetables in rice fields. Some adaptive vegetables in freshwater swamps include cowpea (*Vigna unguiculata*) (Bhaskar et al., 2010), cucumber (*Cucumis sativus*) (Baptiste & Smardon, 2012), ridged gourd (*Luffa acutangula*) and bitter melon (*Momordica charantia*) (Widuri et al., 2016), chili pepper (*Capsicum annum L.*) (Alert et al., 2018), common bean (*Phaseolus vulgaris*) (Lakitan, 2019), and tomatoes (Emile et al., 2012). Without realizing it by local farmers, the vegetables planted around the rice fields have multiple functions. Besides being able to increase land productivity, these vegetables can provide natural habitats and niches for natural enemies of the rice insect pest

Cowpeas are inhabited by 21 insect species of 12 families and 5 orders (Coleoptera, Hemiptera, Orthroptera, Homoptera, and Lepidoptera) (Niba, 2011). Cucumbers are visited by 11 insect species of 7 families and 3 orders (Hymenoptera, Diptera, and Coleoptera) (Hossain et al., 2018). Ridged gourds are inhabited by 6 insect species of 3 families and 2 orders (Hymenoptera and Diptera), while bitter melons are visited by 4 insect species of 3 families and 2 orders (Bodlah & Waqar, 2013). Chili pepper is visited by 41 species of arthropods consisting of 14 species of pests and natural enemies, 12 species of visitors and 1 species of pollinator (Kaur & Sangha, 2016).

The diversity of arthropods in freshwater swamps is also supported by the presence of flowering wild plants or non-crop plants as refugia around rice fields. Non-crop plants and refugia provide niches, additional food, and other resources for natural enemies of rice pests (Zhu et al., 2014; Hasan et al., 2016; Benvenuti & Bretzel, 2017; Lopes et al., 2017; McCabe et al., 2017). Grassy rice fields in ecosystems that are directly planted have a higher number of arthropods than those in non-weed ecosystems (Hu et al., 2012). The existence of refugia sunflower plants (*Helianthus annuus*), indian mustard (*Brassica juncea*), sesame (*Sesamum indicum*), marigold (*Tagetes erecta*), kenikir (*Cosmos caudatus*), and Zinnia (*Zinnia sp.*) is known to be effective in reducing the attack of leaf-rolling pests (*Cnaphalocrocis medinalis*) in several rice varieties in India (Desai et al., 2017). Refugia of marigold is reported to be associated with several species of predatory arthropods such as *Oxyopes javanus, Coccinella septumpunctata, Syrphus* spp., and *Geoceris* spp. (Ganai et al., 2017). Zinnia is also reported to be associated with several species of spiders including *Argiope aemula, Oxyopes* sp., and *Perenethis* sp. (Desai et al., 2017). Consequently, vegetables and flower refugia are beneficial for habitat and niches of entomophagous arthropods (parasitoid and predatory arthropods) which are natural enemies of insect pests; yet, the species unknown to the entomophagous arthropods are associated with vegetables and refugia in freshwater swamps of South Sumatra. This study aimed to identify species of entomophagous arthropods of rice insect pests and to analyze their abundance and community in adaptive vegetables and refugia in freshwater swamps.

MATERIALS AND METHODS

The field experiment was carried out in the center of freshwater swamps in the Pelabuhan Dalam Village of Pemulutan Subdistrict, Ogan Ilir District, South Sumatra Province from May to

September 2018. The area of rice fields is around 7.1 Mha. The species identification was carried out in the laboratory from September 2018 to May 2019.

Planting of Rice, Vegetables, and Refugia

The rice plot used an area of 1 ha, surrounded by 4 species of refugia and 1 ha of rice surrounded by 4 vegetable species with the distance between plots was around 100 m. The 1 ha area plot was divided into three sub-plots used as replications. Each rice subplot was surrounded by 4 species of refugia (*Zinnia* sp*., T. erecta, C. caudatus,* and *S. indicum*), as well as other rice subplots surrounded by 4 vegetable species (*V. unguiculata*, *M. charantia*, *C. sativus*, *L. acutangula*). The position of the 4 refugium species or the 4 species of vegetables in each rice sub-plot was in four embankments surrounding the sub-plot and each embankment was planted with one plant species. In consequence, the four embankments surrounding the rice subplots were planted with different species of refugia or vegetables. This choice of position was to give entomophagous arthropods freedom to choose alternative habitats other than rice. The planting of refugia and vegetables was carried out 30 days before planting the rice so that when it entered the vegetative phase of the age of 14 days after transplanting (DAT), the refugia would have been blooming. The distance of planting vegetables followed the habits of the local farmers (30 cm), meanwhile, the refugia was planted closely (15 cm) per hole containing 5 individuals.

The rice was planted according to the habits of the local farmers but it applied 2:1 "jajar legowo" spacing (50 cm x 25 cm x 12.5 cm) and did not use synthetic pesticides; the fertilizing used manure at a dose of 1 ton/ha and 2 L compost extract liquid whose manufacturing method followed that of Suwandi et al. (2012). The rice planting began with the land preparation by cultivating the soil and at the same time applying the manure fertilizer. Then, the rice seeds were sown according to the traditions of local farmers, using the "samir" method, i.e. the seeds of 7-10 days old were transplanted into the fields. When the rice plant reached 2 weeks after planting, the fertilization was applied using liquid compost extract every 2 weeks.

Sampling the arboreal arthropods inhabiting refugia and vegetables

Sampling the arthropod inhabiting flowers of refugia and vegetables surrounding the rice was conducted once a week starting when it was 14 to 84 DAT. The sampling was carried out twice for every observation, i.e. in the morning from 7:00 to 08:00 and in the afternoon from 16:00 to 17:00. The sampling was carried out by randomly taking 5 flowers for each species of refugia and vegetables. The flowers were cut from the their stalks and put them in a 150 ml plastic container (diameter = 7 cm and height = 6.5 cm) perforated on the lid with a diameter of 2 cm and covered with gauze glued together. Each flower was put into a plastic container separately and labeled. Having been put into plastic containers, the flowers were left that way and observed until the arthropods were produced out of the flower. These produced arthropods were separated from the flowers and put into a 10 ml glass bottle containing 80% ethanol. The glass bottles containing arthropods were labeled and then identified in the Entomology Laboratory of the Department of Plant Pests and Diseases of the Faculty of Agriculture, Universitas Sriwijaya. The identification of spiders referred to Barrion &

Litsinger (1995) and the identification of insects referred to Heinrichs (1994), Kalshoven (1981), and McAlpine et al. (1987).

Sampling of Arboreal Arthropods in Rice

Observation of the arthropods was conducted weekly starting when the rice reached the age of 14 to 84 DAT. The sampling of the arboreal arthropods for the observations used nets (the net handle of 100 cm in length, the net length of 75 cm, and 30 cm net diameter) at five points scattered in four corners of the land and one in the middle of the land for each subplot study (3 subplots as a repetition). The sampling was carried out in the morning from 06.00 to 07.00 in good weather condition with no rain. The collection of arthropods with nets was carried out based on the modification of Janzen method (2013), i.e. the arthropods were collected by swinging a net of one double swing in a straight line at a depth of 30 cm in the canopy of the plants. The net coverage was based on the modified methods of Masika et al. (2017) by swinging a net tied on a plant stem. The nets were intentionally applied to the rice stems to obtain insects on the stems and leaves of the rice plants. The obtained arthropods were sorted, put into vial bottles containing 80% ethanol, labeled, and then identified in the laboratory. The identification of the spiders referred to Barrion & Litsinger (1995), and identification of insects referred to Heinrichs (1994), Kalshoven (1981), and McAlpine et al. (1987).

Data Analysis

The data on species composition and abundance of entomophagous arthropods inhabiting refugia or vegetables were presented in tables and charts. Their subsequent abundance data were also grouped according to guilds, namely predators, parasitoid, herbivore, and neutral insect to be displayed in graphical form. A correspondence analysis was used to investigate how species of arthropods and plants (refugia, vegetables and rice) fell into groups, based on the arthropod species they interacted with (Raffaelli & Hall 1992) and the species of data analyzed were grouped in species community of predators, parasitoid, herbivore, and neutral insects. Calculation of the correspondence analysis used the software of SAS University Edition 2.7 9.4 M5.

RESULTS AND DISCUSSION

Species Composition and Abundance of Arboreal Entomophagous Arthropods

Arboreal entomophagous arthropods are arthropods acting as predators and parasitoid for natural enemies of insect pests. In this study, arboreal entomophagous arthropods found in rice were grouped into predatory arthropods and parasitoids. Predatory arthropods consisted of groups of spiders and predatory insects, while parasitoid was a group of insects that were parasitic to insects or other arthropods. The total numbers of the species of predatory arthropods and parasitoids found were 67 species (Table 1) and 22 species (Table 2) respectively. In rice alone, the number of species of predatory arthropods was found the most number (51 species) compared to refugia and vegetables. In refugia, the most species predatory arthropods were found in *Zinnia* sp. (15 species), while the most vegetables were found in *M. charantia* (9 species). The predatory arthropods' preference for refugia, *S. indicum* as their least habitat was the least in number, while *L. acutangula* was a vegetable plant less chosen as the habitat by the predatory arthropods.

The five species of arboreal predatory arthropods dominantly found in rice were *Tetragnatha javana, Tetragnatha virescens, Tetragnatha mandibulata, Paederus fuscipes,* and *Micraspis inops*. Of the five species in the rice, the four species (*T. javana, T. virescens, T. mandibulata,* and *P. fuscipes*) were found, including those in *Zinnia* sp., whereas in *M. charantia,* two species of the predatory arthropods were found (*T. virescens* and *M. inops*). In addition, there were other predatory arthropods found in rice, refugia, and vegetables, namely *O. javanus, Oxyopes matiensis, Menochilus sexmaculatus,* and *Coccinella septempunctata*.

In this study, the species arboreal predatory arthropods found in rice, refugia, and vegetables were important predators attacking insect pests of rice. *T. javana, T. virescens,* and *T. mandibulata* are family spiders of Tetragnathidae that can prey on orders of Homoptera and Lepidoptera in rice (Tahir et al., 2009). Betz and Tscharntke (2017) added that the Tetragnathidae also prey on orders of Homoptera (leafhoppers) on rice. *P. fuscipes* is a predator of *Nilaparvata lugens* (Meng et al., 2016) and *M. inops* is an insect pest of rice generalist predator (Karindah et al., 2011). *O. javanus* effectively preys on *Hieroglyphus banian, Sogetella furcilera, Marasmia patnalis,* and *Scripophaga innotata* on rice in Pakistan (Tahir & Butt, 2009). *T. virescens* effectively controls *S. furcifera* on rice in India (Prasad, Prabhu, & Balikai, 2015). Coccinellidae prey on *N. virescens*, *N. lugens* and *S. furcifera* on rice in India (Shanker et al., 2018).

The number of species of parasitoids were the most commonly found in rice (19 species) compared to refugia and vegetables. In refugia, the most species of parasitoids were found in *Zinnia* sp. (7 species), whereas in most vegetables were found those in *M. charantia* (6 species) (Table 2). The dominant parasitoids found in rice were *Cardiochiles* sp. and this species was also found in *Zinnia* sp. and *M. charantia*. *Cardiochiles* sp. is a parasitoid effectively controlling *medinal Caphaphococci* in rice (Behera 2012). In addition, at *Zinnia* sp., *Snellenius* sp. and *Elasmus* sp*.,* were found, while *Blondelia sp.* in *M. charantia* was also found. *Snellenius* sp. is a parasitoid of *Spodoptera litura* larvae (Javier & Ceballo 2018). *Elasmus* sp*.* is a parasitoid attacking *dominulus polystes* (Gumovsky et al., 2007), while *Blondelia* sp. generally attacks Lepidoptera of the Geometridae family (Cutler et al., 2015).

If only comparing refugia and vegetables without rice, the abundance of predatory arthropods is higher than in any of the following three habitats, namely *Zinnia* sp*., T. erecta,* and *M. charantia*, while parasitoid is high in *Zinnia* sp*., S. indicum,* and *M. charantia* (Fig. 1). Refugia and vegetables were preferred by both entomopahgous arthropods because they had good morphological attraction, long flower blooms, and the availability of floral nectar and pollen. In this study, the flowers of *T. erecta, S. indicum,* and *M. charantia* were preferred by the entomophagous arthropods (Fig. 2) compared to other colors because of their yellow flowers. The data were in line with the study results of Rocha-Filho and Rinaldi (2011) stating that yellow flowers were preferred arthropods compared to white and pink flowers. Of the four species of plants, despite having red color, the flowers of *Zinnia* sp. were the most preferred due to its longest blooming period compared to other flowers. The flowers of *Zinnia* sp*.* bloom for 23.67 days (Wahocho et al., 2016). The form of flower rosette of *Zinnia* sp*., T. erecta,* and *M. charantia* is also a high attraction for predators and parasitoid. In line with the opinion of Jennings et al. (2017), rosette-shaped flowers are longer visited by arthropods. Pollen and nectar from the refugia and vegetable flowers become high attraction for niche arthropods, such as spiders (Eggs & Sanders, 2013) and parasitoids (Foti et al., 2017).

Based on the time of visiting flowers there was an interesting phenomenon. Predators, especially spiders, their visiting time to refugia and vegetables was high from 7:00 a.m. to 08:00 a.m. and from 4:00 p.m. to 5:00 p.m. (Fig. 3), while the parasitoid generally visited the flowers from 7:00 a.m. to 08:00 p.m. (Fig. 4). *Zinnia* sp*., T. erecta,* and *M. charantia* were visited by the predators in the morning and evening time frequency more often than any of the other refugia or vegetable species. This is related to the longest blooming period of *Zinnia* sp. described previously. Predators generally visit refugia and vegetables in the morning and evening since the predators search for prey there and the prey they need is more than the parasitoid host needs. For example, spiders have periods of predation ranging from 5 a.m. to 10 p.m. (Arango et al. 2012). As for parasitoid, their activity of visiting refugia and vegetables is generally carried out in the morning due to parasitoid looking for pollen and nectar there; while the direct observation result showed that the host's activity by parasitoid was generally conducted in rice. Quite similarly, Schmidt et al. (2012) stated that in the morning parasitoid is generally looking for plants that produce nectar and pollen for their feed. The availability of nectar and pollen generally occurs in the morning because many flowers bloom in the morning. Therefore, the existence of flower-producing refugia and vegetables around rice is useful in providing alternative habitats and niches to the parasitoids and predators of rice pest insects.

Community of Arboreal Arthropods in One Rice Growing Season

Arthropods can be grouped into groups of guilds, namely predators, parasitoids, herbivores, and neutral insects. The data showed that the four species of refugia were generally dominated by predators and parasitoids, while the four vegetable species were dominated by parasitoids and herbivores. The rice were dominated by herbivores, but the predators followed the development of the population of herbivores, the higher the population of herbivores was, the higher the abundance of predators would be. These data showed that in rice, predators played a role in suppressing herbivores compared to parasitoid populations and this is in line with the study results of Settle et al. (1996) and Herlinda et al. (2018). Neutral insects were also high in rice plants, while the lowest one was the abundance of parasitoids. In *S. indicum* and *V. unguiculata*, neutral insects were high due to the presence of honeydew hunter ants produced by homopterous insects inhabiting both plants (Fig. 5). From the data, an interesting phenomenon was found in refugia, especially in *Zinnia* sp., parasitoid and predator were found to be more abundant at the beginning of the rice growing season, while when the rice was at 35 DAT the abundance of both entomophagous arthropods at *Zinnia* sp. began to decrease, whereas in the early rice planting the abundance of the parasitoid began to increase at 42 DAT and the predator abundance began to increase at 21 DAT. According to Settle et al. (1996) the population dynamics in rice is affected by the flow of the entomophagous arthropods from surrounding non-crop plants and vegetables to rice, and vice versa and this can occur if habitats and other niches are available around the rice fields that are appropriate for the arthropods.

Figures 6, 7, and 8 showed the results of the correspondence analysis at vegetative, milky, and ripening stage of rice, respectively. When rice was at vegetative stage, the species of predatory arthropods inhabiting rice, vegetables and refugia generally have high community similarity, except the arthropod that inhabits cowpea (Fig. 6a). The found predatory arthropods gathered in these plants, including *Pardosa pseudoannulata, Cyrtophora koronadalensis,* and *Neoscona theisi* which were the hunting spiders. Species composition in rice, refugia, and vegetables had a high similarity and this showed that the predatory arthropods actively transferred from rice to vegetables and refugia or vice versa. Their displacement was caused by the rice inhabited by herbivores, such as *N. lugens, Sogatella furcifera,* and *Spodoptera* sp. (Fig. 6c) which were the main preys for the predatory arthropods, while the alternative prey was neutral insects in rice, such as *Tetanocera* sp*., Tipula maxima,* and *Psorophora* sp. (Fig. 6d). The parasitoid species composition in rice was a high resemblance to the parasitoid at zinnia and bitter melon (Fig 6b). Thus, zinnia and bitter melon were preferred by the parasitoids as habitats and alternative niches besides rice. In line with the result of the study by Settle et al. (1996) the flow of spiders among habitats was due to generalist predators seeking preys in alternative habitats. The species of parasitoid composition in rice were generally similar to those in the vegetable and refugia species, except those inhabiting marigolds and ridged gourd. The species of neutral insects in rice were most similar to the neutral species inhabiting bitter melon.

When rice was at the milky stage, the predatory arthropod species composition in rice was quite similar to the arthropods that inhabited bitter melon, sesame, zinnia, "kenikir", and marigold. The arthropod species grouped in these plants were *Coccinella repanda, T. virescens, Tagalogensis Bathyphantes,* and *O. javanus* (Fig. 7a). The parasitoid species composition inhabiting rice such as *Cardiochiles sp.* and *Sarcophagidae* (Fig. 7b) was quite similar to the parasitoid inhabiting cucumber and bitter melon. The herbivore composition species in rice were most similar to those of herbivores inhabiting zinnia and marigolds, particularly *Leptocorisa acuta* species. The species of herbivores found in rice *were N. lugens, S. furcifera,* and *L. acuta* (Fig. 7c). The predatory arthropods found in bitter melon, sesame, zinnia, "kenikir", marigold were the predators of *N. lugens, S. furcifera, L. acuta* in rice. The neutral insect species *(Chironomus sp.* and *Tipula maxima*) (Fig. 7d) in rice and marigolds were preys for these predatory generalists. Thus, the flow of species from refugia and vegetables to rice occur if the rice is in preys for predatory generalists. This result is quite similar to those conducted by Settle et al. (1996) and Herlinda et al. (2018).

When rice was at ripening stage, the species of predatory arthropod composition inhabiting the rice was more similar to the arthropods inhabiting zinnia, "kenikir", and cowpea and those predatory species were *P. pseudoannulata, Cylosa insulana, Cyrtophora koronadalensis,* and *T. javana* (Fig. 8a); while the herbivore species were available in rice including *N. lugens* and *L. acuta* (Fig 8c) and other alternative preys were neutral insects, such as *Tetanocera* sp. and *T. maxima* (Fig. 8d). The species of parasitoid composition in rice was quite similar to the parasitoid composition that inhabited bitter melon and zinnia. The results of this study showed that the predators and parasitoid rice pests were found in refugia and vegetables. The refugia species most often chosen by the predators and parasitoid of rice pest as an alternative habitat besides rice were *Zinnia* sp. As for the vegetables, they were most fond of bitter melon.

CONCLUSIONS AND SUGGESTION

Of the 4 species of refugia (*Zinnia* sp*., T. erecta, C. caudatus,* and *S. indicum*) which were mostly chosen by the entomophagous arthropods as an alternative habitat in addition to rice, it was Zinnia sp. Of the 4 species of vegetables (*V. unguiculata, M. charantia, C. sativus,* and *L. acutangula*), the most preferred habitat alternative for the entomophagous arthropods was *M. charantia*. However, economically *M. charantia* was more beneficial than *Zinnia sp.* to be used in the conservation of entomophagous arthropods because in addition to habitats and niches for the entomophagous arthropods, *M. charantia* planting was also for land productivity.

REFERENCES

Arango, A. M., López-Portillo, J., Parra-Tabla, V., Hernández-Salazar, L. T., Morales-Mávil, J. E., Rico-Gray, V. (2012). Effect of the spider *Peucetia viridans* (Oxyopidae) on floral visitors and seed set of *Cnidoscolus multilobus* (euphorbiaceae). *Acta Botanica Mexicana*, 100, 1–14. http://www.scielo.org.mx/pdf/abm/n100/n100a1.pdf

Baptiste, A. K., & Smardon, R. (2012). A review of wetland use and management of the Nariva Swamp, Trinidad. *Caribbean Geography*, 17(1–2), 73–91. https://www.researchgate.net/publication/273001155

Barrion, A., & Litsinger, J. (1995). *Riceland spiders of South and Southeast Asia*. Entomology Division International Rice Research Institute Philippines.

Behera, K. S. (2012). Biology of *Cardiochiles nigricollis* Cameron, a larval endo-parasitoid of *Cnaphalocrocis medinalis* (Guen.) and *Marasmia exigua* Butler. *Journal of Biological Control*, *26*(4), 376–379. http://www.informaticsjournals.com/index.php/jbc/article/download/3485/2570

Benvenuti, S., & Bretzel, F. (2017). Agro-biodiversity restoration using wildflowers: what is the appropriate weed management for their long-term sustainability?. *Ecological Engineering*, 102, 519–526. https://doi.org/10.1016/j.ecoleng.2017.02.062

Betz, L., & Tscharntke, T. (2017). Enhancing spider families and spider webs in Indian rice fields for conservation biological control, considering local and landscape management. *Journal of Insect Conservation*, 21(3), 495–508. https://link.springer.com/article/10.1007/s10841-017-9990-2

Bhaskar, B. P., Baruah, U., Vadivelu, S., Raja, P., Sarkar, D. (2010). Remote sensing and GIS in the management of wetland resources of Majuli Island, Assam, India. *Tropical Ecology*, 51(1), 31–40. https://www.researchgate.net/publication/280251875

Bodlah, I., & Waqar, M. (2013). Pollinators visiting summer vegetables ridge gourd (*Luffa acutangula*), bitter gourd (*Momordica charantia* L.) and brinjal (S*olanum melongena*). *Asian Journal of Agriculture and Biology*, 1(1), 8–12. https://www.researchgate.net/publication/311644274

Cutler, G. C*.,* Gariepy, T. D., De Silva, E. C. A., Hilier, N. K. (2015). High rates of parasitism of blueberry spanworm (Lepidoptera: Geometridae) by Ichneumonidae and Tachinidae in commercial lowbush blueberry fields High rates of parasitism of blueberry spanworm

(Lepidoptera: Geometridae) by Ichneumonidae and Tachinidae. *Journal of Pest Science*, 88, 219–223. https://link.springer.com/article/10.1007/s10340-015-0650-6

Desai, S. D., Swaminathan, R. Desai, V. S. (2017). Effect of habitat manipulation on infestation of paddy leaf folder, *Cnaphalocrocis medinalis* (Guenee). *Int.J.Curr.Microbiol.App.Sci*, 6(10), 1469–1477. https://doi.org/10.20546/ijcmas.2017.610.174

Eggs, B., & Sanders, D. (2013). Herbivory in spiders: The importance of pollen for orb-weavers. *PLoS ONE*, 8(11), 1–5. https://doi.org/10.1371/journal.pone.0082637

Emile, T., Honorine, N.T., Thomas N., Marie-Anne, S. (2012). Vegetable production systems of swamp zone in urban environment in west cameroon: case of Dschang city. *Universal Journal of Environmental Research and Technology All*, 2(2), 83–92. http://www.environmentaljournal.org/2-2/ujert-2-2-9.pdf

Foti, M. C., Rostás, M., Peri, E., Park, K. C., Slimani, T., Wratten, S. D., Colazza, S. (2017). Chemical ecology meets conservation biological control: identifying plant volatiles as predictors of floral resource suitability for an egg parasitoid of stink bugs. *Journal of Pest Science*, 90(1), 299–310. https://link.springer.com/article/10.1007/s10340-016-0758-3

Ganai, S. A., Ahmad, H., Sharma, D., Sharma, S. (2017). Diversity of arthropod fauna associated with marigold (*Tagetes erecta* L.) in Jammu. *Journal of Entomology and Zoology Studeis*, *5*(5), 1940–1943. http://www.entomoljournal.com/archives/2017/vol5issue5/PartY/5-5-193-255.pdf

Gumovsky, A., Rusina, L., Firman, L. (2007). Bionomics and morphological and molecular characterization of *Elasmus schmitti* and *Baryscapus elasmi* (Hymenoptera: Chalcidoidea, Eulophidae), parasitoids associated with a paper wasp, *Polistes dominulus* (Vespoidea, Vespidae). *Entomological Science*, 10, 21–34. https://doi.org/10.1111/j.1479-8298.2006.00195.x

Hasan, K., Pervin, M., Manda, F., Mala, M. (2016). Habitat management: a key option to enhance natural enemies of crop pest. *Universal Journal of Plant Science*, 4, 50–57. http://www.hrpub.org/journals/article_info.php?aid=5517

Heinrichs, E. A. (1994). *Biology and management of rice insect*. International Rice Research Intitute.

Herlinda, S., Yudha, S., Thalib, R., Khodijah, Suwandi, Lakitan, B., Verawaty, M. (2018). Species richness and abundance of spiders inhabiting rice in fresh swamps and tidal lowlands in South Sumatera, Indonesia. *J. ISSAAS*, 24, 82–93. https://www.cabdirect.org/cabdirect/abstract/20183221277

Hossain, M. S., Yeasmin, F., Rahman, M. M., Akhtar, S., Hasnat, M. A. (2018). Role of insect visits on cucumber (*Cucumis sativus* L.) yield. *J. biodivers. conserv. bioresour. manag.*, 4(2), 81–88. https://doi.org/10.3329/jbcbm.v4i2.39854

Hu, S., Fu, D. Y., Liu, X. J., Zhao, T., Han, Z. L., Lu, J. P., Wan, H. L., Ye, H. (2012). Diversity of planthoppers associated with the winter rice agroecosystems in Southern Yunnan, China. *Journal of Insect Science*, 12(29), 1–11. https://doi.org/10.1673/031.012.2901

Janzen, D. H. (2013). Differences in insect abundance and diversity between wetter and drier sites during a tropical dry season. *Ecology*, 49(1), 96–110. https://www.jstor.org/stable/1933565

Javier, A. M. V. (2018). Life history and biological control potential of *Snellenius manilae* Ashmead

(Hymenoptera: Braconidae), a parasitoid of *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae). *Philipp Agric Scientist*, 101(2), 148–157. https://www.researchgate.net/publication/326981932_Life_History_and_Biological_Control_Potential_of_Snellenius_manilae_Ashmead_Hymenoptera_Braconidae_a_Parasitoid_of_Spodoptera_litura_Fabricius_Lepidoptera_Noctuidae

Jennings, D. T., Longcore, J. R., Bird, J. E. (2017). Spiders (Araneae) inhabit Lepidopteran-feeding shelters on ferns. *J. Acad. Entomol. Soc.* 13, 5–14. http://acadianes.org/journal/papers/jennings_16-3.pdf

Kalshoven, L. G. (1981). The pest of crops in Indonesia. Van Hoeve, Jakarta : PT. Ichtiar Baru.

Karindah, S., Yanuwiadi, B., Sulistyowati, L., Green, P. T. (2011). Abundance of *Metioche vittalicollis* (Orthoptera: Gryllidae) and natural enemies in a rice agroecosystem as influenced by weed species. *Agrivita*, 33(2), 133–141. http://doi.org/10.17503/agrivita.v33i2.55

Kaur, G., & Sangha, K. S. (2016). Evaluation of yellow sticky trap shapes for capturing alate insects in chilli agroecosystem. *Journal of Insect Science*, 29(1), 67–72. https://www.researchgate.net/publication/305771775

Lakitan, B., Alberto, A., Lindiana, L., Kartika, K., Herlinda, S., Kurnianingsih, A. (2018). The benefits of biochar on rice growth and yield in tropical riparian wetland, South Sumatra, Indonesia. *Chiang Mai University Journal of Natural Sciences*, 17(2), 111–126. http://cmuj.cmu.ac.th/ns/full/2120180410110810.pdf

Lakitan, B. 2019. Cultivation of common bean (*Phaseolus vulgaris* L.) subjected to shallow water table at riparian wetland in South Sumatra, Indonesia. *Australian journal of crop science*, 13(1), 98–104. https://www.researchgate.net/publication/332009012_Cultivation_of_common_bean_Phaseolus_vulgaris_L_subjected_to_shallow_water_table_at_riparian_wetland_in_South_Sumatra_Indonesia

Lakitan, B., Lindiana, L., Widuri, L. I., Kartika, K., Siaga, E., Meihana, M. (2019). Inclusive and Ecologically-Sound Food Crop Cultivation at Tropical Non-Tidal. *AGRIVITA*, 41(1), 1–9. http://doi.org/10.17503/agrivita.v40i0.1717

Lopes, S. de F., Ramos, M. B., de Almeida, G. R. (2017). The role of mountains as refugia for biodiversity in Brazilian Caatinga: Conservationist implications. *Tropical Conservation Science*, 10: 1–12. https://doi.org/10.1177%2F1940082917702651

Margono, B. A., Bwangoy, J. R. B., Potapov, P. V., Hansen, M. C. (2014). Mapping wetlands in Indonesia using landsat and PALSAR data-sets and derived topographical indices. *Geo-Spatial Information Science*, 17(1), 60–71. https://doi.org/10.1080/10095020.2014.898560

Masika, F. B., Masanza, M., Aluana, G., Barrigossi, A. F., Kizito, E. B. (2017). Abundance, distribution and effects of temperature and humidity on arthropod fauna in different rice ecosystems in Uganda. *Journal of Entomology and Zoology Studies*, 5(5), 964–973. https://www.researchgate.net/publication/321676101_Abundance_distribution_and_effects_of_temperature_and_humidity_on_arthropod_fauna_in_different_rice_ecosystems_in_Uganda

McAlpine, J. F., Peterson, B. V., Shewel, G. E., Teskey, H. J., Vockeroth, J. R., Wood, D. M., (1987).

Manual of Neartic Diptera. Agriculture Canada, Research Branch.

McCabe, E., Loeb, G., Grab, H. (2017). Responses of crop pests and natural enemies to wildflower borders depends on functional group. *Insects*, 8(73), 1–8. https://doi.org/10.3390/insects8030073

Meng, J., Mabubu, J. I., Han, Y., He, Y., Zhao, J., Hua, H., Feng, Y., Wu, H. (2016). No impact of transgenic cry1C rice on the rove beetle *Paederus fuscipes*, a generalist predator of brown planthopper *Nilaparvata lugens*. *Scientific reports*. https://www.nature.com/articles/srep30303

Niba, A. 2011. Arthropod assemblage dynamics on cowpea (*Vigna unguiculata* L. Walp) in a subtropical agro-ecosystem, South Africa. *African Journal of Agricultural Research*, 6(4), 1009–1015. https://doi.org/10.5897/AJAR10.751

Prasad, R., Prabhu, S. T., Balikai, R. A. (2015). Incidence of white backed plant hopper on rice and its predators under rainfed ecosystems and their correlation with weather parameters. *Research Journal of Agricultural Sciences*, 1(4), 322–326. https://www.researchgate.net/publication/264846092_Incidence_of_White_Backed_Plant_Hopper_on_Rice_and_its_Predators_under_Rainfed_Ecosystems_and_their_Correlation_with_Weather_Parameters

Raffaelli, D. & Hall, S.J. (1992). Compartments and predation in an estuarine food web. *Journal of Animal Ecology*, 61, 551–560. https://www.jstor.org/stable/5610?seq=1#page_scan_tab_contents

Rocha-Filho, L. C., & Rinaldi, I. M. P. (2011). Crab spiders (Araneae: Thomisidae) in flowering plants in a Brazilian "Cerrado" ecosystem. *Brazilian journal of biology*, 71(2), 359–364. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1519-69842011000300004

Schmidt, K., Orosz-Kovacs, Z. Farkas, A. (2012). Nectar secretion dynamics in some raspberry and blackberry cultivars. *The International Journal of Plant Reproductive Biology*, 4(2), 147–150. https://www.researchgate.net/publication/233808478_Nectar_secretion_dynamics_in_some_raspberry_and_blackberry_cultivars

Settle, W. H., Ariawan, H., Astuti, E. T., Cahyana, W., Hakim, A. L., Hindayana, D., Lestari, A. S., Pajarningsih. (1996). Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. *Ecology*, 77(7), 1975–1988. https://www.jstor.org/stable/2265694

Shanker, C., Chintagunta, L., Muthusamy, S., Vailla, S., Srinivasan, A., Katti, G. (2018). Flora surrounding rice fields as a source of alternative prey for coccinellids feeding on the pests of rice. *European Journal of Entomology*, 115, 364-371. https://doi.10.14411/eje.2018.036. https://www.eje.cz/pdfs/eje/2018/01/36.pdf

Siaga, E., Lakitan, B., Hasbi., Bernas, S. M., Wijaya, A., Lisda, R., Ramadhani, F., Widuri, L. I., Kartika, K., Meihana, M. 2018. Application of floating culture system in chili pepper (*Capsicum annum* L.) during prolonged flooding period at riparian wetland in Indonesia. *Australian Journal of Crop Science*, 12(5), 808–816. http://www.cropj.com/siaga_supp_12_5_2018_808_816.pdf

Suwandi, Ammar, M., Irsan, C. (2012). Application of extract compost increased yield and suppressed the diseases of ratoon rice crop in tidal swamp of Banyuasin Regency. *J. Lahan Suboptimal*, 1, 116–122. [Indonesian]. http://www.jlsuboptimal.unsri.ac.id/index.php/jlso/article/download/15/13

Tahir, H. M., & Butt, A. (2009). Predatory potential of three hunting spiders inhabiting the rice ecosystems. *J Pest Sci*, 82, 217–225. https://link.springer.com/article/10.1007/s10340-008-0242-9

Wahocho, S. A., Miano, T. F., Memon, N. U. N., Wahocho, N. A. (2016). Photoperiodic effect on vegetative growth and flower quality of zinnia (*Zinnia elegans* Jacq.). *Sarhad Journal of Agriculture*, 32(4), 316–324. http://dx.doi.org/10.17582/journal.sja/2016.32.4.316.324

Widuri, L. I., Lindiana, L., Kartika, K., Siaga, E., Meihana, M., Hasmeda, M., Sodikin, E., Lakitan, B. (2016). Identification of farmer's needs and vegetable cultivation constraints in riparian wetlands using grounded theory. *Prosiding seminar nasional lahan suboptimal*, 587–594. [Indonesian]. http://pur-plso.unsri.ac.id/userfiles/71_%20HAL%20587-594%20%20Laily-ilman-widuri-identifikasi-kebutuhan-petani-lahan-rawa-lebak.pdf

Zhu, P., Wang, G ., Zheng, X., Tian, J., Lu, Z., Heong, K. K., Xu, H., Chen, G., Yang, Y., Gurr, G. M. (2014). Selective enhancement of parasitoids of rice Lepidoptera pests by sesame (*Sesamum indicum*) flowers. *BioControl*, 1-11. https://link.springer.com/article/10.1007/s10526-014-9628-1

Figures and Tables

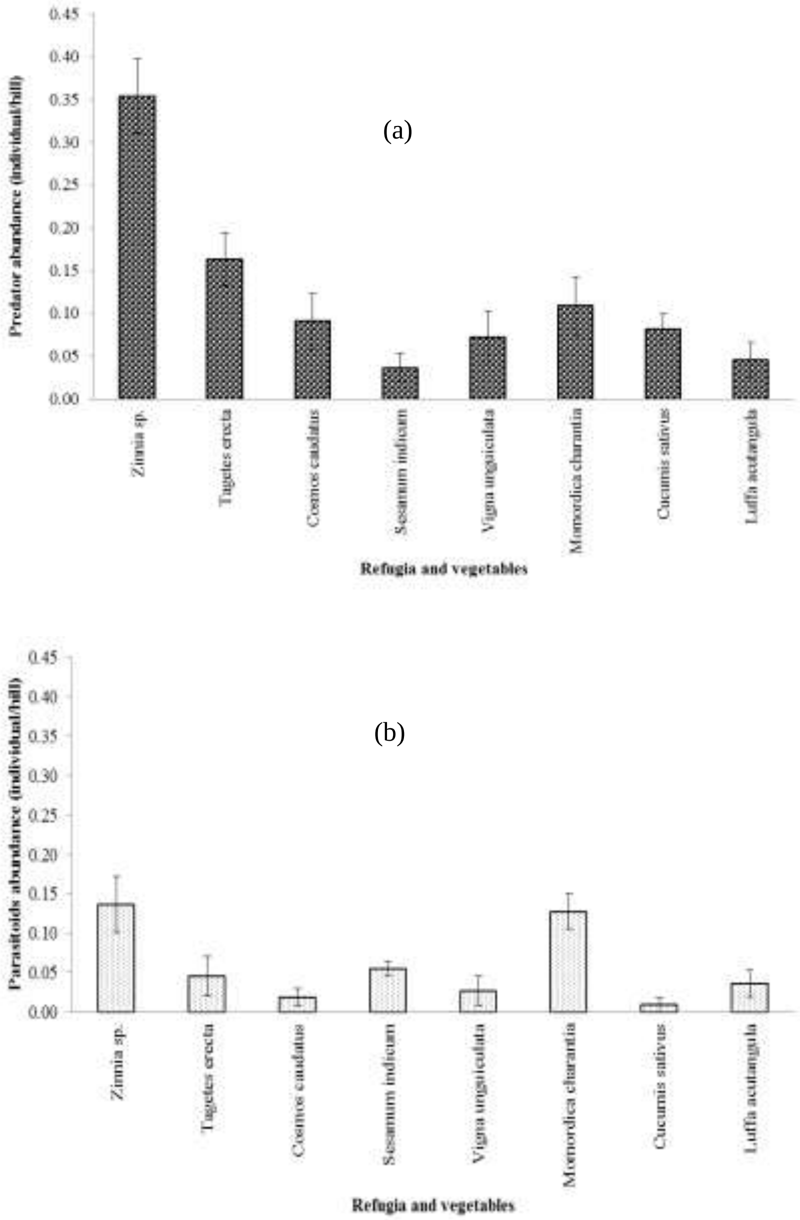


Fig. 1. Abundace of predatory arthropods (a) and parasitoids (b) predatory arthropods inhabiting refugia and vegetables

Fig. 2. Flower of refugia and vegetables; zinnia (a), marigold (b), “kenikir” (c), sesame (d), cowpea (e), bitter melon (f), cucumber (g), ridged gourd (h)

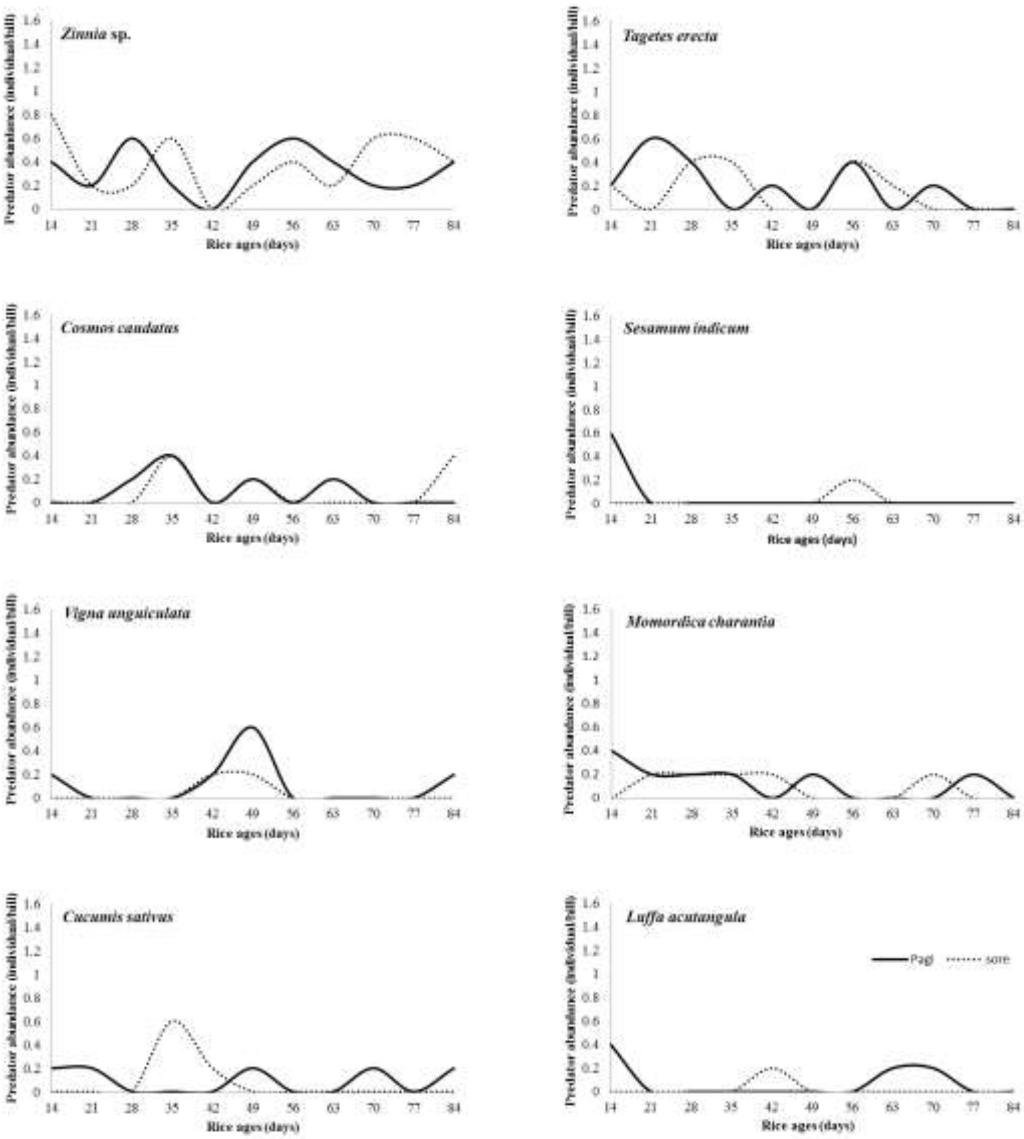


Fig. 3. Predatory abundance found on refugia and vegetables in the period 14-84 days after rice transplanting

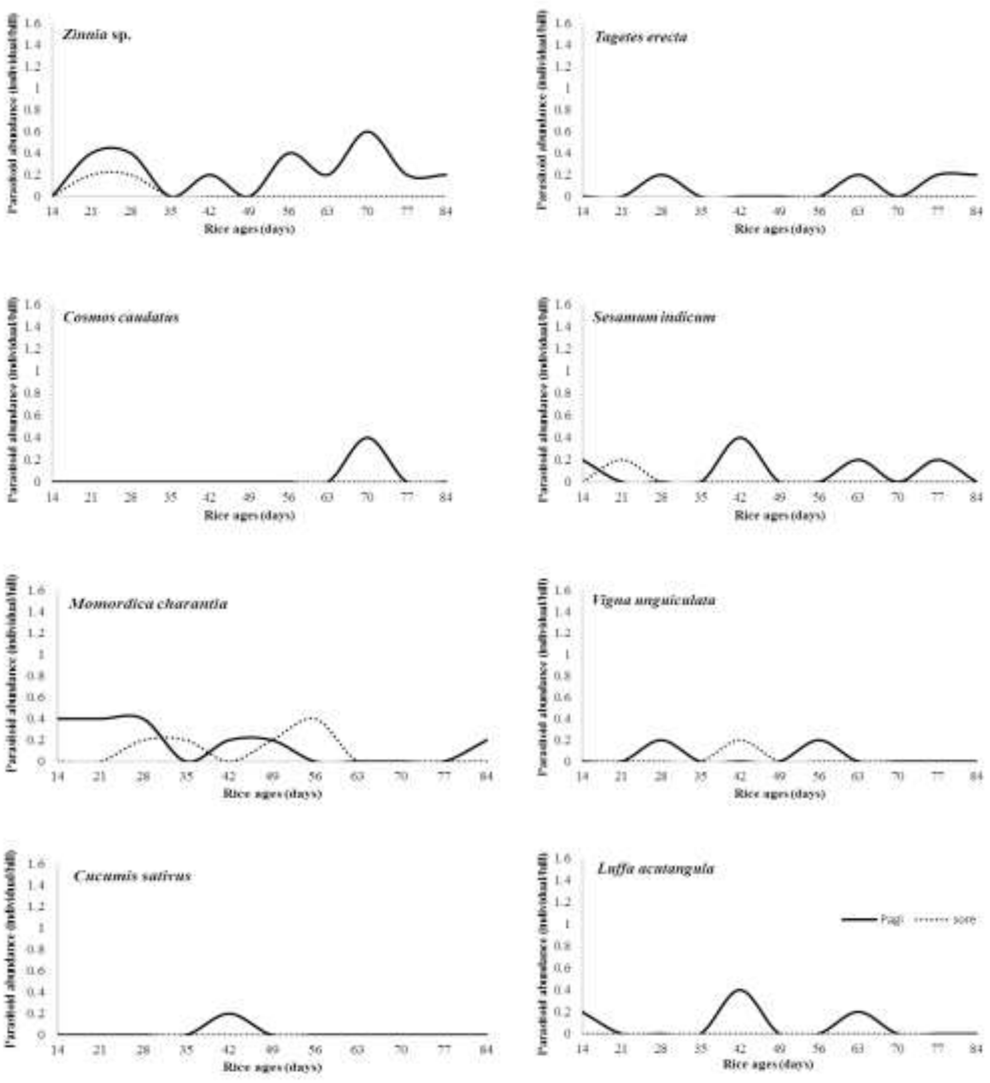


Fig. 4. Parasitoid abundance found on refugia and vegetables in the period 14-84 days after rice transplanting or during a rice season

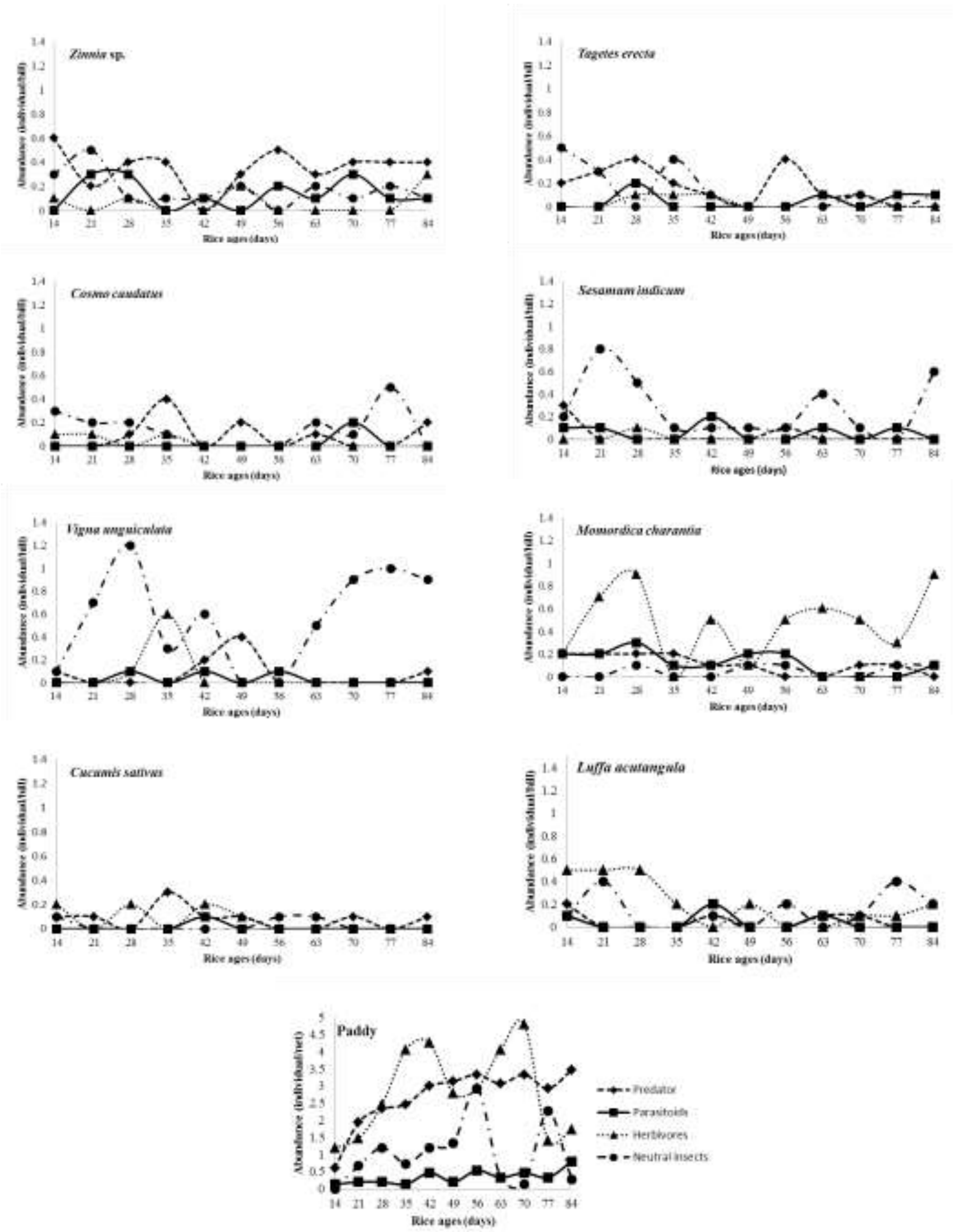


Fig. 5. Arthropod abundance found on refugia, vegetables, and rice in the period 14-84 days after rice transplanting or during a rice season

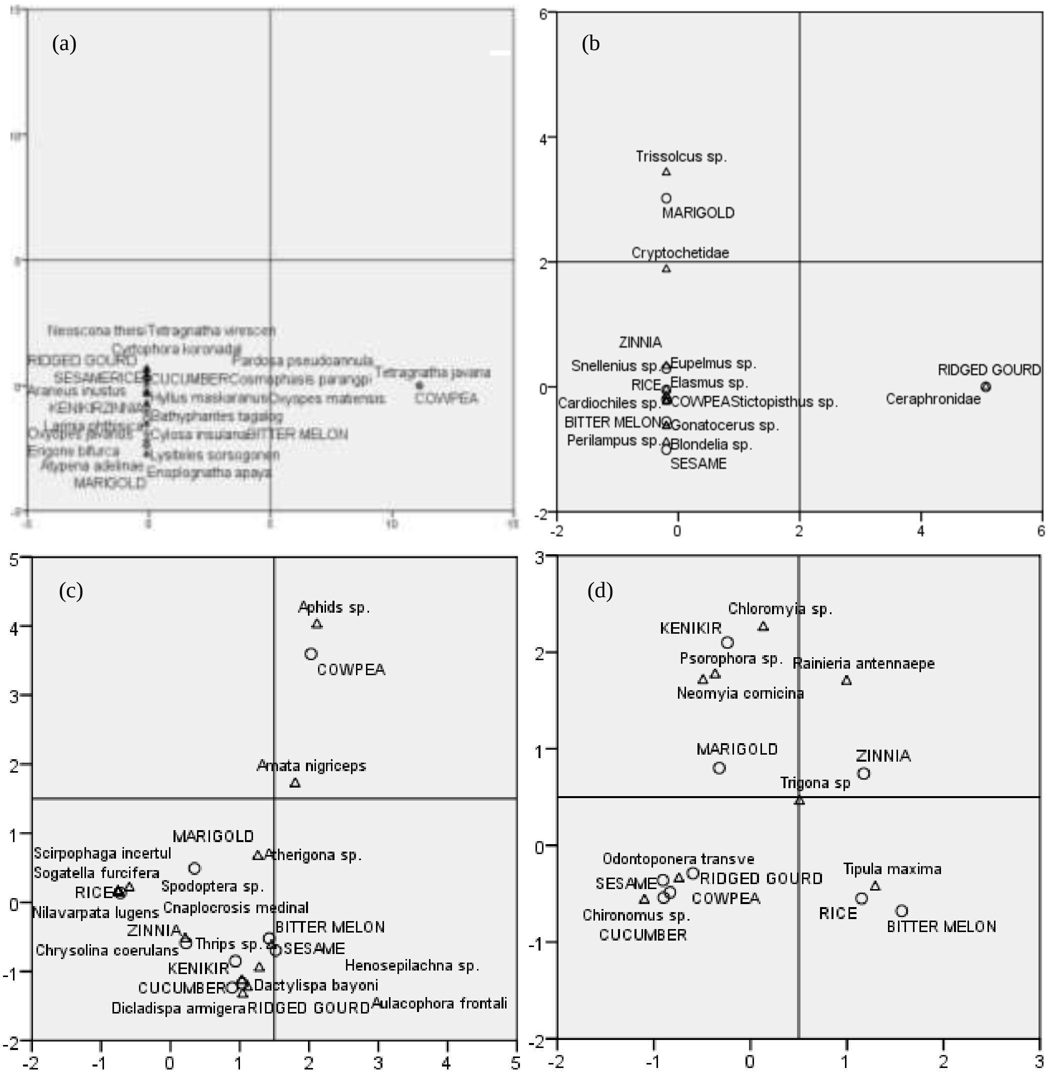


Fig. 6. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice vegetative stage; arthropods (o); plant (Δ)

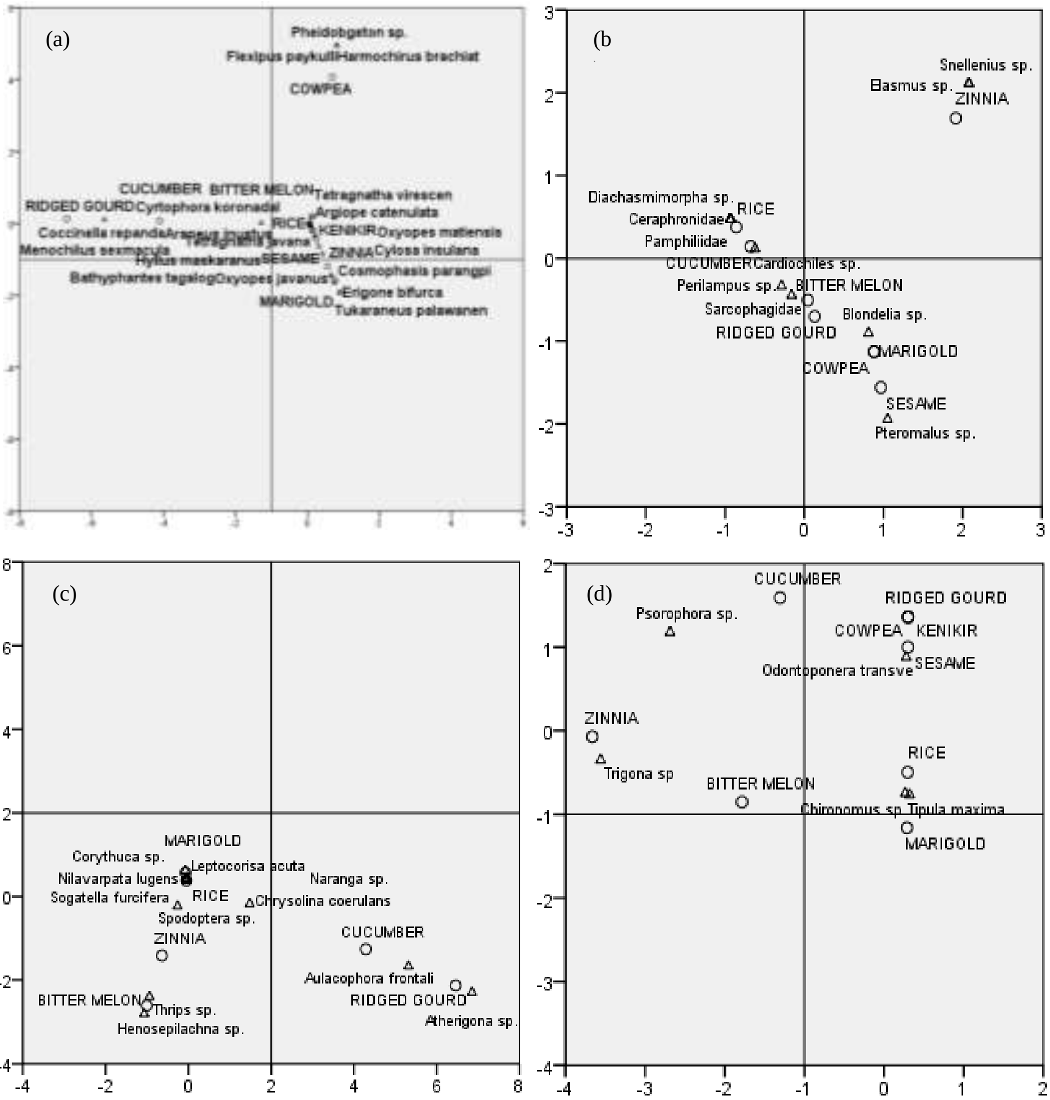


Fig. 7. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice milky stage; arthropods (o); plant (Δ)

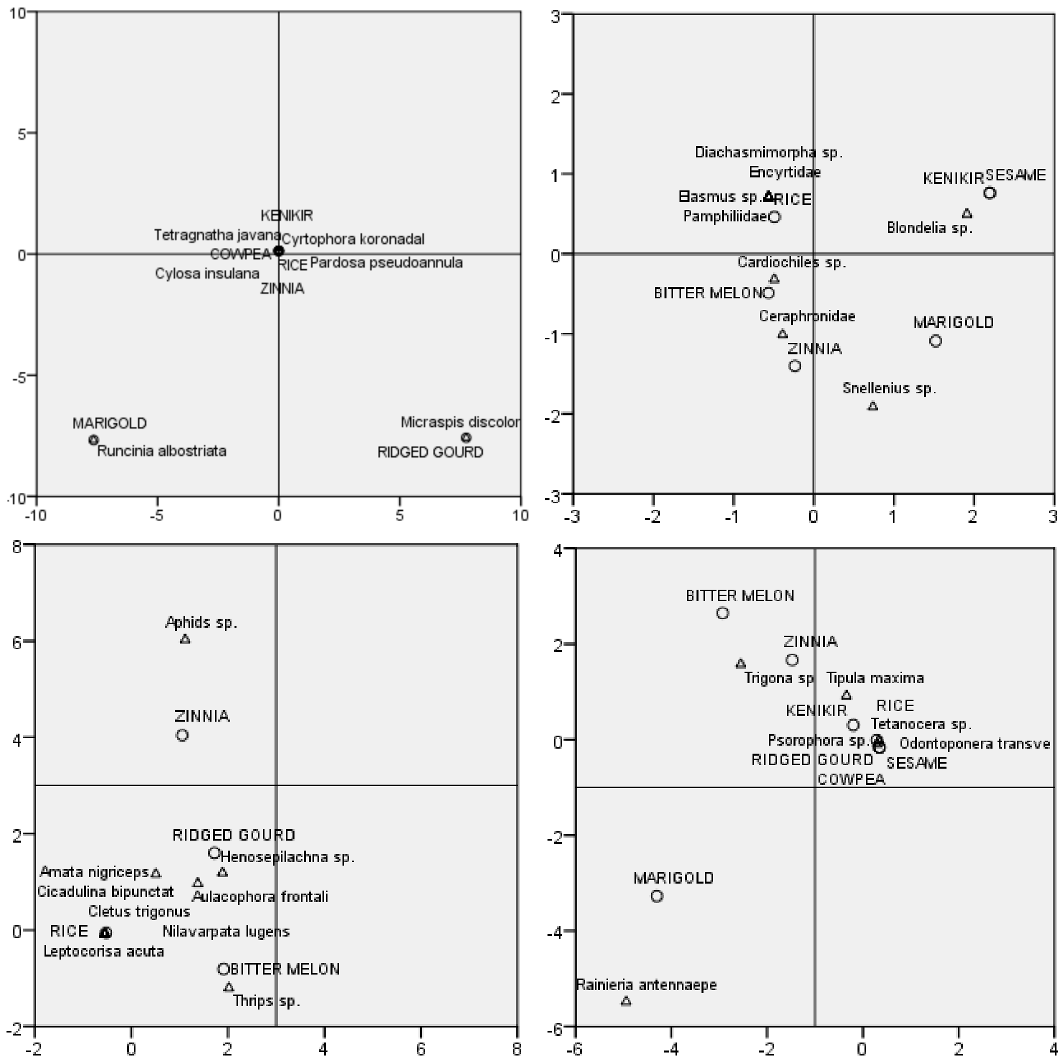


Fig. 8. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice ripening stage; arthropods (o); plant (Δ)

Table 1. Species composition of predatory arthropods found on rice, refugia, and vegetables

No.	Species	Habitat (individual/net or individual/flower)								
		A	B	C	D	E	F	G	H	I
1.	*Pardosa pseudoannulata*	0.04	0	0	0	0	0	0	0	0
2.	*Araneus inustus*	0.01	0	0	0.01	0	0	0	0	0
3.	*Cylosa insulana*	0.05	0.02	0.02	0.01	0	0	0	0	0
4.	*Cyrtophora koronadalensis*	0.02	0	0	0	0	0	0	0	0
5.	*Neoscona theisi*	0.01	0	0	0	0	0	0	0	0
6.	*Argiope catenulate*	0.04	0	0	0	0	0	0	0	0
7.	*Larinia phthisica*	0	0.01	0.01	0	0	0	0	0	0
8.	*Tukaraneus palawanensis*	0	0	0.01	0	0	0	0	0	0
9.	*Tetragnatha javana*	0.17	0.02	0	0	0	0.01	0	0	0
10.	*Tetragnatha virescens*	0.68	0.01	0.01	0	0	0.03	0.02	0	0
11.	*Tetragnatha mandibulata*	0.24	0.01	0	0.01	0	0	0	0	0
12.	*T. maxillosa*	0.10	0	0	0	0	0	0	0	0
13.	*T. vermiformis*	0.12	0	0	0	0	0	0	0	0
14.	*T. Okumae n. Sp.*	0.01	0	0	0	0	0	0	0	0
15.	*T. iwahigensis*	0.01	0	0	0	0	0	0	0	0
16.	*T. natans*	0.01	0	0	0	0	0	0	0	0
17.	*Bathyphantes tagalogensis*	0.07	0.01	0.01	0	0	0	0	0	0
18.	*Bathyphantes sp.*	0.02	0	0	0	0	0	0	0	0
19.	*Erigone bifurca*	0	0	0.02	0	0	0	0.01	0	0
20.	*Enoplognatha sp.*	0.02	0	0	0	0	0	0	0	0
21.	*Linyphiidae (unknown species)*	0.01	0	0	0	0	0	0	0	0
22.	*Atypena adelinae*		0	0.01	0	0	0	0	0	0
23.	*Oxyopes javanus*	0.02	0.05	0.01	0	0	0	0.01	0	0
24.	*O. matiensis*	0.09	0.05	0.00	0.03	0.01	0	0.01	0	0
25.	*O. pingasus*	0.01	0	0	0	0	0	0	0	0
26.	*Theridion sp.*	0.01	0	0	0	0	0	0	0	0
27.	*Enoplognatha apaya*	0	0	0.01	0	0	0	0	0	0
28	*Lysiteles sorsogonensis*	0	0	0.01	0	0	0	0	0	0
29.	*Thomisus ilocanus*	0	0	0.01	0	0	0	0	0	0
30.	*Thomisus italongus*	0	0	0	0	0	0	0.02	0	0
31.	*Runcinia albostriata*	0	0	0.01	0	0	0	0	0	0
32.	*Myrmarachne bidentata*	0.01	0	0	0	0	0	0	0	0
33.	*Hyllus maskaranus*	0.03	0.05	0	0	0.01	0	0	0	0
34.	*Myrmarachne onceana*	0	0	0.02	0	0	0	0.01	0	0
35.	*Cosmophasis parangpilota*	0.01	0.05	0.02	0.01	0	0	0	0	0
36.	*Cosmophasis sp.*	0.02	0.02	0	0.01	0	0	0	0	0
37.	*Flexipus paykulli*	0	0.02	0	0	0	0.01	0	0	0
38.	*Harmochirus brachiatus*	0.01	0	0	0	0	0.01	0	0	0
39.	*Bianor hotingchiehi*	0.01	0	0	0	0	0	0	0	0
40.	*Emathis sp.*	0.01	0	0	0	0	0	0	0	0
41.	*Hahnia tuybaana*	0.02	0	0	0	0	0	0	0	0
42.	*Cyrtorhinus lividipennis*	0.02	0	0	0	0	0	0	0	0
43.	*Orthotylus sp.*	0.02	0	0	0	0	0	0	0	0
44.	*Ophionea nigrofasciata*	0.01	0	0	0	0	0	0	0	0
45.	*Paederus fuscipes*	0.18	0.04	0	0	0.01	0	0	0	0.01
46.	*Micraspis inops*	0.24	0	0	0	0	0	0.01	0.02	0.01
47.	*Verania lineata*	0.01	0	0	0	0	0	0	0	0
48.	*Micraspis vincta*	0.02	0	0	0	0	0	0	0	0
49.	*Harmonia octomaculata*	0.01	0	0	0	0	0	0	0	0
50.	*Coccinella repanda*	0.03	0	0	0	0	0	0	0.01	0

Remarks: rice; B= *Zinnia* sp.; C= *Tagetes erecta*; D= *Cosmos caudatus*;E= *Sesamum indicum*; F=*Vigna unguiculata*; G=*Momordica charantia*; H=*Cucumis sativus*; I=*Luffa acutangula*

Table 1. Continued

No.	Species	Habitat (individual/net or individual/flower)								
		A	B	C	D	E	F	G	H	I
51.	*Brumoides suturalis*	0.02	0	0	0	0	0	0	0	0
52.	*Menochilus sexmaculatus*	0.01	0	0	0	0.01	0	0	0.03	0.02
53.	*Propylaea japonica*	0	0.01	0	0	0	0	0	0	0
54.	*Coccinella septempunctata*	0	0	0	0	0	0	0	0.01	0
55.	*Micraspis discolor*	0	0	0	0	0	0	0	0	0.01
56.	*Larva Coccinellidae*	0.16	0	0	0.02	0	0	0.02	0.02	0
57.	*Elateridae (unknown species)*	0.01	0	0	0	0	0	0	0	0
58.	*Formicomus sp.*	0.01	0.01	0	0	0	0	0.01	0	0
59.	*Agriocnemis sp.*	0.03	0	0	0	0	0	0	0	0
60.	*Pyrrhosoma sp.*	0.01	0	0	0	0	0	0	0	0
61.	*Argia sp.*	0.01	0	0	0	0	0	0	0	0
62.	*Pantala sp.*	0.01	0	0	0	0	0	0	0	0
63.	*Conocephalus longipennis*	0.02	0	0	0	0	0	0	0	0
64.	*Monomorium destructor*	0	0	0	0	0	0.02	0	0	0
65.	*Solenopsis sp.*	0.01	0	0	0	0	0	0	0	0
66.	*Volucella sp.*	0.01	0	0	0	0	0	0	0	0
67.	*Mantidae (unknown species)*	0.01	0	0	0	0	0	0	0	0
	Total Abundance (N)	2.74	0.38	0.18	0.1	0.04	0.08	0.12	0.09	0.05
	Number of Species (S)	51	15	14	7	4	5	9	5	4

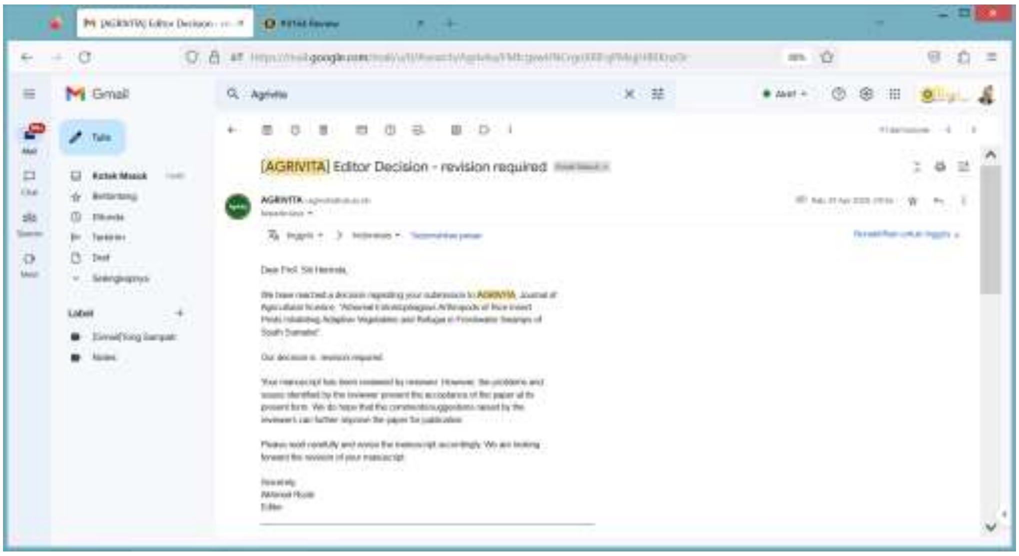
Remarks: A= rice; B= *Zinnia* sp.; C= *Tagetes erecta*; D= *Cosmos caudatus*;E= *Sesamum indicum*; F=*Vigna unguiculata*; G=*Momordica charantia*; H=*Cucumis sativus*; I=*Luffa acutangula*

Table 2. Species composition of parasitoid found on rice, refugia, and vegetables

No.	Species	Habitat (individual/net or individual/flower)								
		A	B	C	D	E	F	G	H	I
1	*Stictopisthus* sp.	0.01	0	0	0	0	0	0	0	0
2	*Elasmus* sp.	0.02	0.03	0	0	0	0	0.01	0	0
3	*Trissolcus* sp.	0	0	0.01	0	0	0	0	0	0
4	*Snellenius* sp.	0.02	0.03	0.01	0	0	0.01	0	0	0
5	*Cardiochiles* sp.	0.09	0.04	0	0	0	0	0.05	0.01	0
6	*Diachasmimorpha* sp.	0.02	0	0	0	0	0	0	0	0
7	*Gonatocerus* sp.	0	0	0	0	0	0	0.01	0	0
8	*Perilampus* sp.	0.01	0	0	0	0	0	0.01	0	0.01
9	Ceraphronidae (unknown species)	0.04	0.02	0	0	0	0	0	0	0.01
10	Pamphiliidae (unkown species)	0.02	0	0	0	0	0	0	0	0
11	Encyrtidae (unknown species)	0.02	0	0	0	0	0	0	0	0
12	*Eupelmus* sp.	0.01	0.01	0	0	0	0	0	0	0
13	*Helorus* sp.	0.02	0	0	0	0	0	0	0	0
14	*Pteromalus* sp.	0.01	0	0	0	0.01	0	0	0	0
15	*Netomocera* sp.	0.02	0	0	0	0	0	0	0	0
16	*Haltichella* sp.	0.01	0	0	0	0	0	0	0	0
17	*Tetramesa* sp	0.01	0	0	0	0	0	0	0	0
18	*Eurytomidae* sp.	0.01	0	0	0	0	0	0	0	0
19	*Athrycia* sp.	0.01	0	0	0	0	0	0	0	0
20	*Blondelia* sp.	0.01	0.01	0.02	0.02	0.05	0.02	0.04	0	0.01
21	Cryptochetidae (unknown species)	0	0.01	0.01	0	0	0	0	0	0
22	Sarcophagidae (unknown species)	0.01	0	0	0	0	0	0.01	0	0.01
	Total Abundance (N)	0.37	0.15	0.05	0.02	0.06	0.03	0.13	0.01	0.04
	Number of Species (S)	19	7	4	1	2	2	6	1	4

Remarks: A= rice; B= *Zinnia* sp.; C= *Tagetes erecta*; D= *Cosmos caudatus*;E= *Sesamum indicum*; F=*Vigna unguiculata*; G=*Momordica charantia*; H=*Cucumis sativus*; I=*Luffa acutangula*

2. Bukti konfirmasi review pertama dan hasil revisi pertama



Arboreal Entomophagous Arthropods of Rice Insect Pests Inhabiting Adaptive Vegetables and Refugia in Freshwater Swamps of South Sumatra

ABSTRACT

Plants growing around the rice fields can be used as a habitat and niche for entomophagous arthropods. This study aimed to identify the species of entomophagous arthropods of rice insect pests and to analyze their abundance and community in adaptive vegetables and refugia in freshwater swamps. The field was surrounded by 4 species of refugia (*Zinnia* sp., *Tagetes erecta, Cosmos caudatus,* and *Sesamum indicum*) and 4 species of vegetables (*Vigna unguiculata, Momordica charantia, Cucumis sativus,* and *Luffa acutangula*). Arthropods were sampled using nets. The results showed that predatory arthropods and parasitoids found were 67 and 22 species, respectively. The predatory arthropods species were mostly found in rice (51 species), *Zinnia* sp. (15 species), and *M. charantia* (9 species). Parasitoid species were dominantly found in rice (19 species), *Zinnia* sp. (7 species), and *M. charantia* (6 species). The predatory arthropods dominantly found were *Tetragnatha javana, Tetragnatha virescens,* and *Paederus fuscipes*, while the dominant parasitoids were *Cardiochiles* sp., *Elasmus* sp., and *Snellenius* sp. *Zinnia* sp. and *M. charantia* were the most chosen habitat by entomophagous arthropods besides rice fields. However, *M. charantia* is more beneficial than *Zinnia* sp. due to its function not only for conservation of natural enemies and also for land productivity.

Comment [A1]: Please mention the entomophagous in this sentence

Comment [A2]: What about the community or similarity of species composition between vegetable or refugia?

Comment [A3]: Add an article

KEYWORDS

Habitat, niche, parasitoid, predator, refugia, and vegetable

INTRODUCTION

Wetland is a land saturated with water, both year-round and seasonal. Wetland in Indonesia generally consists of freshwater (non-tidal) swamp and tidal lowland. Freshwater swamp is a wetland that is flooded due to the flow of river water or rain, while the lowland tidal is inundated due to the tides. According to Margono et al. (2014), the wetland area in Indonesia is around 39.6 Mha, 77% of them are spread in Sumatra Island (11.9 Mha), Kalimantan (12.2 Mha), and Papua (11.8 Mha), while the remaining 23% are spread in Java (1.9 Mha), Sulawesi (1.2 Mha), Maluku (0.5 Mha), and Bali-Nusa Tenggara (0.2 Mha).

Freshwater swamps in South Sumatra are generally inundated from November to April, or May depend on the lowland typology, and in dry season the land often drought (based on direct observation in the center of freshwater swamps, Ogan Ilir District, South Sumatra since 2012 up to now). When they are inundated, some local farmers raise swamp fish or local "pegagan" ducks, while in the dry season, they grow rice (Lakitan et al., 2018) or adaptive vegetables (Lakitan et al., 2019). Another local habit is when they grow rice, they also grow adaptive vegetables in rice fields. Some adaptive vegetables in freshwater swamps are cowpea (*Vigna unguiculata*) (Bhaskar et al., 2010), cucumber (*Cucumis sativus*) (Baptiste & Smardon, 2012), ridged gourd (*Luffa acutangula*) and bitter melon (*Momordica charantia*) (Widuri et al., 2016), chili pepper (*Capsicum annum L.*) (Siaga *et al*., 2018) common bean (*Phaseolus vulgaris*) (Lakitan, 2019), and tomatoes (Emile et al., 2012). The vegetables which planted around the rice fields have multiple functions, but it is not relized by the local farmers. Besides being able to increase land productivity, these vegetables can provide natural habitat and niche for natural enemies of the rice insect pest.

Cowpeas are inhabited by 21 insect species of 12 families and 5 orders (Coleoptera, Hemiptera, Orthroptera, Homoptera, and Lepidoptera) (Niba, 2011). Cucumbers are visited by 11 insect species of 7 families and 3 orders (Hymenoptera, Diptera, and Coleoptera) (Hossain et al., 2018). Ridged gourds are inhabited by 6 insect species of 3 families and 2 orders (Hymenoptera and Diptera), while bitter melons are visited by 4 insect species of 3 families and 2 orders (Bodlah & Waqar, 2013). Chili pepper is visited by 41 species of arthropods consisting of 14 species of pests and natural enemies, 12 species of visitors, and 1 species of pollinator (Kaur & Sangha, 2016).

The diversity of arthropods in freshwater swamps is also supported by the presence of flowering wild plant or non-crop plant as refugia around rice field. Non-crop plants and refugia provide niche, additional food, and other resources for natural enemies of rice pests (Zhu et al., 2014; Hasan et al., 2016; Benvenuti & Bretzel, 2017; Lopes et al., 2017; McCabe et al., 2017). Grassy rice fields in ecosystems have a higher number of arthropods than those in non-weed ecosystems (Hu et al., 2012). The existence of refugia, sunflower plants (*Helianthus annuus*), indian mustard (*Brassica juncea*), sesame (*Sesamum indicum*), marigold (*Tagetes erecta*), kenikir (*Cosmos caudatus*), and Zinnia (*Zinnia* sp.) is known to be effective in reducing the attack of leaf-rolling pests (*Cnaphalocrocis medinalis*) in several rice varieties in India (Desai et al., 2017). Marigold is reported to be associated with several species of predatory arthropods such as *Oxyopes javanus, Coccinella septumpunctata, Syrphus* spp., and *Geoceris* spp. (Ganai et al., 2017). Zinnia is also reported to be associated with

Comment [A4]: Add an article

Comment [A5]: Add an article

Comment [A6]: It's better to use scientific name

Comment [A7]: Inconsistent, italic or not italic

Comment [A8]: Realized?

Comment [A9]: Orthoptera?

Comment [A10]: Wild flowering

Comment [A11]: Add an article

Comment [A12]: yellow ray flower

Comment [A13]: Geocoris?

several species of spiders, including *Argiope aemula, Oxyopes* sp., and *Perenethis* sp. (Desai et al., 2017). Consequently, vegetables and refugia are beneficial as habitat and niche for entomophagous arthropods (parasitoid and predatory arthropods) which are natural enemies of insect pests. Few information is available about the entomophagous arthropods that are associated with vegetables and refugia in freshwater swamps of South Sumatra. This study aimed to identify the species of entomophagous arthropods of rice insect pests and to analyze their abundance and community in adaptive vegetables and refugia in freshwater swamps of South Sumatra.

Comment [A14]: There is little information available

MATERIALS AND METHODS

The field experiment was carried out in the center of freshwater swamps in Pelabuhan Dalam Village of Pemulutan Subdistrict, Ogan Ilir District, South Sumatra Province, from May to September 2018. The area of rice field is around 7.1 Mha. The species identification was carried out in the laboratory from September 2018 to May 2019.

Comment [A15]: Add an article

Rice, Vegetables, and Refugia Planting

The rice plot area used was 1 ha, surrounded by 4 species of refugia and 4 vegetable species with the distance between plots was around 100 m, and 1 ha of plot area was divided into three sub-plots and used as replications. Each rice subplot was surrounded by 4 species of refugia (*Zinnia* sp., *T. erecta, C. caudatus,* and *S. indicum*), as well as other rice subplots were surrounded by 4 vegetable species (*V. unguiculata*, *M. charantia*, *C. sativus*, and *L. acutangula*). The position of 4 refugia species or the 4 species of vegetables in each rice sub-plot was in four embankments surrounding the sub-plot, and each embankment was planted with one plant species. In consequence, the four embankments surrounding the rice subplots were planted with different species of refugia or vegetables. This position was to give a freedom for entomophagous arthropods to choose the alternative habitat other than rice. The planting of refugia and vegetables was carried out 30 days before rice planting so that when it was in vegetative phase of 14 days after transplanting (DAT), the refugia would have been blooming. The plant sapcing of vegetables followed the habit of the local farmers (30 cm); meanwhile, the refugia was planted closer (15 cm) and containing 5 seeds per hole.

Comment [A16]: Add an article

Comment [A17]: Spacing?

Comment [A18]: were

The rice was planted according to planting system of 2:1 "jajar legowo" spacing (50 cm x 25 cm x 12.5 cm) and did not use synthetic pesticides; the fertilizing used manure at a dose of 1 ton/ha and 2 L of extract liquid compost made following the method of Suwandi et al. (2012). The rice planting began with land preparation by cultivating the soil and applying the manure at the same time. Then, the rice seeds were sown according to the traditions of local farmers, using the "Samir" method, i.e., the seeds of 7-10 days old were transplanted into the field. When the rice plant was in 2 weeks after planting, the fertilization was applied using extract liquid compost every 2 weeks.

Sampling the arboreal arthropods inhabiting refugia and vegetables

Arthropod sampling that inhabiting refugia and vegetables surrounding the rice field was conducted once a week started from 14 to 84 DAT. The sampling was carried out twice for every

Comment [A19]: that was

observation, i.e., in the morning at 7:00 to 08:00 a.m. and in the afternoon at 4:00 to 5:00 p.m. The sampling was carried out by randomly picking 5 flowers for each species of refugia and vegetables. The flowers were cut from their stalks and put them in a 150 ml plastic container (Ø = 7 cm and height = 6.5 cm) perforated on the lid with a diameter of 2 cm and covered with gauze glued together. Each flower was separately put into a plastic container and labeled. The flowers were incubated and observed until the arthropods were released from the flower. The arthropods were separated from the flowers and put into a 10 ml glass bottle containing 80% ethanol. The glass bottles containing arthropods were labeled and then identified in Entomology Laboratory, Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Sriwijaya. The identification of spiders referred to Barrion & Litsinger (1995) and the identification of insects referred to Heinrichs (1994), Kalshoven (1981), and McAlpine et al. (1987).

Comment [A20]: it's not necessary because there are using of a.m.

Comment [A21]: it's not necessary

Sampling of Arboreal Arthropods in Rice

Comment [A22]: add an article

Observation of the arthropods was conducted weekly started when the rice in 14 to 84 DAT. The sampling of the arboreal arthropods for the observations used nets (net handle length = 100 cm, net length = 75 cm, and net Ø = 30 cm) at five points scattered in four corners of the land and one in the middle of the land for each subplot study (3 subplots as a repetition). The sampling was carried out in the morning at 06.00 to 07.00 a.m. in good weather conditions with no rain. The arthropods collection with nets was carried out based on the modification of Janzen method (2013), i.e., the arthropods were collected by swinging a net of one double swing in a straight line in 30 cm depth in the canopy of the plants. The net coverage was based on the modified methods of Masika et al. (2017) by swinging a net which tied on a plant stem. The nets were intentionally applied on the rice stem to obtain the insects on the stems and leaves of the rice plants. The obtained arthropods were sorted, put into the vial bottles containing 80% ethanol, labeled, and then identified in the laboratory. The identification of the spiders referred to Barrion and Litsinger (1995), and identification of insects referred to Heinrichs (1994), Kalshoven (1981), and McAlpine et al. (1987).

Comment [A23]: it's not necessary

Comment [A24]: replace with "that"

Data Analysis

The data on species composition and abundance of entomophagous arthropods inhabiting refugia and vegetables were presented in tables and charts. Their subsequent abundance data were also grouped according to the guild, i.e., predator, parasitoid, herbivore, and neutral insect, to be displayed in graphical form. A correspondence analysis was used to investigate how species of arthropods and plants (refugia, vegetables, and rice) were grouped based on the arthropod species they interacted with (Raffaelli & Hall 1992) and the species of data analyzed were grouped in species community of predators, parasitoid, herbivore, and neutral insects. The calculation of correspondence analysis used the software of SAS University Edition 2.7 9.4 M5.

Comment [A25]: remove the article

Comment [A26]: inconsistent, choose and or &

RESULTS AND DISCUSSION

Species Composition and Abundance of Arboreal Entomophagous Arthropods

Comment [A27]: there is no explanation of abundance, whereas abundance is also crucial in explaining a community

Arboreal entomophagous arthropods are arthropods that act as predators and parasitoids for natural enemies of insect pests. In this study, arboreal entomophagous arthropods found in rice were grouped into predatory arthropods and parasitoids. Predatory arthropods consisted of groups of spiders and predatory insects, while parasitoid was a group of insects that were parasite to insects or other arthropods. The total species number of predatory arthropods and parasitoids were 67 species (Table 1) and 22 species (Table 2), respectively. In the rice field, the number of predatory arthropods species was dominant (51 species) compared to refugia and vegetables. In refugia, the predatory arthropods species were dominantly found in *Zinnia* sp. (15 species), while in vegetables were mostly found in *M. charantia* (9 species). *S. indicum* was a refugia less chosen as the predatory arthropod habitat, while *L. acutangula* was a vegetable plant less chosen as the habitat by the predatory arthropods. The five species of arboreal predatory arthropods which dominantly found in rice were *Tetragnatha javana, Tetragnatha virescens, Tetragnatha mandibulata, Paederus fuscipes,* and *Micraspis inops*. Four of five species that found in rice (*T. javana, T. virescens, T. mandibulata,* and *P. fuscipes*) were found in *Zinnia* sp. In contrast, in *M. charantia,* two species of the predatory arthropods were found (*T. virescens* and *M. inops*). In addition, there were other predatory arthropods found in rice, refugia, and vegetables, i.e., *O. javanus, Oxyopes matiensis, Menochilus sexmaculatus,* and *Coccinella septempunctata*.

In this study, the arboreal predatory arthropods species that found in rice, refugia, and vegetables were the important predators attacking insect pests of rice. *T. javana, T. virescens,* and *T. mandibulata* are family spiders of Tetragnathidae that can prey on orders of Homoptera and Lepidoptera in rice (Tahir et al., 2009). Betz and Tscharntke (2017) stated that the Tetragnathidae also preys on order of Homoptera (leafhoppers) on rice. *P. fuscipes* is a predator of *Nilaparvata lugens* (Meng et al., 2016), and *M. inops* is an insect pest of rice generalist predator (Karindah et al., 2011). *O. javanus* effectively preys on *Hieroglyphus banian, Sogetella furcilera, Marasmia patnalis,* and *Scripophaga innotata* on rice in Pakistan (Tahir & Butt, 2009). *T. virescens* effectively controls *S. furcifera* on rice in India (Prasad, Prabhu, & Balikai, 2015). Coccinellidae prey on *N. virescens*, *N. lugens,* and *S. furcifera* on rice in India (Shanker et al., 2018).

The number parasitoid species were mostly found in rice (19 species) compared to refugia and vegetables. In refugia, the parasitoids were mostly found in *Zinnia* sp. (7 species), whereas in vegetables were mostly found in *M. charantia* (6 species) (Table 2). The dominant parasitoids that found in rice were *Cardiochiles* sp., and this species was also found in *Zinnia* sp. and *M. charantia*. *Cardiochiles* sp. is an effective parasitoid to control *C. medinalis* in rice (Behera 2012). In addition, *Snellenius* sp. and *Elasmus* sp. were found at Zinnia sp., while in *M. charantia* was found *Blondelia* sp. *Snellenius* sp. is a parasitoid of *Spodoptera litura* larvae (Javier & Ceballo 2018). *Elasmus* sp. is a parasitoid of *dominulus polystes* (Gumovsky et al., 2007), while *Blondelia* sp. is generally attack on Lepidoptera of the Geometridae family (Cutler et al., 2015).

If only comparing refugia and vegetables without rice, the abundance of predatory arthropods was higher in these following three habitats, i.e., *Zinnia* sp*., T. erecta,* and *M. charantia*. At the same time, parasitoid was higher in *Zinnia* sp*., S. indicum,* and *M. charantia* (Fig. 1). Refugia and vegetables were preferred by both entomopahgous arthropods because they had good morphological

Comment [A28]: remove the article

Comment [A29]: it's not necessary

Comment [A30]: add an article

Comment [A31]: number of parasitoid

Comment [A32]: it's not necessary

Comment [A33]: attacked

Comment [A34]: it's not necessary

Comment [A35]: add an article

Comment [A36]: entomophagous

Comment [A37]: add an article

attraction, long flower blooms, and the availability of floral nectar and pollen. In this study, the flower of *T. erecta, S. indicum,* and *M. charantia* was preferred by the entomophagous arthropods (Fig. 2) compared to other colors because of their yellow flower. The data were in line with the study of Rocha-Filho and Rinaldi (2011), stated that yellow flower was preferred for arthropods compared to white and pink flower. Despite having red color, *Zinnia* sp. was the most preferred due to its longest blooming period compared to other flowers. The flower of *Zinnia* sp. bloom for 23.67 days (Wahocho et al., 2016). The form of *Zinnia* sp. flower was rosette-shaped. *T. erecta* and *M. charantia* is also had high attraction for predator and parasitoid. In line with Jennings et al. (2017), rosette-shaped flowers are longer visited by arthropods. Pollen and nectar of the refugia and vegetable flowers become high attraction for arthropods, such as spiders (Eggs & Sanders, 2013) and parasitoids (Foti et al., 2017).

Based on the time visiting flowers, there was an interesting phenomenon. Predators, especially spiders, their visiting time to refugia and vegetables was high at 7:00 a.m. to 08:00 a.m. and 4:00 p.m. to 5:00 p.m. (Fig. 3), while the parasitoid generally visited the flowers at 7:00 a.m. to 08:00 p.m. (Fig. 4). *Zinnia* sp., *T. erecta,* and *M. charantia* were visited by the predators in the morning and evening, and more often than other refugia or vegetable species. This is related to the longest blooming period of *Zinnia* sp. Predators generally visit refugia and vegetables in the morning and evening since the predators looking for the prey. The prey that needed by predator is more than host need by parasitoid. For example, spiders periods of predation ranging from 5 a.m. to 10 p.m. (Arango et al. 2012). As for parasitoids, their activity of visiting refugia and vegetables is generally carried out in the morning due to parasitoid looking for pollen and nectar, while the direct observation result showed that the host finding activity by parasitoid was generally conducted at 7:00 a.m. in rice. Similarly with Schmidt et al. (2012) stated that parasitoid is generally looking for plants that produce nectar and pollen for their feed in the morning. The availability of nectar and pollen is generally occur in the morning because many flowers are blooming in the morning. Therefore, the existence of refugia and vegetables around the rice field is useful in providing alternative habitat and niche for the parasitoid and predator of rice pest insects.

Community of Arboreal Arthropods in One Rice Growing Season

Arthropods can be grouped into the guilds, i.e., predators, parasitoids, herbivores, and neutral insects. The data showed that the four species of refugia were generally dominated by predators and parasitoids, while the four vegetable species were dominated by parasitoids and herbivores. The rice was dominated by herbivores, and predators followed the development of the herbivores population. The higher the population of herbivores, the higher the abundance of predators would be. These data showed that predators played a role in suppressing herbivores compared to parasitoid population in rice, and this is in line with the study of Settle et al. (1996) and Herlinda et al. (2018). The abundance of neutral insects was also high in rice plants, while the lowest one was the abundance of parasitoids. In *S. indicum* and *V. unguiculata*, the abundance of neutral insects were high due to the presence of honeydew hunter ants produced by homopterous insects inhabiting both plants (Fig. 5). From the data, an interesting phenomenon was found in refugia, especially in *Zinnia* sp., parasitoid and predator were found to be more abundant at the beginning of the rice-growing season. At the same

Comment [A38]: add an article
Comment [A39]: add an article
Comment [A40]: add an article
Comment [A41]: add an article
Comment [A42]: are looking
Comment [A43]: add an article
Comment [A44]: add an article
Comment [A45]: generally occurs
Comment [A46]: add an article
Comment [A47]: add an article

time, when the rice was at 35 DAT, the abundance of both entomophagous arthropods at *Zinnia* sp. began to decrease. In contrast, in the early rice planting, the abundance of the parasitoid began to increase at 42 DAT, and the predator abundance began to increase at 21 DAT. According to Settle et al. (1996) the population dynamics in rice is affected by the flow of the entomophagous arthropods from surrounding non-crop plants and vegetables to rice, and vice versa and this can occur if habitat and other niches are available around the rice fields that are appropriate for the arthropods.

Figures 6, 7, and 8 showed the results of the correspondence analysis in vegetative, milky, and ripening stages of rice, respectively. When rice was at vegetative stage, the species of predatory arthropods inhabiting rice, vegetables, and refugia generally have high similar community, except the arthropod that inhabits cowpea (Fig. 6a). The found predatory arthropods gathered in these plants, including *Pardosa pseudoannulata, Cyrtophora koronadalensis,* and *Neoscona theisi* which were the hunting spiders. Species composition in rice, refugia, and vegetables had high similarity, and this was showed that predatory arthropods were actively migrated from rice to vegetables and refugia or vice versa. Their movement was caused by the herbivores inhabited in rice, such as *N. lugens, Sogatella furcifera,* and *Spodoptera* sp. (Fig. 6c) which were the main preys for the predatory arthropods, while the alternative prey was neutral insects in rice, such as *Tetanocera* sp.*, Tipula maxima,* and *Psorophora* sp. (Fig. 6d). The parasitoid species composition in rice was highly similar to the parasitoid in zinnia and bitter melon (Fig 6b). Thus, zinnia and bitter melon were preferred by parasitoids as habitat and alternative niche beside rice. In line with Settle et al. (1996), the movement of spiders among habitats was due to generalist predators on hunting prey in alternative habitat. The species of parasitoid composition in rice were generally similar to those in the vegetable and refugia species, except those that inhabiting marigolds and ridged gourd. The species of neutral insects in rice were mostly similar to the neutral species in bitter melon.

When rice was in the milky stage, the predatory arthropod species composition in rice was quite similar to the arthropods that inhabited in bitter melon, sesame, zinnia, "kenikir", and marigold. The arthropod species grouped in these plants were *Coccinella repanda, T. virescens, Bathyphantes tagalogensis*, and *O. javanus* (Fig. 7a). The parasitoid species composition inhabiting rice such as *Cardiochiles* sp. and *Sarcophagidae* (Fig. 7b) was quite similar to the parasitoid inhabiting cucumber and bitter melon. The herbivore composition species in rice were most similar to those of herbivores inhabiting zinnia and marigolds, particularly *Leptocorisa acuta*. The species of herbivores that found in rice were *N. lugens, S. furcifera,* and *L. acuta* (Fig. 7c). The predatory arthropods that found in bitter melon, sesame, zinnia, "kenikir," marigold were the predators of *N. lugens, S. furcifera,* and *L. acuta* in rice. The neutral insect species (*Chironomus sp.* and *Tipula maxima*) (Fig. 7d) in rice and marigolds were preys for these predatory generalists. Thus, the movement of species from refugia and vegetables to rice occur if in the rice field is available a lot of preys for predatory generalists. This result is quite similar to Settle et al. (1996) and Herlinda et al. (2018).

When rice was in the ripening stage, the predatory arthropod species composition inhabiting the rice was more similar to the arthropods inhabiting zinnia, "kenikir," and cowpea. The predatory species were *P. pseudoannulata, Cylosa insulana, Cyrtophora koronadalensis,* and *T. javana* (Fig. 8a); while the herbivore species that were found in rice including *N. lugens* and *L. acuta* (Fig 8c) and

Comment [A48]: add an article
Comment [A49]: add an article
Comment [A50]: similar high
Comment [A51]: add an article
Comment [A52]: yellow ray flower
Comment [A53]: can be removed
Comment [A54]: can be removed
Comment [A55]: yellow ray flower
Comment [A56]: it's not italic
Comment [A57]: add an article
Comment [A58]: yellow ray flower

other alternative preys were neutral insects, such as *Tetanocera* sp. and *T. maxima* (Fig. 8d). The species of parasitoid composition in rice was quite similar to the parasitoid composition that inhabited in bitter melon and zinnia. The results of this study showed that the predator and parasitoid of rice pests were found in refugia and vegetables. The refugia species that more frequently chosen by the predators and parasitoid of rice pest as an alternative habitat were *Zinnia* sp. Still, for the vegetables, they were most fond of bitter melon.

CONCLUSIONS AND SUGGESTION

Of the 4 species of refugia (*Zinnia* sp*., T. erecta, C. caudatus,* and *S. indicum*), which were mostly chosen by the entomophagous arthropods as an alternative habitat in addition to rice, it was Zinnia sp. Of the 4 species of vegetables (*V. unguiculata, M. charantia, C. sativus,* and *L. acutangula*), the most preferred habitat alternative for the entomophagous arthropods was *M. charantia*. However, economically *M. charantia* was more beneficial than *Zinnia* sp. to be used as the conservation of entomophagous arthropods because it is not only provide alternative habitat and niche for the entomophagous arthropods but also it is used as land productivity.

Comment [A59]: italic

Comment [A60]: does

ACKNOWLEDGEMENT

This research was supported financially by Program of Professor Research Grant (Penelitian Unggulan Profesi Profesor) 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, a postgraduate student.

Comment [A61]: add an article

Comment [A62]: add an article

Comment [A63]: add an article

REFERENCES

Arango, A. M., López-Portillo, J., Parra-Tabla, V., Hernández-Salazar, L. T., Morales-Mávil, J. E., Rico-Gray, V. (2012). Effect of the spider *Peucetia viridans* (Oxyopidae) on floral visitors and seed set of *Cnidoscolus multilobus* (euphorbiaceae). *Acta Botanica Mexicana*, 100, 1–14. http://www.scielo.org.mx/pdf/abm/n100/n100a1.pdf

Baptiste, A. K., & Smardon, R. (2012). A review of wetland use and management of the Nariva Swamp, Trinidad. *Caribbean Geography*, 17(1–2), 73–91. https://www.researchgate.net/publication/273001155

Barrion, A., & Litsinger, J. (1995). *Riceland spiders of South and Southeast Asia*. Entomology Division International Rice Research Institute Philippines.

Behera, K. S. (2012). Biology of *Cardiochiles nigricollis* Cameron, a larval endo-parasitoid of *Cnaphalocrocis medinalis* (Guen.) and *Marasmia exigua* Butler. *Journal of Biological Control*, *26*(4), 376–379. http://www.informaticsjournals.com/index.php/jbc/article/download/3485/2570

Benvenuti, S., & Bretzel, F. (2017). Agro-biodiversity restoration using wildflowers: what is the appropriate weed management for their long-term sustainability?. *Ecological Engineering*, 102, 519–526. https://doi.org/10.1016/j.ecoleng.2017.02.062

Betz, L., & Tscharntke, T. (2017). Enhancing spider families and spider webs in Indian rice fields for conservation biological control, considering local and landscape management. *Journal of Insect*

Conservation, 21(3), 495–508. https://link.springer.com/article/10.1007/s10841-017-9990-2

Bhaskar, B. P., Baruah, U., Vadivelu, S., Raja, P., Sarkar, D. (2010). Remote sensing and GIS in the management of wetland resources of Majuli Island, Assam, India. *Tropical Ecology*, 51(1), 31–40. https://www.researchgate.net/publication/280251875

Bodlah, I., & Waqar, M. (2013). Pollinators visiting summer vegetables ridge gourd (*Luffa acutangula*), bitter gourd (*Momordica charantia* L.) and brinjal (S*olanum melongena*). *Asian Journal of Agriculture and Biology*, 1(1), 8–12. https://www.researchgate.net/publication/311644274

Cutler, G. C., Gariepy, T. D., De Silva, E. C. A., Hilier, N. K. (2015). High rates of parasitism of blueberry spanworm (Lepidoptera: Geometridae) by Ichneumonidae and Tachinidae in commercial lowbush blueberry fields High rates of parasitism of blueberry spanworm (Lepidoptera: Geometridae) by Ichneumonidae and Tachinidae. *Journal of Pest Science*, 88, 219–223. https://link.springer.com/article/10.1007/s10340-015-0650-6

Desai, S. D., Swaminathan, R. Desai, V. S. (2017). Effect of habitat manipulation on infestation of paddy leaf folder, *Cnaphalocrocis medinalis* (Guenee). *Int.J.Curr.Microbiol.App.Sci*, 6(10), 1469–1477. https://doi.org/10.20546/ijcmas.2017.610.174

Eggs, B., & Sanders, D. (2013). Herbivory in spiders: The importance of pollen for orb-weavers. *PLoS ONE*, 8(11), 1–5. https://doi.org/10.1371/journal.pone.0082637

Emile, T., Honorine, N.T., Thomas N., Marie-Anne, S. (2012). Vegetable production systems of swamp zone in urban environment in west cameroon: case of Dschang city. *Universal Journal of Environmental Research and Technology All*, 2(2), 83–92. http://www.environmentaljournal.org/2-2/ujert-2-2-9.pdf

Foti, M. C., Rostás, M., Peri, E., Park, K. C., Slimani, T., Wratten, S. D., Colazza, S. (2017). Chemical ecology meets conservation biological control: identifying plant volatiles as predictors of floral resource suitability for an egg parasitoid of stink bugs. *Journal of Pest Science*, 90(1), 299–310. https://link.springer.com/article/10.1007/s10340-016-0758-3

Ganai, S. A., Ahmad, H., Sharma, D., Sharma, S. (2017). Diversity of arthropod fauna associated with marigold (*Tagetes erecta* L.) in Jammu. *Journal of Entomology and Zoology Studeis*, *5*(5), 1940–1943. http://www.entomoljournal.com/archives/2017/vol5issue5/PartY/5-5-193-255.pdf

Gumovsky, A., Rusina, L., Firman, L. (2007). Bionomics and morphological and molecular characterization of *Elasmus schmitti* and *Baryscapus elasmi* (Hymenoptera: Chalcidoidea, Eulophidae), parasitoids associated with a paper wasp, *Polistes dominulus* (Vespoidea, Vespidae). *Entomological Science*, 10, 21–34. https://doi.org/10.1111/j.1479-8298.2006.00195.x

Hasan, K., Pervin, M., Manda, F., Mala, M. (2016). Habitat management: a key option to enhance natural enemies of crop pest. *Universal Journal of Plant Science*, 4, 50–57. http://www.hrpub.org/journals/article_info.php?aid=5517

Heinrichs, E. A. (1994). *Biology and management of rice insect*. International Rice Research Intitute.

Herlinda, S., Yudha, S., Thalib, R., Khodijah, Suwandi, Lakitan, B., Verawaty, M. (2018). Species richness and abundance of spiders inhabiting rice in fresh swamps and tidal lowlands in South Sumatera, Indonesia. *J. ISSAAS*, 24, 82–93.

https://www.cabdirect.org/cabdirect/abstract/20183221277

Hossain, M. S., Yeasmin, F., Rahman, M. M., Akhtar, S., Hasnat, M. A. (2018). Role of insect visits on cucumber (*Cucumis sativus* L.) yield. *J. biodivers. conserv. bioresour. manag.*, 4(2), 81–88. https://doi.org/10.3329/jbcbm.v4i2.39854

Hu, S., Fu, D. Y., Liu, X. J., Zhao, T., Han, Z. L., Lu, J. P., Wan, H. L., Ye, H. (2012). Diversity of planthoppers associated with the winter rice agroecosystems in Southern Yunnan, China. *Journal of Insect Science*, 12(29), 1–11. https://doi.org/10.1673/031.012.2901

Janzen, D. H. (2013). Differences in insect abundance and diversity between wetter and drier sites during a tropical dry season. *Ecology*, 49(1), 96–110. https://www.jstor.org/stable/1933565

Javier, A. M. V. (2018). Life history and biological control potential of *Snellenius manilae* Ashmead (Hymenoptera: Braconidae), a parasitoid of *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae). *Philipp Agric Scientist*, 101(2), 148–157. https://www.researchgate.net/publication/326981932_Life_History_and_Biological_Control_Potential_of_Snellenius_manilae_Ashmead_Hymenoptera_Braconidae_a_Parasitoid_of_Spodoptera_litura_Fabricius_Lepidoptera_Noctuidae

Jennings, D. T., Longcore, J. R., Bird, J. E. (2017). Spiders (Araneae) inhabit Lepidopteran-feeding shelters on ferns. *J. Acad. Entomol. Soc.* 13, 5–14. http://acadianes.org/journal/papers/jennings_16-3.pdf

Kalshoven, L. G. (1981). The pest of crops in Indonesia. Van Hoeve, Jakarta : PT. Ichtiar Baru.

Karindah, S., Yanuwiadi, B., Sulistyowati, L., Green, P. T. (2011). Abundance of *Metioche vittalicollis* (Orthoptera: Gryllidae) and natural enemies in a rice agroecosystem as influenced by weed species. *Agrivita*, 33(2), 133–141. http://doi.org/10.17503/agrivita.v33i2.55

Kaur, G., & Sangha, K. S. (2016). Evaluation of yellow sticky trap shapes for capturing alate insects in chilli agroecosystem. *Journal of Insect Science*, 29(1), 67–72. https://www.researchgate.net/publication/305771775

Lakitan, B., Alberto, A., Lindiana, L., Kartika, K., Herlinda, S., Kurnianingsih, A. (2018). The benefits of biochar on rice growth and yield in tropical riparian wetland, South Sumatra, Indonesia. *Chiang Mai University Journal of Natural Sciences*, 17(2), 111–126. http://cmuj.cmu.ac.th/ns/full/2120180410110810.pdf

Lakitan, B. 2019. Cultivation of common bean (*Phaseolus vulgaris* L.) subjected to shallow water table at riparian wetland in South Sumatra, Indonesia. *Australian journal of crop science*, 13(1), 98–104. https://www.researchgate.net/publication/332009012_Cultivation_of_common_bean_Phaseolus_vulgaris_L_subjected_to_shallow_water_table_at_riparian_wetland_in_South_Sumatra_Indonesia

Lakitan, B., Lindiana, L., Widuri, L. I., Kartika, K., Siaga, E., Meihana, M. (2019). Inclusive and Ecologically-Sound Food Crop Cultivation at Tropical Non-Tidal. *AGRIVITA*, 41(1), 1–9. http://doi.org/10.17503/agrivita.v40i0.1717

Lopes, S. de F., Ramos, M. B., de Almeida, G. R. (2017). The role of mountains as refugia for biodiversity in Brazilian Caatinga: Conservationist implications. *Tropical Conservation Science*, 10: 1–12. https://doi.org/10.1177%2F1940082917702651

Margono, B. A., Bwangoy, J. R. B., Potapov, P. V., Hansen, M. C. (2014). Mapping wetlands in Indonesia using landsat and PALSAR data-sets and derived topographical indices. *Geo-Spatial Information Science*, 17(1), 60–71. https://doi.org/10.1080/10095020.2014.898560

Masika, F. B., Masanza, M., Aluana, G., Barrigossi, A. F., Kizito, E. B. (2017). Abundance, distribution and effects of temperature and humidity on arthropod fauna in different rice ecosystems in Uganda. *Journal of Entomology and Zoology Studies*, 5(5), 964–973. https://www.researchgate.net/publication/321676101_Abundance_distribution_and_effects_of_temperature_and_humidity_on_arthropod_fauna_in_different_rice_ecosystems_in_Uganda

McAlpine, J. F., Peterson, B. V., Shewel, G. E., Teskey, H. J., Vockeroth, J. R., Wood, D. M., (1987). *Manual of Neartic Diptera*. Agriculture Canada, Research Branch.

McCabe, E., Loeb, G., Grab, H. (2017). Responses of crop pests and natural enemies to wildflower borders depends on functional group. *Insects*, 8(73), 1–8. https://doi.org/10.3390/insects8030073

Meng, J., Mabubu, J. I., Han, Y., He, Y., Zhao, J., Hua, H., Feng, Y., Wu, H. (2016). No impact of transgenic cry1C rice on the rove beetle *Paederus fuscipes*, a generalist predator of brown planthopper *Nilaparvata lugens*. *Scientific reports*. https://www.nature.com/articles/srep30303

Niba, A. 2011. Arthropod assemblage dynamics on cowpea (*Vigna unguiculata* L. Walp) in a subtropical agro-ecosystem, South Africa. *African Journal of Agricultural Research*, 6(4), 1009–1015. https://doi.org/10.5897/AJAR10.751

Prasad, R., Prabhu, S. T., Balikai, R. A. (2015). Incidence of white backed plant hopper on rice and its predators under rainfed ecosystems and their correlation with weather parameters. *Research Journal of Agricultural Sciences*, 1(4), 322–326. https://www.researchgate.net/publication/264846092_Incidence_of_White_Backed_Plant_Hopper_on_Rice_and_its_Predators_under_Rainfed_Ecosystems_and_their_Correlation_with_Weather_Parameters

Raffaelli, D. & Hall, S.J. (1992). Compartments and predation in an estuarine food web. *Journal of Animal Ecology*, 61, 551–560. https://www.jstor.org/stable/5610?seq=1#page_scan_tab_contents

Rocha-Filho, L. C., & Rinaldi, I. M. P. (2011). Crab spiders (Araneae: Thomisidae) in flowering plants in a Brazilian "Cerrado" ecosystem. *Brazilian journal of biology*, 71(2), 359–364. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1519-69842011000300004

Schmidt, K., Orosz-Kovacs, Z. Farkas, A. (2012). Nectar secretion dynamics in some raspberry and blackberry cultivars. *The International Journal of Plant Reproductive Biology*, 4(2), 147–150. https://www.researchgate.net/publication/233808478_Nectar_secretion_dynamics_in_some_raspberry_and_blackberry_cultivars

Settle, W. H., Ariawan, H., Astuti, E. T., Cahyana, W., Hakim, A. L., Hindayana, D., Lestari, A. S., Pajarningsih. (1996). Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. *Ecology*, 77(7), 1975–1988. https://www.jstor.org/stable/2265694

Shanker, C., Chintagunta, L., Muthusamy, S., Vailla, S., Srinivasan, A., Katti, G. (2018). Flora surrounding rice fields as a source of alternative prey for coccinellids feeding on the pests of rice. *European Journal of Entomology*, 115, 364-371. https://doi.10.14411/eje.2018.036. https://www.eje.cz/pdfs/eje/2018/01/36.pdf

Siaga, E., Lakitan, B., Hasbi., Bernas, S. M., Wijaya, A., Lisda, R., Ramadhani, F., Widuri, L. I., Kartika, K., Meihana, M. 2018. Application of floating culture system in chili pepper (*Capsicum annum* L.) during prolonged flooding period at riparian wetland in Indonesia. *Australian Journal of Crop Science*, 12(5), 808–816. http://www.cropj.com/siaga_supp_12_5_2018_808_816.pdf

Suwandi, Ammar, M., Irsan, C. (2012). Application of extract compost increased yield and suppressed the diseases of ratoon rice crop in tidal swamp of Banyuasin Regency. *J. Lahan Suboptimal*, 1, 116–122. [Indonesian]. http://www.jlsuboptimal.unsri.ac.id/index.php/jlso/article/download/15/13

Tahir, H. M., & Butt, A. (2009). Predatory potential of three hunting spiders inhabiting the rice ecosystems. *J Pest Sci*, 82, 217–225. https://link.springer.com/article/10.1007/s10340-008-0242-9

Wahocho, S. A., Miano, T. F., Memon, N. U. N., Wahocho, N. A. (2016). Photoperiodic effect on vegetative growth and flower quality of zinnia (*Zinnia elegans* Jacq.). *Sarhad Journal of Agriculture*, 32(4), 316–324. http://dx.doi.org/10.17582/journal.sja/2016.32.4.316.324

Widuri, L. I., Lindiana, L., Kartika, K., Siaga, E., Meihana, M., Hasmeda, M., Sodikin, E., Lakitan, B. (2016). Identification of farmer's needs and vegetable cultivation constraints in riparian wetlands using grounded theory. *Prosiding seminar nasional lahan suboptimal*, 587–594. [Indonesian]. http://pur-plso.unsri.ac.id/userfiles/71_%20HAL%20587-594%20%20Laily-ilman-widuri-identifikasi-kebutuhan-petani-lahan-rawa-lebak.pdf

Zhu, P., Wang, G ., Zheng, X., Tian, J., Lu, Z., Heong, K. K., Xu, H., Chen, G., Yang, Y., Gurr, G. M. (2014). Selective enhancement of parasitoids of rice Lepidoptera pests by sesame (*Sesamum indicum*) flowers. *BioControl*, 1-11. https://link.springer.com/article/10.1007/s10526-014-9628-1

Figures and Tables

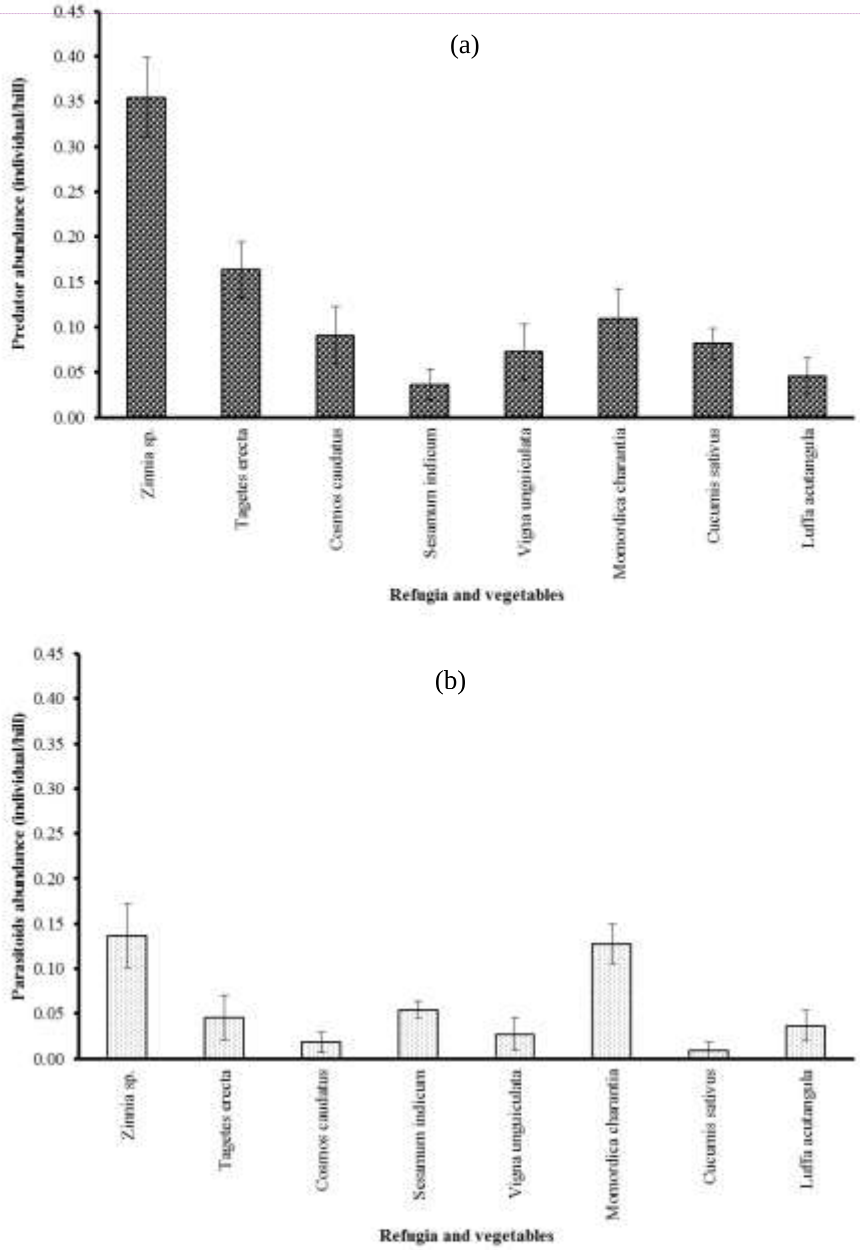


Fig. 1. Abundace of predatory arthropods (a) and parasitoids (b) inhabiting refugia and vegetables

Comment [A64]: the figure can combine in one graphic

Fig. 2. Flower of refugia and vegetables: zinnia (a), marigold (b), "kenikir" (c), sesame (d), cowpea (e), bitter melon (f), cucumber (g), ridged gourd (h)

Comment [A65]: yellow ray flower

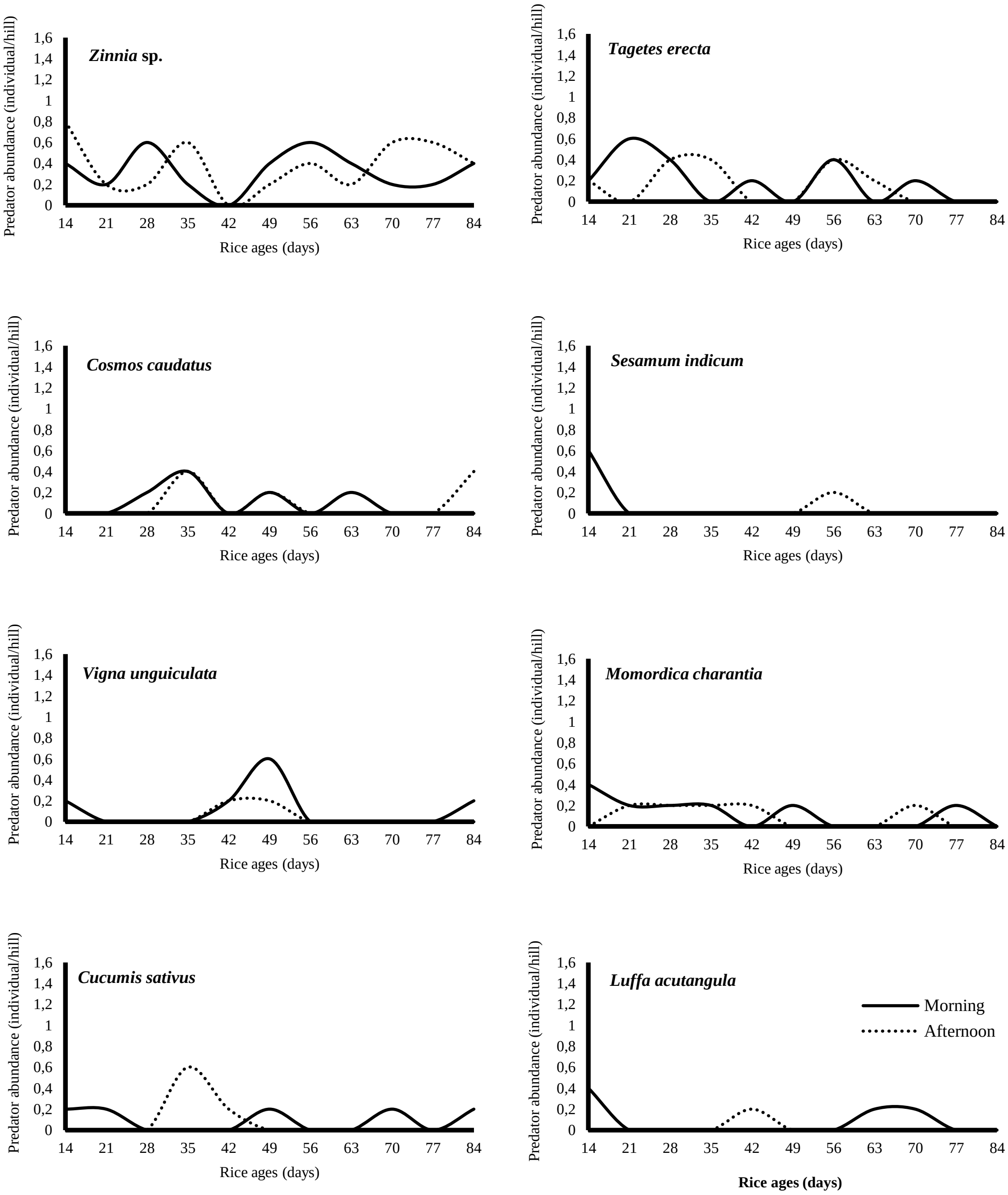


Fig. 3. Predatory abundance found on refugia and vegetables in the period of 14-84 days after rice transplanting

Comment [A66]: it's better to use specific time (07:00 to 08:00 a.m and 4:00 to 5:00 p.m) than morning or afternoon

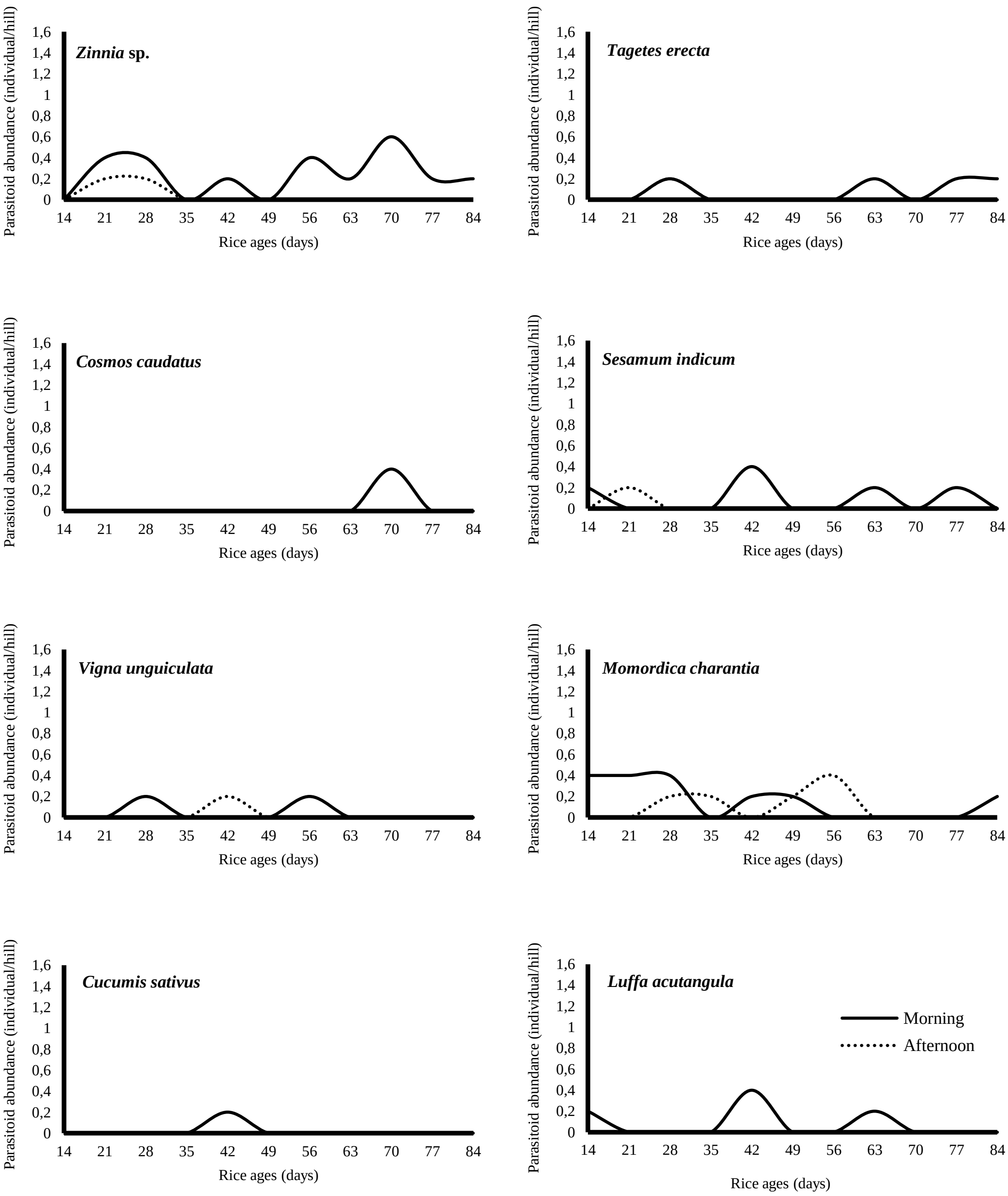


Fig. 4. Parasitoid abundance found on refugia and vegetables in the period of 14-84 days after rice transplanting or during a rice season

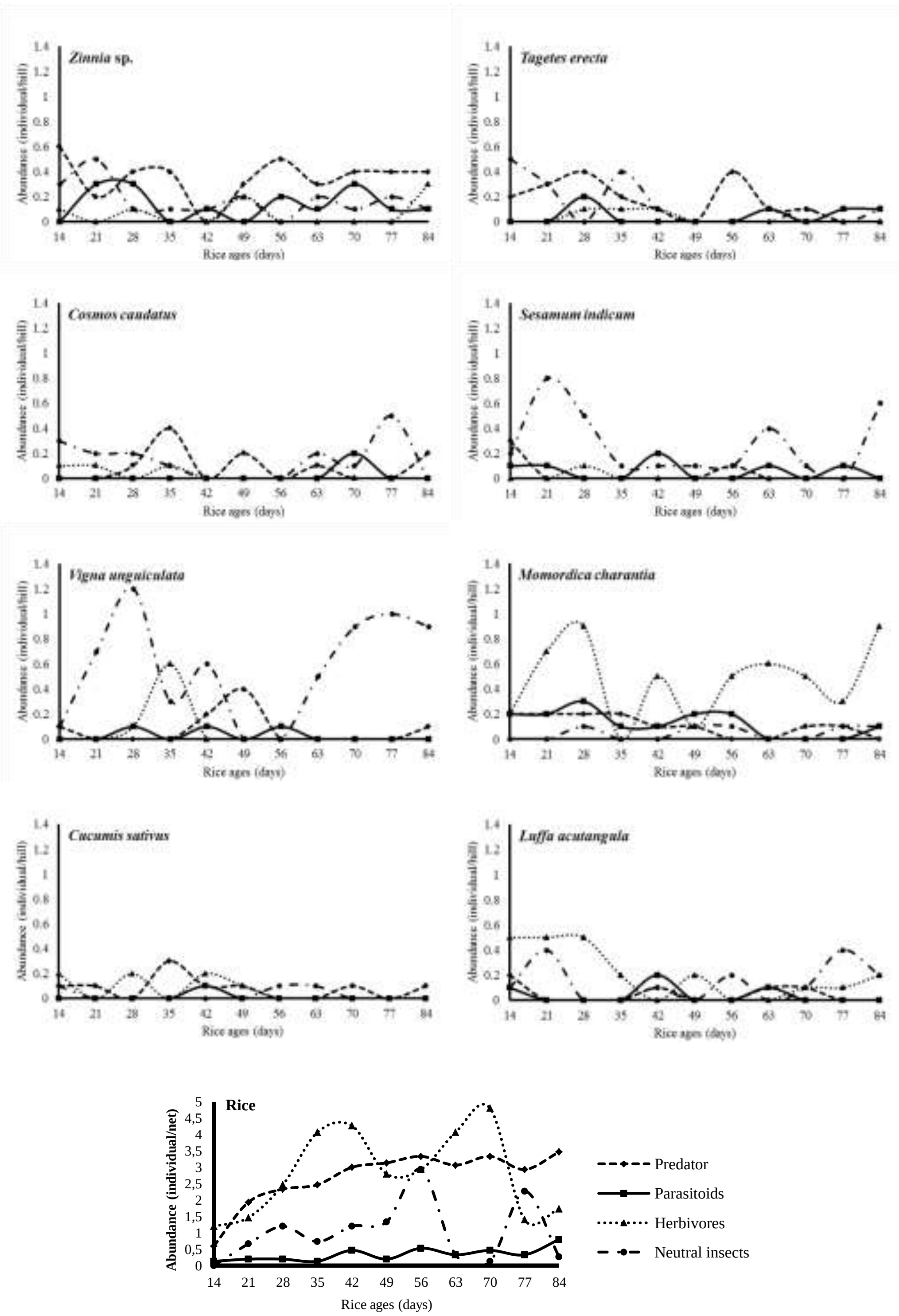


Fig. 5. Arthropod abundance found on refugia, vegetables, and rice in the period of 14-84 days after rice transplanting or during a rice season

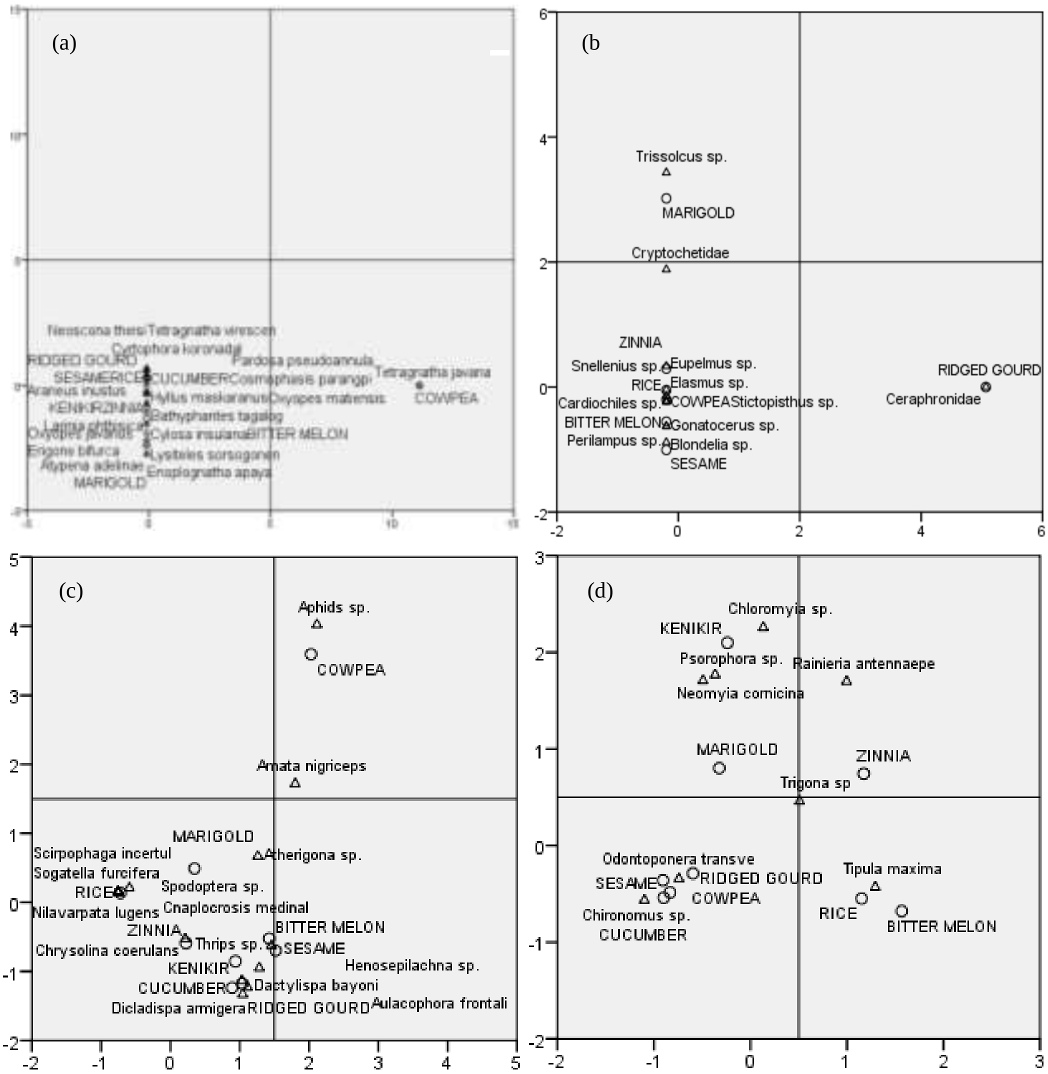


Fig. 6. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice vegetative stage; arthropods (o); plant (Δ)

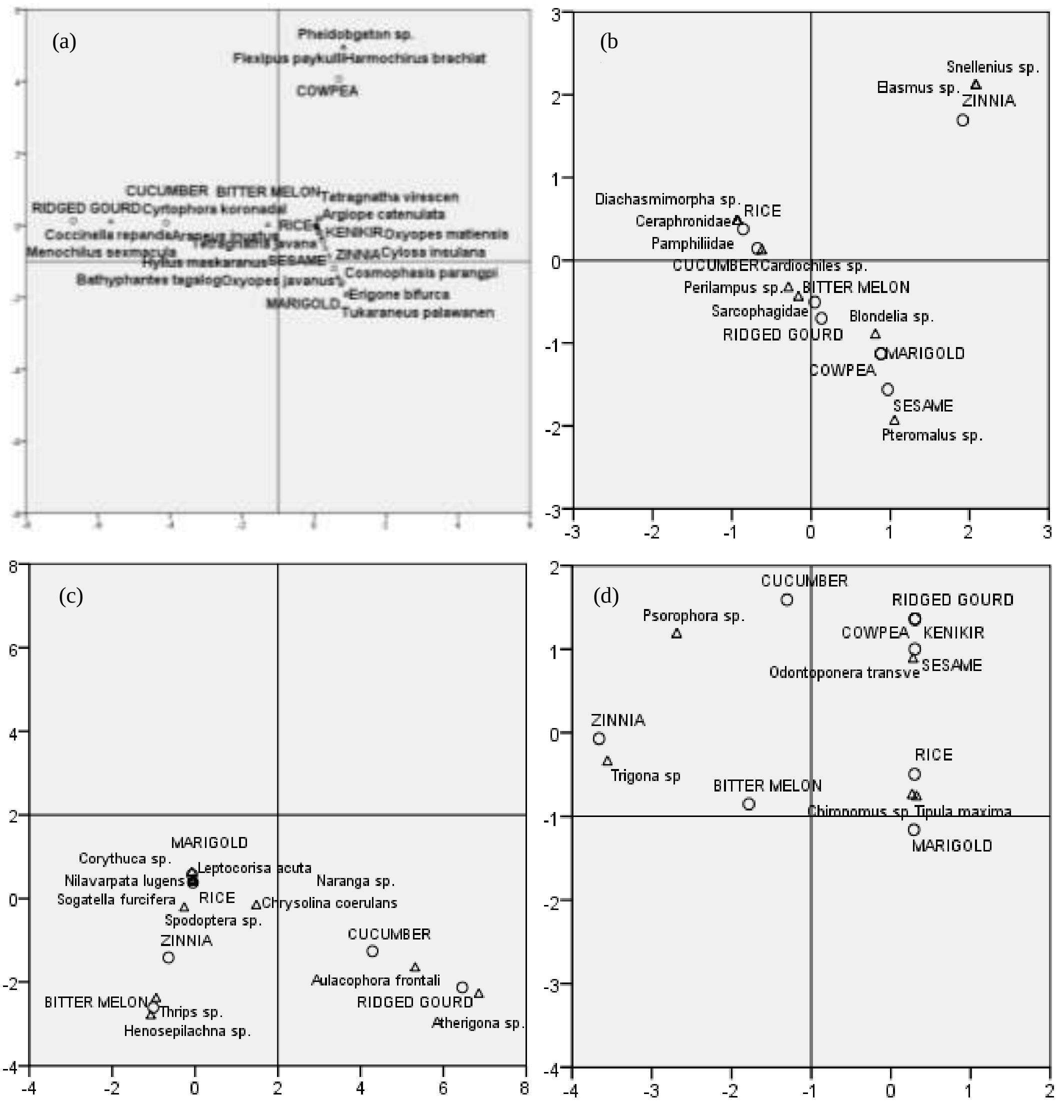


Fig. 7. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice milky stage; arthropods (o); plant (Δ)

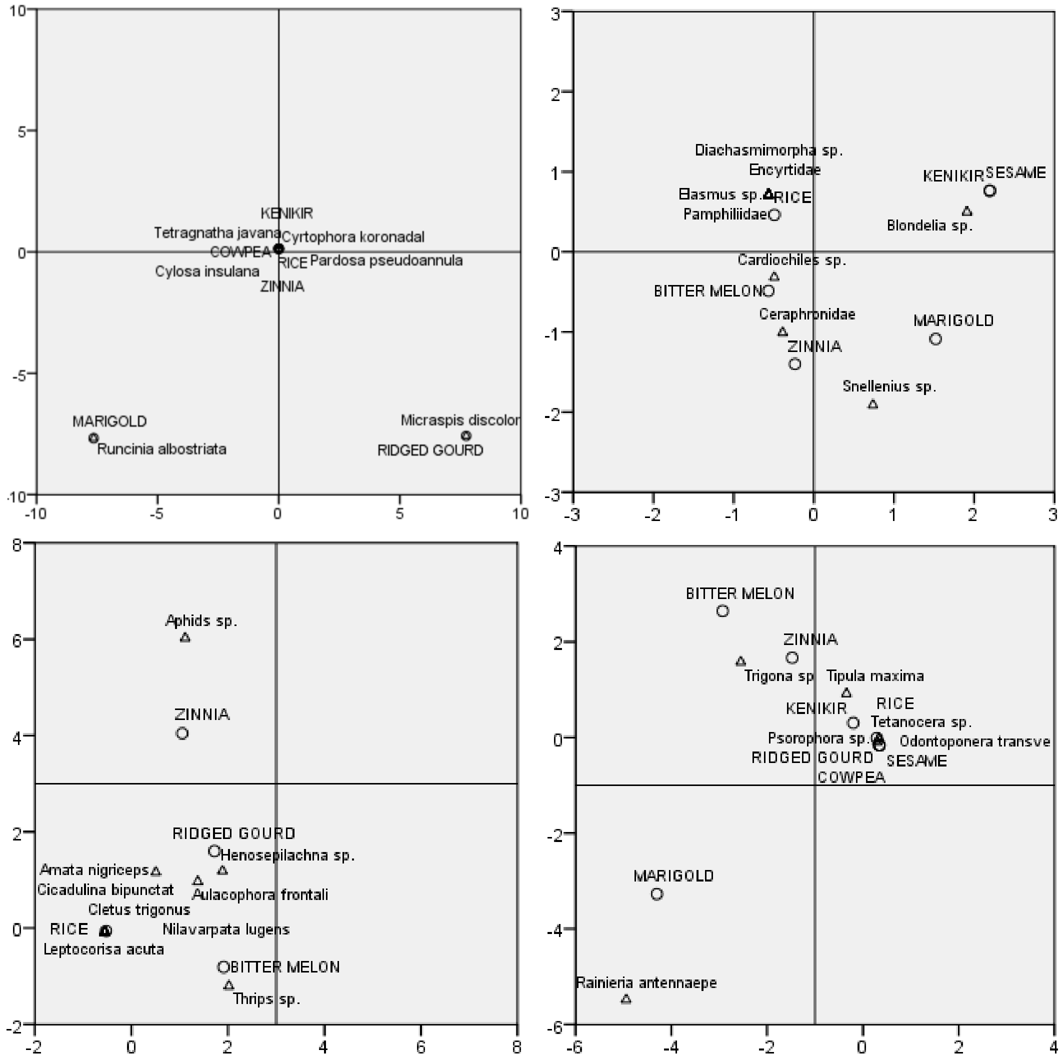


Fig. 8. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice ripening stage; arthropods (o); plant (Δ)

Table 1. Species composition of predatory arthropods found in rice, refugia, and vegetables

No.	Species	Habitat (individual/net or individual/flower)								
		A	B	C	D	E	F	G	H	I
1.	*Pardosa pseudoannulata*	0.04	0	0	0	0	0	0	0	0
2.	*Araneus inustus*	0.01	0	0	0.01	0	0	0	0	0
3.	*Cylosa insulana*	0.05	0.02	0.02	0.01	0	0	0	0	0
4.	*Cyrtophora koronadalensis*	0.02	0	0	0	0	0	0	0	0
5.	*Neoscona theisi*	0.01	0	0	0	0	0	0	0	0
6.	*Argiope catenulate*	0.04	0	0	0	0	0	0	0	0
7.	*Larinia phthisica*	0	0.01	0.01	0	0	0	0	0	0
8.	*Tukaraneus palawanensis*	0	0	0.01	0	0	0	0	0	0
9.	*Tetragnatha javana*	0.17	0.02	0	0	0	0.01	0	0	0
10.	*Tetragnatha virescens*	0.68	0.01	0.01	0	0	0.03	0.02	0	0
11.	*Tetragnatha mandibulata*	0.24	0.01	0	0.01	0	0	0	0	0
12.	*Tetragnatha maxillosa*	0.10	0	0	0	0	0	0	0	0
13.	*Tetragnatha vermiformis*	0.12	0	0	0	0	0	0	0	0
14.	*Tetragnatha Okumae n. Sp.*	0.01	0	0	0	0	0	0	0	0
15.	*Tetragnatha iwahigensis*	0.01	0	0	0	0	0	0	0	0
16.	*Tetragnatha natans*	0.01	0	0	0	0	0	0	0	0
17.	*Bathyphantes tagalogensis*	0.07	0.01	0.01	0	0	0	0	0	0
18.	*Bathyphantes sp.*	0.02	0	0	0	0	0	0	0	0
19.	*Erigone bifurca*	0	0	0.02	0	0	0	0.01	0	0
20.	*Enoplognatha sp.*	0.02	0	0	0	0	0	0	0	0
21.	*Linyphiidae (unknown species)*	0.01	0	0	0	0	0	0	0	0
22.	*Atypena adelinae*		0	0.01	0	0	0	0	0	0
23.	*Oxyopes javanus*	0.02	0.05	0.01	0	0	0	0.01	0	0
24.	*Oxyopes matiensis*	0.09	0.05	0.00	0.03	0.01	0	0.01	0	0
25.	*Oxyopes pingasus*	0.01	0	0	0	0	0	0	0	0
26.	*Theridion sp.*	0.01	0	0	0	0	0	0	0	0
27.	*Enoplognatha apaya*	0	0	0.01	0	0	0	0	0	0
28	*Lysiteles sorsogonensis*	0	0	0.01	0	0	0	0	0	0
29.	*Thomisus ilocanus*	0	0	0.01	0	0	0	0	0	0
30.	*Thomisus italongus*	0	0	0	0	0	0	0.02	0	0
31.	*Runcinia albostriata*	0	0	0.01	0	0	0	0	0	0
32.	*Myrmarachne bidentata*	0.01	0	0	0	0	0	0	0	0
33.	*Hyllus maskaranus*	0.03	0.05	0	0	0.01	0	0	0	0
34.	*Myrmarachne onceana*	0	0	0.02	0	0	0	0.01	0	0
35.	*Cosmophasis parangpilota*	0.01	0.05	0.02	0.01	0	0	0	0	0
36.	*Cosmophasis sp.*	0.02	0.02	0	0.01	0	0	0	0	0
37.	*Flexipus paykulli*	0	0.02	0	0	0	0.01	0	0	0
38.	*Harmochirus brachiatus*	0.01	0	0	0	0	0.01	0	0	0
39.	*Bianor hotingchiehi*	0.01	0	0	0	0	0	0	0	0
40.	*Emathis sp.*	0.01	0	0	0	0	0	0	0	0
41.	*Hahnia tuybaana*	0.02	0	0	0	0	0	0	0	0
42.	*Cyrtorhinus lividipennis*	0.02	0	0	0	0	0	0	0	0
43.	*Orthotylus sp.*	0.02	0	0	0	0	0	0	0	0
44.	*Ophionea nigrofasciata*	0.01	0	0	0	0	0	0	0	0
45.	*Paederus fuscipes*	0.18	0.04	0	0	0.01	0	0	0	0.01
46.	*Micraspis inops*	0.24	0	0	0	0	0	0.01	0.02	0.01
47.	*Verania lineata*	0.01	0	0	0	0	0	0	0	0
48.	*Micraspis vincta*	0.02	0	0	0	0	0	0	0	0
49.	*Harmonia octomaculata*	0.01	0	0	0	0	0	0	0	0
50.	*Coccinella repanda*	0.03	0	0	0	0	0	0	0.01	0

Remarks: A= rice; B= *Zinnia* sp.; C= *Tagetes erecta*; D= *Cosmos caudatus*;E= *Sesamum indicum*; F=*Vigna unguiculata*; G=*Momordica charantia*; H=*Cucumis sativus*; I=*Luffa acutangula*

Table 1. Continued

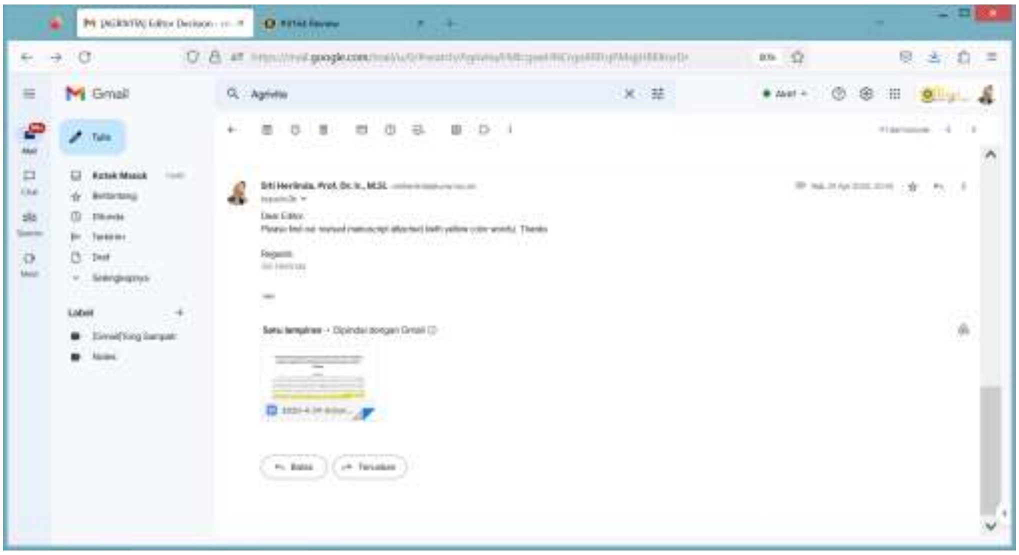
No.	Species	Habitat (individual/net or individual/flower)								
		A	B	C	D	E	F	G	H	I
51.	*Brumoides suturalis*	0.02	0	0	0	0	0	0	0	0
52.	*Menochilus sexmaculatus*	0.01	0	0	0	0.01	0	0	0.03	0.02
53.	*Propylaea japonica*	0	0.01	0	0	0	0	0	0	0
54.	*Coccinella septempunctata*	0	0	0	0	0	0	0	0.01	0
55.	*Micraspis discolor*	0	0	0	0	0	0	0	0	0.01
56.	*Larva Coccinellidae*	0.16	0	0	0.02	0	0	0.02	0.02	0
57.	Elateridae (unknown species)	0.01	0	0	0	0	0	0	0	0
58.	*Formicomus* sp.	0.01	0.01	0	0	0	0	0.01	0	0
59.	*Agriocnemis* sp.	0.03	0	0	0	0	0	0	0	0
60.	*Pyrrhosoma* sp.	0.01	0	0	0	0	0	0	0	0
61.	*Argia* sp.	0.01	0	0	0	0	0	0	0	0
62.	*Pantala* sp.	0.01	0	0	0	0	0	0	0	0
63.	*Conocephalus longipennis*	0.02	0	0	0	0	0	0	0	0
64.	*Monomorium destructor*	0	0	0	0	0	0.02	0	0	0
65.	*Solenopsis* sp.	0.01	0	0	0	0	0	0	0	0
66.	*Volucella* sp.	0.01	0	0	0	0	0	0	0	0
67.	Mantidae (unknown species)	0.01	0	0	0	0	0	0	0	0
	Total Abundance (N)	2.74	0.38	0.18	0.1	0.04	0.08	0.12	0.09	0.05
	Number of Species (S)	51	15	14	7	4	5	9	5	4

Remarks: A= rice; B= *Zinnia* sp.; C= *Tagetes erecta*; D= *Cosmos caudatus*;E= *Sesamum indicum*; F=*Vigna unguiculata*; G=*Momordica charantia*; H=*Cucumis sativus*; I=*Luffa acutangula*

Table 2. Species composition of parasitoid found on rice, refugia, and vegetables

No.	Species	Habitat (individual/net or individual/flower)								
		A	B	C	D	E	F	G	H	I
1	*Stictopisthus* sp.	0.01	0	0	0	0	0	0	0	0
2	*Elasmus* sp.	0.02	0.03	0	0	0	0	0.01	0	0
3	*Trissolcus* sp.	0	0	0.01	0	0	0	0	0	0
4	*Snellenius* sp.	0.02	0.03	0.01	0	0	0.01	0	0	0
5	*Cardiochiles* sp.	0.09	0.04	0	0	0	0	0.05	0.01	0
6	*Diachasmimorpha* sp.	0.02	0	0	0	0	0	0	0	0
7	*Gonatocerus* sp.	0	0	0	0	0	0	0.01	0	0
8	*Perilampus* sp.	0.01	0	0	0	0	0	0.01	0	0.01
9	Ceraphronidae (unknown species)	0.04	0.02	0	0	0	0	0	0	0.01
10	Pamphiliidae (unkown species)	0.02	0	0	0	0	0	0	0	0
11	Encyrtidae (unknown species)	0.02	0	0	0	0	0	0	0	0
12	*Eupelmus* sp.	0.01	0.01	0	0	0	0	0	0	0
13	*Helorus* sp.	0.02	0	0	0	0	0	0	0	0
14	*Pteromalus* sp.	0.01	0	0	0	0.01	0	0	0	0
15	*Netomocera* sp.	0.02	0	0	0	0	0	0	0	0
16	*Haltichella* sp.	0.01	0	0	0	0	0	0	0	0
17	*Tetramesa* sp	0.01	0	0	0	0	0	0	0	0
18	*Eurytomidae* sp.	0.01	0	0	0	0	0	0	0	0
19	*Athrycia* sp.	0.01	0	0	0	0	0	0	0	0
20	*Blondelia* sp.	0.01	0.01	0.02	0.02	0.05	0.02	0.04	0	0.01
21	Cryptochetidae (unknown species)	0	0.01	0.01	0	0	0	0	0	0
22	Sarcophagidae (unknown species)	0.01	0	0	0	0	0	0.01	0	0.01
	Total Abundance (N)	0.37	0.15	0.05	0.02	0.06	0.03	0.13	0.01	0.04
	Number of Species (S)	19	7	4	1	2	2	6	1	4

Remarks: A= rice; B= *Zinnia* sp.; C= *Tagetes erecta*; D= *Cosmos caudatus*;E= *Sesamum indicum*; F=*Vigna unguiculata*; G=*Momordica charantia*; H=*Cucumis sativus*; I=*Luffa acutangula*



Arboreal Entomophagous Arthropods of Rice Insect Pests Inhabiting Adaptive Vegetables and Refugia in Freshwater Swamps of South Sumatra

ABSTRACT

Plants growing around the rice fields can be used as a habitat and niche for entomophagous arthropods. This study aimed to identify the species of entomophagous arthropods of rice insect pests and to analyze their abundance and community in adaptive vegetables and refugia in freshwater swamps. The field was surrounded by 4 species of refugia (*Zinnia* sp., *Tagetes erecta, Cosmos caudatus,* and *Sesamum indicum*) and 4 species of vegetables (*Vigna unguiculata, Momordica charantia, Cucumis sativus,* and *Luffa acutangula*). Arthropods were sampled using nets. The results showed that entomophagous arthropods found consisted of 67 species of predatory arthropods and 22 species of parasitoids. The predatory arthropods species were mostly found in rice (51 species), *Zinnia* sp. (15 species), and *M. charantia* (9 species). Parasitoid species were dominantly found in rice (19 species), *Zinnia* sp. (7 species), and *M. charantia* (6 species). The predatory arthropods dominantly found were *Tetragnatha javana, Tetragnatha virescens,* and *Paederus fuscipes*, while the dominant parasitoids were *Cardiochiles* sp., *Elasmus* sp., and *Snellenius* sp. The parasitoid species composition in rice was more similar to the species composition in bitter melon and zinnia. However, predatory arthropod species composition in rice was similar to the species composition in all vegetables and refugia, except the species composition in cowpea. *Zinnia* sp. and *M. charantia* were the most chosen habitat by entomophagous arthropods besides rice fields. However, *M. charantia* is more beneficial than *Zinnia* sp. due to its function not only for conservation of natural enemies and also for land productivity.

KEYWORDS

Habitat, niche, parasitoid, predator, refugia, and vegetable

INTRODUCTION

Wetland is a land saturated with water, both year-round and seasonal. Wetland in Indonesia generally consists of freshwater (non-tidal) swamp and tidal lowland. Freshwater swamp is a wetland that is flooded due to the flow of river water or rain, while the lowland tidal is inundated due to the tides (Lakitan et al., 2018). According to Margono et al. (2014), the wetland area in Indonesia is around 39.6 Mha, 77% of them are spread in Sumatra Island (11.9 Mha), Kalimantan (12.2 Mha), and Papua (11.8 Mha), while the remaining 23% are spread in Java (1.9 Mha), Sulawesi (1.2 Mha), Maluku (0.5 Mha), and Bali-Nusa Tenggara (0.2 Mha).

Freshwater swamps in South Sumatra are generally inundated from November to April, or May depend on the lowland typology, and in dry season the land often drought (based on direct observation in the center of freshwater swamps, Ogan Ilir District, South Sumatra since 2012 up to now). When they are inundated, some local farmers raise swamp fish or local duck, alabio duck (*Anas platyrhynchos*), while in the dry season, they grow rice (Lakitan et al., 2018) or adaptive vegetables (Lakitan et al., 2019). Another local habit is when they grow rice, they also grow adaptive vegetables in rice fields. Some adaptive vegetables in freshwater swamps are cowpea (*Vigna unguiculata*) (Bhaskar et al., 2010), cucumber (*Cucumis sativus*) (Baptiste & Smardon, 2012), ridged gourd (*Luffa acutangula*) and bitter melon (*Momordica charantia*) (Widuri et al., 2016), chili pepper (*Capsicum annum L.*) (Siaga et al., 2018) common bean (*Phaseolus vulgaris*) (Lakitan, 2019), and tomatoes (Emile et al., 2012). The vegetables which planted around the rice fields have multiple functions, but it is not realized by the local farmers. Besides being able to increase land productivity, these vegetables can provide natural habitat and niche for natural enemies of the rice insect pest.

Cowpeas are inhabited by 21 insect species of 12 families and 5 orders (Coleoptera, Hemiptera, Orthoptera, Homoptera, and Lepidoptera) (Niba, 2011). Cucumbers are visited by 11 insect species of 7 families and 3 orders (Hymenoptera, Diptera, and Coleoptera) (Hossain et al., 2018). Ridged gourds are inhabited by 6 insect species of 3 families and 2 orders (Hymenoptera and Diptera), while bitter melons are visited by 4 insect species of 3 families and 2 orders (Bodlah & Waqar, 2013). Chili pepper is visited by 41 species of arthropods consisting of 14 species of pests and natural enemies, 12 species of visitors, and 1 species of pollinator (Kaur & Sangha, 2016).

The diversity of arthropods in freshwater swamps is also supported by the presence of wild flowering plant or non-crop plant as refugia around rice field. Non-crop plants and refugia provide niche, additional food, and other resources for natural enemies of rice pests (Zhu et al., 2014; Hasan et al., 2016; Benvenuti & Bretzel, 2017; Lopes et al., 2017; McCabe et al., 2017). Grassy rice fields in ecosystems have a higher number of arthropods than those in non-weed ecosystems (Hu et al., 2012). The existence of refugia, sunflower plants (*Helianthus annuus*), indian mustard (*Brassica juncea*), sesame (*Sesamum indicum*), marigold (*Tagetes erecta*), yellow ray flower (*Cosmos caudatus*), and Zinnia (*Zinnia* sp.) is known to be effective in reducing the attack of leaf-rolling pests (*Cnaphalocrocis medinalis*) in several rice varieties in India (Desai et al., 2017). Marigold is reported to be associated with several species of predatory arthropods such as *Oxyopes javanus, Coccinella septumpunctata, Syrphus* spp., and *Geocoris* spp. (Ganai et al., 2017). Zinnia is also reported to be associated with several species of spiders, including *Argiope aemula, Oxyopes* sp., and *Perenethis* sp. (Desai et al., 2017). Consequently, vegetables and refugia are beneficial as habitat and niche for entomophagous arthropods (parasitoid and predatory arthropods) which are natural enemies of insect pests. There is little information available the entomophagous arthropods that are associated with vegetables and refugia in freshwater swamps of South Sumatra. This study aimed to identify the species of entomophagous arthropods of rice insect pests and to analyze their abundance and community in adaptive vegetables and refugia in freshwater swamps of South Sumatra.

MATERIALS AND METHODS

The field experiment was carried out in the center of freshwater swamps in Pelabuhan Dalam Village of Pemulutan Subdistrict, Ogan Ilir District, South Sumatra Province, from May to September 2018. The area of rice field is around 7.1 Mha. The species identification was carried out in the laboratory from September 2018 to May 2019.

Rice, Vegetables, and Refugia Planting

The rice plot area used was 1 ha, surrounded by 4 species of refugia and 4 vegetable species with the distance between plots was around 100 m, and 1 ha of plot area was divided into three sub-plots and used as replications. Each rice subplot was surrounded by 4 species of refugia (*Zinnia* sp., *T. erecta, C. caudatus,* and *S. indicum*), as well as other rice subplots were surrounded by 4 vegetable species (*V. unguiculata*, *M. charantia*, *C. sativus*, and *L. acutangula*). The position of 4 refugia species or the 4 species of vegetables in each rice sub-plot was in four embankments surrounding the sub-plot, and each embankment was planted with one plant species. In consequence, the four embankments surrounding the rice subplots were planted with different species of refugia or vegetables. This position was to give a freedom for entomophagous arthropods to choose the alternative habitat other than rice. The planting of refugia and vegetables was carried out 30 days before rice planting so that when it was in vegetative phase of 14 days after transplanting (DAT), the refugia would have been blooming. The plant spacing of vegetables followed the habit of the local farmers (30 cm); meanwhile, the refugia were planted closer (15 cm) and containing 5 seeds per hole.

The rice was planted according to planting system of 2:1 "jajar legowo" spacing (50 cm x 25 cm x 12.5 cm) and did not use synthetic pesticides; the fertilizing used manure at a dose of 1 ton/ha and 2 L of extract liquid compost made following the method of Suwandi et al. (2012). The rice planting began with land preparation by cultivating the soil and applying the manure at the same time. Then, the rice seeds were sown according to the traditions of local farmers, using the "Samir" method, i.e., the seeds of 7-10 days old were transplanted into the field. When the rice plant was in 2 weeks after planting, the fertilization was applied using extract liquid compost every 2 weeks.

Sampling the arboreal arthropods inhabiting refugia and vegetables

Arthropod sampling that was inhabiting refugia and vegetables surrounding the rice field was conducted once a week started from 14 to 84 DAT. The sampling was carried out twice for every observation, i.e., at 07:00 to 08:00 a.m. and at 04:00 to 05:00 p.m. The sampling was carried out by randomly picking 5 flowers for each species of refugia and vegetables. The flowers were cut from their stalks and put them in a 150 ml plastic container (Ø = 7 cm and height = 6.5 cm) perforated on the lid with a diameter of 2 cm and covered with gauze glued together. Each flower was separately put into a plastic container and labeled. The flowers were incubated and observed until the arthropods were released from the flower. The arthropods were separated from the flowers and put into a 10 ml glass bottle containing 80% ethanol. The glass bottles containing arthropods were labeled and then identified in Entomology Laboratory, Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Sriwijaya. The identification of spiders referred to Barrion & Litsinger (1995) and the identification of insects referred to Heinrichs (1994), Kalshoven (1981), and McAlpine et al. (1987).

Sampling of Arboreal Arthropods in Rice

Observation of the arthropods was conducted weekly started when the rice in 14 to 84 DAT. The sampling of the arboreal arthropods for the observations used nets (net handle length = 100 cm, net length = 75 cm, and net Ø = 30 cm) at five points scattered in four corners of the land and one in the middle of the land for each subplot study (3 subplots as a repetition). The sampling was carried out at 06.00 to 07.00 a.m. in good weather conditions with no rain. The arthropods collection with nets was carried out based on the modification of Janzen method (2013), i.e., the arthropods were collected by swinging a net of one double swing in a straight line in 30 cm depth in the canopy of the plants. The net coverage was based on the modified methods of Masika et al. (2017) by swinging a net that tied on a plant stem. The nets were intentionally applied on the rice stem to obtain the insects on the stems and leaves of the rice plants. The obtained arthropods were sorted, put into the vial bottles containing 80% ethanol, labeled, and then identified in the laboratory. The identification of the spiders referred to Barrion and Litsinger (1995), and identification of insects referred to Heinrichs (1994), Kalshoven (1981), and McAlpine et al. (1987).

Data Analysis

The data on species composition and abundance of entomophagous arthropods inhabiting refugia and vegetables were presented in tables and charts. Their subsequent abundance data were also grouped according to the guild, i.e., predator, parasitoid, herbivore, and neutral insect, to be displayed in graphical form. Correspondence analysis was used to investigate how species of arthropods and plants (refugia, vegetables, and rice) were grouped based on the arthropod species they interacted with (Raffaelli & Hall 1992) and the species of data analyzed were grouped in species community of predators, parasitoid, herbivore, and neutral insects. The calculation of correspondence analysis used the software of SAS University Edition 2.7 9.4 M5.

RESULTS AND DISCUSSION

Species Composition and Abundance of Arboreal Entomophagous Arthropods

Arboreal entomophagous arthropods are arthropods that act as predators and parasitoids for natural enemies of insect pests. In this study, arboreal entomophagous arthropods found in rice were grouped into predatory arthropods and parasitoids. Predatory arthropods consisted of groups of spiders and predatory insects, while parasitoid was a group of insects that were parasite to insects or other arthropods. The total species number of predatory arthropods and parasitoids were 67 species (Table 1) and 22 species (Table 2), respectively. In the rice field, the number of predatory arthropods species was dominant (51 species) compared to refugia and vegetables. In refugia, the predatory arthropods species were dominantly found in *Zinnia* sp. (15 species), while in vegetables were mostly found in *M. charantia* (9 species). *S. indicum* was a refugia less chosen as the predatory arthropod habitat, while *L. acutangula* was a vegetable plant less chosen as the habitat by the predatory arthropods. The five species of arboreal predatory arthropods which dominantly found in rice were *Tetragnatha javana, Tetragnatha virescens, Tetragnatha mandibulata, Paederus fuscipes,* and *Micraspis inops*. Four of five species that found in rice (*T. javana, T. virescens, T. mandibulata,* and *P. fuscipes*) were found in *Zinnia* sp. In contrast, in *M. charantia,* two species of predatory arthropods were found (*T. virescens* and *M. inops*). In addition, there were other predatory arthropods found in rice, refugia, and vegetables, i.e., *O. javanus, Oxyopes matiensis, Menochilus sexmaculatus,* and *Coccinella septempunctata*.

In this study, the arboreal predatory arthropods species found in rice, refugia, and vegetables were the important predators attacking insect pests of rice. *T. javana, T. virescens,* and *T. mandibulata* are family spiders of Tetragnathidae that can prey on orders of Homoptera and Lepidoptera in rice (Tahir et al., 2009). Betz and Tscharntke (2017) stated that the Tetragnathidae also preys on order of Homoptera (leafhoppers) on rice. *P. fuscipes* is a predator of *Nilaparvata lugens* (Meng et al., 2016), and *M. inops* is an insect pest of rice generalist predator (Karindah et al., 2011). *O. javanus* effectively preys on *Hieroglyphus banian, Sogetella furcilera, Marasmia patnalis,* and *Scripophaga innotata* on rice in Pakistan (Tahir & Butt, 2009). *T. virescens* effectively controls *S. furcifera* on rice in India (Prasad, Prabhu, & Balikai, 2015). Coccinellidae prey on *N. virescens*, *N. lugens,* and *S. furcifera* on rice in India (Shanker et al., 2018).

Number parasitoid species were mostly found in rice (19 species) compared to refugia and vegetables. In refugia, the parasitoids were mostly found in *Zinnia* sp*.* (7 species), whereas in vegetables were mostly found in *M. charantia* (6 species) (Table 2). The most abundant parasitoids found in rice were *Cardiochiles* sp. (0.09 individual/flower), and this species was also found in *Zinnia* sp. (0.04 individual/flower), *M. charantia* (0.05 individual/flower), and *C. sativus* (0.01 individual/flower). *Cardiochiles* sp. is an effective parasitoid to control *C. medinalis* in rice (Behera 2012). In addition, *Snellenius* sp. and *Elasmus* sp*.* were found at Zinnia sp., while in *M. charantia* was found *Blondelia* sp. *Snellenius* sp. is a parasitoid of *Spodoptera litura* larvae (Javier & Ceballo 2018). *Elasmus* sp. is a parasitoid of *dominulus polystes* (Gumovsky et al., 2007), while *Blondelia* sp. is generally attacked Lepidoptera of the Geometridae family (Cutler et al., 2015).

If only comparing refugia and vegetables without rice, the abundance of predatory arthropods was higher in these following three habitats, i.e., *Zinnia* sp*., T. erecta,* and *M. charantia*. At the same time, parasitoid was higher in *Zinnia* sp*., S. indicum,* and *M. charantia* (Fig. 1). Refugia and vegetables were preferred by both entomophagous arthropods because they had good morphological attraction, long flower blooms (Jennings et al., 2017), and the availability of floral nectar and pollen (Eggs & Sanders, 2013; Foti et al., 2017). In this study, the flower of *T. erecta, S. indicum,* and *M. charantia* was preferred by the entomophagous arthropods (Fig. 2) compared to other colors because of their yellow flower. The data were in line with the study of Rocha-Filho & Rinaldi (2011), stated that yellow flower was preferred for arthropods compared to white and pink flower. Despite having red color, *Zinnia* sp. was the most preferred due to its longest blooming period compared to other flowers because its flower blooms for 23.67 days (Wahocho et al., 2016). The form of *Zinnia* sp. flower was rosette-shaped. *T. erecta* and *M. charantia* is also had high attraction for predator and parasitoid, and rosette-shaped flowers are longer visited by arthropods (Jennings et al., 2017). Pollen and nectar of the refugia and vegetable flowers become high attraction for arthropods, such as spiders (Eggs & Sanders, 2013) and parasitoids (Foti et al., 2017).

Based on the time visiting flowers, there was an interesting phenomenon. Predators, especially spiders, their visiting time to refugia and vegetables was high at 7:00 a.m. to 08:00 a.m. and 4:00 p.m. to 5:00 p.m. (Fig. 3), while the parasitoid generally visited the flowers at 7:00 a.m. to 08:00 p.m. (Fig. 4). *Zinnia* sp.*, T. erecta,* and *M. charantia* were visited by the predators in the morning and evening, and more often than other refugia or vegetable species. This is related to the longest blooming period of *Zinnia* sp. Predators generally visit refugia and vegetables in the morning and evening since the predators are looking for the prey. The prey that needed by predator is more than host need by parasitoid, for example, spiders periods of predation ranging from 5 a.m. to 10 p.m. (Arango et al. 2012). As for parasitoids, their activity of visiting refugia and vegetables is generally carried out in the morning due to parasitoid looking for pollen and nectar, while the direct observation result showed that the host finding activity by parasitoid was generally conducted at 7:00 a.m. in rice. Similarly with Schmidt et al. (2012) stated that parasitoid is generally looking for plants that produce nectar and pollen for their feed in the morning. The availability of nectar and pollen generally occurs in the morning because many flowers are blooming in the morning. Therefore, the existence of refugia and vegetables around the rice field is useful in providing alternative habitat and niche for the parasitoid and predator of rice pest insects.

Community of Arboreal Arthropods in One Rice Growing Season

Arthropods can be grouped into the guilds, i.e., predators, parasitoids, herbivores, and neutral insects. The data showed that the four species of refugia were generally dominated by predators and parasitoids, while the four vegetable species were dominated by parasitoids and herbivores. The rice was dominated by herbivores, and predators followed the development of the herbivores population. The higher the population of herbivores, the higher the abundance of predators would be. These data showed that predators played a role in suppressing herbivores compared to parasitoid population in rice, and this is in line with the study of Settle et al. (1996) and Herlinda et al. (2018). The abundance of neutral insects was also high in rice plants, while the lowest one was the abundance of parasitoids. In *S. indicum* and *V. unguiculata*, the abundance of neutral insects were high due to the presence of honeydew hunter ants produced by homopterous insects inhabiting both plants (Fig. 5). From the data, an interesting phenomenon was found in refugia, especially in *Zinnia* sp., parasitoid and predator were found to be more abundant at the beginning of the rice-growing season. At the same time, when the rice was at 35 DAT, the abundance of both entomophagous arthropods at *Zinnia* sp. began to decrease. In contrast, in the early rice planting, the abundance of the parasitoid began to increase at 42 DAT, and the predator abundance began to increase at 21 DAT. According to Settle et al. (1996) the population dynamics in rice is affected by the flow of the entomophagous arthropods from surrounding non-crop plants and vegetables to rice, and vice versa and this can occur if habitat and other niches are available around the rice fields that are appropriate for the arthropods.

Figures 6, 7, and 8 showed the results of the correspondence analysis in vegetative, milky, and ripening stages of rice, respectively. When rice was at vegetative stage, the species of predatory arthropods inhabiting rice, vegetables, and refugia generally have similar high community, except the arthropod that inhabits cowpea (Fig. 6a). The found predatory arthropods gathered in these plants, including *Pardosa pseudoannulata, Cyrtophora koronadalensis,* and *Neoscona theisi* which were the hunting spiders. Species composition in rice, refugia, and vegetables had high similarity, and this was showed that predatory arthropods were actively migrated from rice to vegetables and refugia or vice versa. Their movement was caused by the herbivores inhabited in rice, such as *N. lugens, Sogatella furcifera,* and *Spodoptera* sp. (Fig. 6c) which were the main preys for the predatory arthropods, while the alternative prey was neutral insects in rice, such as *Tetanocera* sp.*, Tipula maxima,* and *Psorophora* sp. (Fig. 6d). The parasitoid species composition in rice was highly similar to the parasitoid in zinnia and bitter melon (Fig 6b). Thus, zinnia and bitter melon were preferred by parasitoids as habitat and alternative niche beside rice. In line with Settle et al. (1996), the movement of spiders among habitats was due to generalist predators on hunting prey in alternative habitat. The species of parasitoid composition in rice were generally similar to those in the vegetable and refugia species, except those that inhabiting marigolds and ridged gourd. The species of neutral insects in rice were mostly similar to the neutral species in bitter melon.

When rice was in the milky stage, the predatory arthropod species composition in rice was quite similar to the arthropods that inhabited in bitter melon, sesame, zinnia, yellow ray flower, and marigold. The arthropod species grouped in these plants were *Coccinella repanda, T. virescens, Bathyphantes tagalogensis*, and *O. javanus* (Fig. 7a). The parasitoid species composition inhabiting rice such as *Cardiochiles* sp. and *Sarcophagidae* (Fig. 7b) was quite similar to the parasitoid inhabiting cucumber and bitter melon. The herbivore composition species in rice were most similar to those of herbivores inhabiting zinnia and marigolds, particularly *Leptocorisa acuta*. The species of herbivores found in rice were *N. lugens, S. furcifera,* and *L. acuta* (Fig. 7c). The predatory arthropods found in bitter melon, sesame, zinnia, yellow ray flower, marigold were the predators of *N. lugens, S. furcifera,* and *L. acuta* in rice. The neutral insect species (*Chironomus* sp. and *Tipula maxima*) (Fig. 7d) in rice and marigolds were preys for these predatory generalists. Thus, the movement of species from refugia and vegetables to rice occur if in the rice field is available a lot of preys for predatory generalists. This result is quite similar to Settle et al. (1996) and Herlinda et al. (2018).

When rice was in the ripening stage, the predatory arthropod species composition inhabiting the rice was more similar to the arthropods inhabiting zinnia, yellow ray flower, and cowpea. The predatory species were *P. pseudoannulata, Cylosa insulana, Cyrtophora koronadalensis,* and *T. javana* (Fig. 8a); while the herbivore species that were found in rice including *N. lugens* and *L. acuta* (Fig 8c) and other alternative preys were neutral insects, such as *Tetanocera* sp. and *T. maxima* (Fig. 8d). The parasitoid species composition in rice was more similar to the parasitoid species composition in bitter melon and zinnia. The results of this study showed that the predator and parasitoid of rice pests were found in refugia and vegetables. The refugia species that more frequently chosen by the predators and parasitoid of rice pest as an alternative habitat were *Zinnia* sp. Still, for the vegetables, they were most fond of bitter melon.

CONCLUSIONS AND SUGGESTION

Of the 4 species of refugia (*Zinnia* sp*., T. erecta, C. caudatus,* and *S. indicum*), which were mostly chosen by the entomophagous arthropods as an alternative habitat in addition to rice, it was *Zinnia* sp. Of the 4 species of vegetables (*V. unguiculata, M. charantia, C. sativus,* and *L. acutangula*), the most preferred habitat alternative for the entomophagous arthropods was *M. charantia*. However, economically *M. charantia* was more beneficial than *Zinnia* sp. to be used as the conservation of entomophagous arthropods because it does not only provide alternative habitat and niche for the entomophagous arthropods but also it is used as land productivity.

ACKNOWLEDGEMENT

This research was supported financially by Program of Professor Research Grant (Penelitian Unggulan Profesi Profesor) 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, a postgraduate student.

REFERENCES

Arango, A. M., López-Portillo, J., Parra-Tabla, V., Hernández-Salazar, L. T., Morales-Mávil, J. E., Rico-Gray, V. (2012). Effect of the spider *Peucetia viridans* (Oxyopidae) on floral visitors and seed set of *Cnidoscolus multilobus* (euphorbiaceae). *Acta Botanica Mexicana*, 100, 1–14. http://www.scielo.org.mx/pdf/abm/n100/n100a1.pdf

Baptiste, A. K., & Smardon, R. (2012). A review of wetland use and management of the Nariva Swamp, Trinidad. *Caribbean Geography*, 17(1–2), 73–91. https://www.researchgate.net/publication/273001155

Barrion, A., & Litsinger, J. (1995). *Riceland spiders of South and Southeast Asia*. Entomology Division International Rice Research Institute Philippines.

Behera, K. S. (2012). Biology of *Cardiochiles nigricollis* Cameron, a larval endo-parasitoid of *Cnaphalocrocis medinalis* (Guen.) and *Marasmia exigua* Butler. *Journal of Biological Control*, *26*(4), 376–379. http://www.informaticsjournals.com/index.php/jbc/article/download/3485/2570

Benvenuti, S., & Bretzel, F. (2017). Agro-biodiversity restoration using wildflowers: what is the appropriate weed management for their long-term sustainability?. *Ecological Engineering*, 102, 519–526. https://doi.org/10.1016/j.ecoleng.2017.02.062

Betz, L., & Tscharntke, T. (2017). Enhancing spider families and spider webs in Indian rice fields for conservation biological control, considering local and landscape management. *Journal of Insect Conservation*, 21(3), 495–508. https://link.springer.com/article/10.1007/s10841-017-9990-2

Bhaskar, B. P., Baruah, U., Vadivelu, S., Raja, P., Sarkar, D. (2010). Remote sensing and GIS in the management of wetland resources of Majuli Island, Assam, India. *Tropical Ecology*, 51(1), 31–40. https://www.researchgate.net/publication/280251875

Bodlah, I., & Waqar, M. (2013). Pollinators visiting summer vegetables ridge gourd (*Luffa acutangula*), bitter gourd (*Momordica charantia* L.) and brinjal (S*olanum melongena*). *Asian Journal of Agriculture and Biology*, 1(1), 8–12. https://www.researchgate.net/publication/311644274

Cutler, G. C., Gariepy, T. D., De Silva, E. C. A., Hilier, N. K. (2015). High rates of parasitism of blueberry spanworm (Lepidoptera: Geometridae) by Ichneumonidae and Tachinidae in commercial lowbush blueberry fields High rates of parasitism of blueberry spanworm (Lepidoptera: Geometridae) by Ichneumonidae and Tachinidae. *Journal of Pest Science*, 88, 219–223. https://link.springer.com/article/10.1007/s10340-015-0650-6

Desai, S. D., Swaminathan, R. Desai, V. S. (2017). Effect of habitat manipulation on infestation of paddy leaf folder, *Cnaphalocrocis medinalis* (Guenee). *Int.J.Curr.Microbiol.App.Sci*, 6(10), 1469–1477. https://doi.org/10.20546/ijcmas.2017.610.174

Eggs, B., & Sanders, D. (2013). Herbivory in spiders: The importance of pollen for orb-weavers. *PLoS ONE*, 8(11), 1–5. https://doi.org/10.1371/journal.pone.0082637

Emile, T., Honorine, N.T., Thomas N., Marie-Anne, S. (2012). Vegetable production systems of swamp zone in urban environment in west cameroon: case of Dschang city. *Universal Journal of Environmental Research and Technology All*, 2(2), 83–92. http://www.environmentaljournal.org/2-2/ujert-2-2-9.pdf

Foti, M. C., Rostás, M., Peri, E., Park, K. C., Slimani, T., Wratten, S. D., Colazza, S. (2017). Chemical ecology meets conservation biological control: identifying plant volatiles as predictors of floral resource suitability for an egg parasitoid of stink bugs. *Journal of Pest Science*, 90(1), 299–310. https://link.springer.com/article/10.1007/s10340-016-0758-3

Ganai, S. A., Ahmad, H., Sharma, D., Sharma, S. (2017). Diversity of arthropod fauna associated with marigold (*Tagetes erecta* L.) in Jammu. *Journal of Entomology and Zoology Studeis*, *5*(5), 1940–1943. http://www.entomoljournal.com/archives/2017/vol5issue5/PartY/5-5-193-255.pdf

Gumovsky, A., Rusina, L., Firman, L. (2007). Bionomics and morphological and molecular characterization of *Elasmus schmitti* and *Baryscapus elasmi* (Hymenoptera: Chalcidoidea, Eulophidae), parasitoids associated with a paper wasp, *Polistes dominulus* (Vespoidea, Vespidae). *Entomological Science*, 10, 21–34. https://doi.org/10.1111/j.1479-8298.2006.00195.x

Hasan, K., Pervin, M., Manda, F., Mala, M. (2016). Habitat management: a key option to enhance natural enemies of crop pest. *Universal Journal of Plant Science*, 4, 50–57. http://www.hrpub.org/journals/article_info.php?aid=5517

Heinrichs, E. A. (1994). *Biology and management of rice insect*. International Rice Research Intitute.

Herlinda, S., Yudha, S., Thalib, R., Khodijah, Suwandi, Lakitan, B., Verawaty, M. (2018). Species richness and abundance of spiders inhabiting rice in fresh swamps and tidal lowlands in South

Sumatera, Indonesia. *J. ISSAAS*, 24, 82–93. https://www.cabdirect.org/cabdirect/abstract/20183221277

Hossain, M. S., Yeasmin, F., Rahman, M. M., Akhtar, S., Hasnat, M. A. (2018). Role of insect visits on cucumber (*Cucumis sativus* L.) yield. *J. biodivers. conserv. bioresour. manag.*, 4(2), 81–88. https://doi.org/10.3329/jbcbm.v4i2.39854

Hu, S., Fu, D. Y., Liu, X. J., Zhao, T., Han, Z. L., Lu, J. P., Wan, H. L., Ye, H. (2012). Diversity of planthoppers associated with the winter rice agroecosystems in Southern Yunnan, China. *Journal of Insect Science*, 12(29), 1–11. https://doi.org/10.1673/031.012.2901

Janzen, D. H. (2013). Differences in insect abundance and diversity between wetter and drier sites during a tropical dry season. *Ecology*, 49(1), 96–110. https://www.jstor.org/stable/1933565

Javier, A. M. V. (2018). Life history and biological control potential of *Snellenius manilae* Ashmead (Hymenoptera: Braconidae), a parasitoid of *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae). *Philipp Agric Scientist*, 101(2), 148–157. https://www.researchgate.net/publication/326981932_Life_History_and_Biological_Control_Potential_of_Snellenius_manilae_Ashmead_Hymenoptera_Braconidae_a_Parasitoid_of_Spodoptera_litura_Fabricius_Lepidoptera_Noctuidae

Jennings, D. T., Longcore, J. R., Bird, J. E. (2017). Spiders (Araneae) inhabit Lepidopteran-feeding shelters on ferns. *J. Acad. Entomol. Soc.* 13, 5–14. http://acadianes.org/journal/papers/jennings_16-3.pdf

Kalshoven, L. G. (1981). The pest of crops in Indonesia. Van Hoeve, Jakarta : PT. Ichtiar Baru.

Karindah, S., Yanuwiadi, B., Sulistyowati, L., Green, P. T. (2011). Abundance of *Metioche vittalicollis* (Orthoptera: Gryllidae) and natural enemies in a rice agroecosystem as influenced by weed species. *Agrivita*, 33(2), 133–141. http://doi.org/10.17503/agrivita.v33i2.55

Kaur, G., & Sangha, K. S. (2016). Evaluation of yellow sticky trap shapes for capturing alate insects in chilli agroecosystem. *Journal of Insect Science*, 29(1), 67–72. https://www.researchgate.net/publication/305771775

Lakitan, B., Alberto, A., Lindiana, L., Kartika, K., Herlinda, S., Kurnianingsih, A. (2018). The benefits of biochar on rice growth and yield in tropical riparian wetland, South Sumatra, Indonesia. *Chiang Mai University Journal of Natural Sciences*, 17(2), 111–126. http://cmuj.cmu.ac.th/ns/full/2120180410110810.pdf

Lakitan, B. 2019. Cultivation of common bean (*Phaseolus vulgaris* L.) subjected to shallow water table at riparian wetland in South Sumatra, Indonesia. *Australian journal of crop science*, 13(1), 98–104. https://www.researchgate.net/publication/332009012_Cultivation_of_common_bean_Phaseolus_vulgaris_L_subjected_to_shallow_water_table_at_riparian_wetland_in_South_Sumatra_Indonesia

Lakitan, B., Lindiana, L., Widuri, L. I., Kartika, K., Siaga, E., Meihana, M. (2019). Inclusive and Ecologically-Sound Food Crop Cultivation at Tropical Non-Tidal. *AGRIVITA*, 41(1), 1–9. http://doi.org/10.17503/agrivita.v40i0.1717

Lopes, S. de F., Ramos, M. B., de Almeida, G. R. (2017). The role of mountains as refugia for biodiversity in Brazilian Caatinga: Conservationist implications. *Tropical Conservation Science*, 10: 1–12. https://doi.org/10.1177%2F1940082917702651

Margono, B. A., Bwangoy, J. R. B., Potapov, P. V., Hansen, M. C. (2014). Mapping wetlands in Indonesia using landsat and PALSAR data-sets and derived topographical indices. *Geo-Spatial Information Science*, 17(1), 60–71. https://doi.org/10.1080/10095020.2014.898560

Masika, F. B., Masanza, M., Aluana, G., Barrigossi, A. F., Kizito, E. B. (2017). Abundance, distribution and effects of temperature and humidity on arthropod fauna in different rice ecosystems in Uganda. *Journal of Entomology and Zoology Studies*, 5(5), 964–973. https://www.researchgate.net/publication/321676101_Abundance_distribution_and_effects_of_temperature_and_humidity_on_arthropod_fauna_in_different_rice_ecosystems_in_Uganda

McAlpine, J. F., Peterson, B. V., Shewel, G. E., Teskey, H. J., Vockeroth, J. R., Wood, D. M., (1987). *Manual of Neartic Diptera*. Agriculture Canada, Research Branch.

McCabe, E., Loeb, G., Grab, H. (2017). Responses of crop pests and natural enemies to wildflower borders depends on functional group. *Insects*, 8(73), 1–8. https://doi.org/10.3390/insects8030073

Meng, J., Mabubu, J. I., Han, Y., He, Y., Zhao, J., Hua, H., Feng, Y., Wu, H. (2016). No impact of transgenic cry1C rice on the rove beetle *Paederus fuscipes*, a generalist predator of brown planthopper *Nilaparvata lugens*. *Scientific reports*. https://www.nature.com/articles/srep30303

Niba, A. 2011. Arthropod assemblage dynamics on cowpea (*Vigna unguiculata* L. Walp) in a subtropical agro-ecosystem, South Africa. *African Journal of Agricultural Research*, 6(4), 1009–1015. https://doi.org/10.5897/AJAR10.751

Prasad, R., Prabhu, S. T., Balikai, R. A. (2015). Incidence of white backed plant hopper on rice and its predators under rainfed ecosystems and their correlation with weather parameters. *Research Journal of Agricultural Sciences*, 1(4), 322–326. https://www.researchgate.net/publication/264846092_Incidence_of_White_Backed_Plant_Hopper_on_Rice_and_its_Predators_under_Rainfed_Ecosystems_and_their_Correlation_with_Weather_Parameters

Raffaelli, D. & Hall, S.J. (1992). Compartments and predation in an estuarine food web. *Journal of Animal Ecology*, 61, 551–560. https://www.jstor.org/stable/5610?seq=1#page_scan_tab_contents

Rocha-Filho, L. C., & Rinaldi, I. M. P. (2011). Crab spiders (Araneae: Thomisidae) in flowering plants in a Brazilian “Cerrado” ecosystem. *Brazilian journal of biology*, 71(2), 359–364. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1519-69842011000300004

Schmidt, K., Orosz-Kovacs, Z. Farkas, A. (2012). Nectar secretion dynamics in some raspberry and blackberry cultivars. *The International Journal of Plant Reproductive Biology*, 4(2), 147–150. https://www.researchgate.net/publication/233808478_Nectar_secretion_dynamics_in_some_raspberry_and_blackberry_cultivars

Settle, W. H., Ariawan, H., Astuti, E. T., Cahyana, W., Hakim, A. L., Hindayana, D., Lestari, A. S., Pajarningsih. (1996). Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. *Ecology*, 77(7), 1975–1988. https://www.jstor.org/stable/2265694

Shanker, C., Chintagunta, L., Muthusamy, S., Vailla, S., Srinivasan, A., Katti, G. (2018). Flora surrounding rice fields as a source of alternative prey for coccinellids feeding on the pests of rice. *European Journal of Entomology*, 115, 364-371. https://doi.10.14411/eje.2018.036. https://www.eje.cz/pdfs/eje/2018/01/36.pdf

Siaga, E., Lakitan, B., Hasbi., Bernas, S. M., Wijaya, A., Lisda, R., Ramadhani, F., Widuri, L. I., Kartika, K., Meihana, M. 2018. Application of floating culture system in chili pepper (*Capsicum annum* L.) during prolonged flooding period at riparian wetland in Indonesia. *Australian Journal of Crop Science*, 12(5), 808–816. http://www.cropj.com/siaga_supp_12_5_2018_808_816.pdf

Suwandi, Ammar, M., Irsan, C. (2012). Application of extract compost increased yield and suppressed the diseases of ratoon rice crop in tidal swamp of Banyuasin Regency. *J. Lahan Suboptimal*, 1, 116–122. [Indonesian]. http://www.jlsuboptimal.unsri.ac.id/index.php/jlso/article/download/15/13

Tahir, H. M., & Butt, A. (2009). Predatory potential of three hunting spiders inhabiting the rice ecosystems. *J Pest Sci*, 82, 217–225. https://link.springer.com/article/10.1007/s10340-008-0242-9

Wahocho, S. A., Miano, T. F., Memon, N. U. N., Wahocho, N. A. (2016). Photoperiodic effect on vegetative growth and flower quality of zinnia (*Zinnia elegans* Jacq.). *Sarhad Journal of Agriculture*, 32(4), 316–324. http://dx.doi.org/10.17582/journal.sja/2016.32.4.316.324

Widuri, L. I., Lindiana, L., Kartika, K., Siaga, E., Meihana, M., Hasmeda, M., Sodikin, E., Lakitan, B. (2016). Identification of farmer's needs and vegetable cultivation constraints in riparian wetlands using grounded theory. *Prosiding seminar nasional lahan suboptimal*, 587–594. [Indonesian]. http://pur-plso.unsri.ac.id/userfiles/71_%20HAL%20587-594%20%20Laily-ilman-widuri-identifikasi-kebutuhan-petani-lahan-rawa-lebak.pdf

Zhu, P., Wang, G ., Zheng, X., Tian, J., Lu, Z., Heong, K. K., Xu, H., Chen, G., Yang, Y., Gurr, G. M. (2014). Selective enhancement of parasitoids of rice Lepidoptera pests by sesame (*Sesamum indicum*) flowers. *BioControl*, 1-11. https://link.springer.com/article/10.1007/s10526-014-9628-1

Figures and Tables

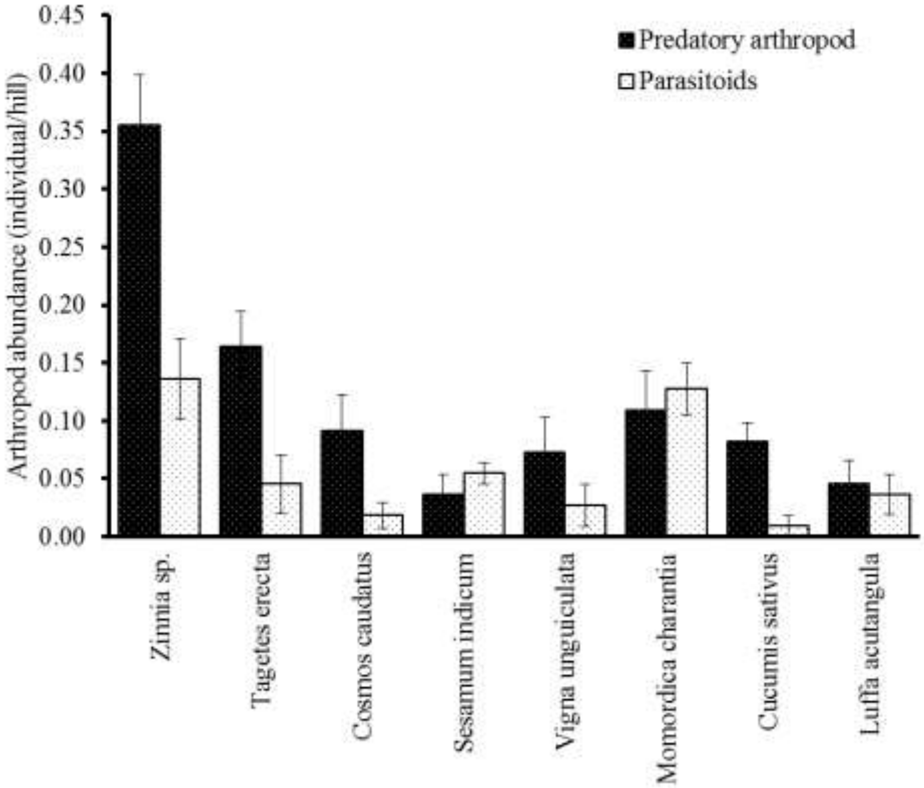


Fig. 1. Abundace of predatory arthropods and parasitoids inhabiting refugia and vegetables

Fig. 2. Flower of refugia and vegetables: zinnia (a), marigold (b), yellow ray flower (c), sesame (d), cowpea (e), bitter melon (f), cucumber (g), ridged gourd (h)

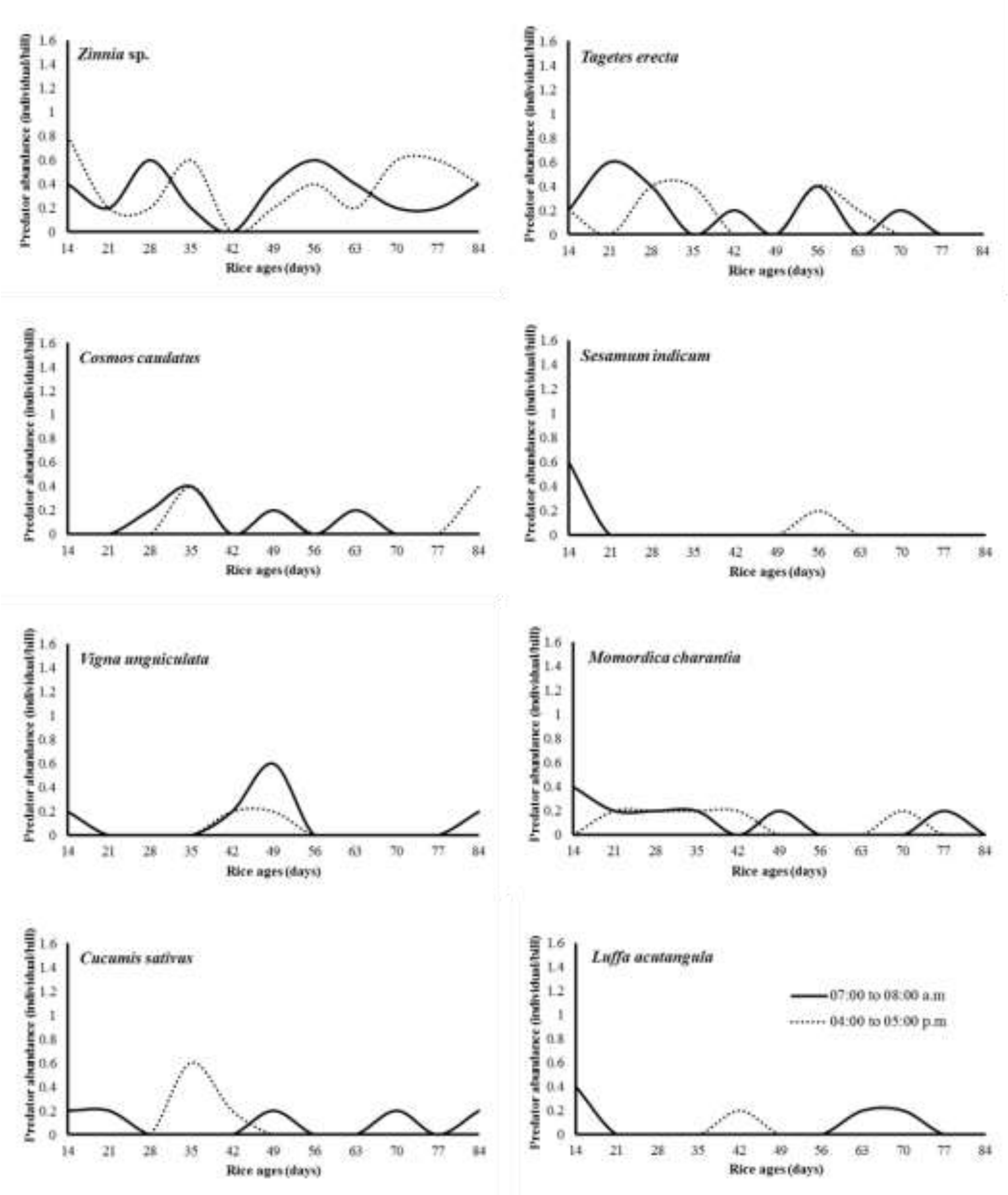


Fig. 3. Predatory abundance found on refugia and vegetables in the period of 14-84 days after rice transplanting

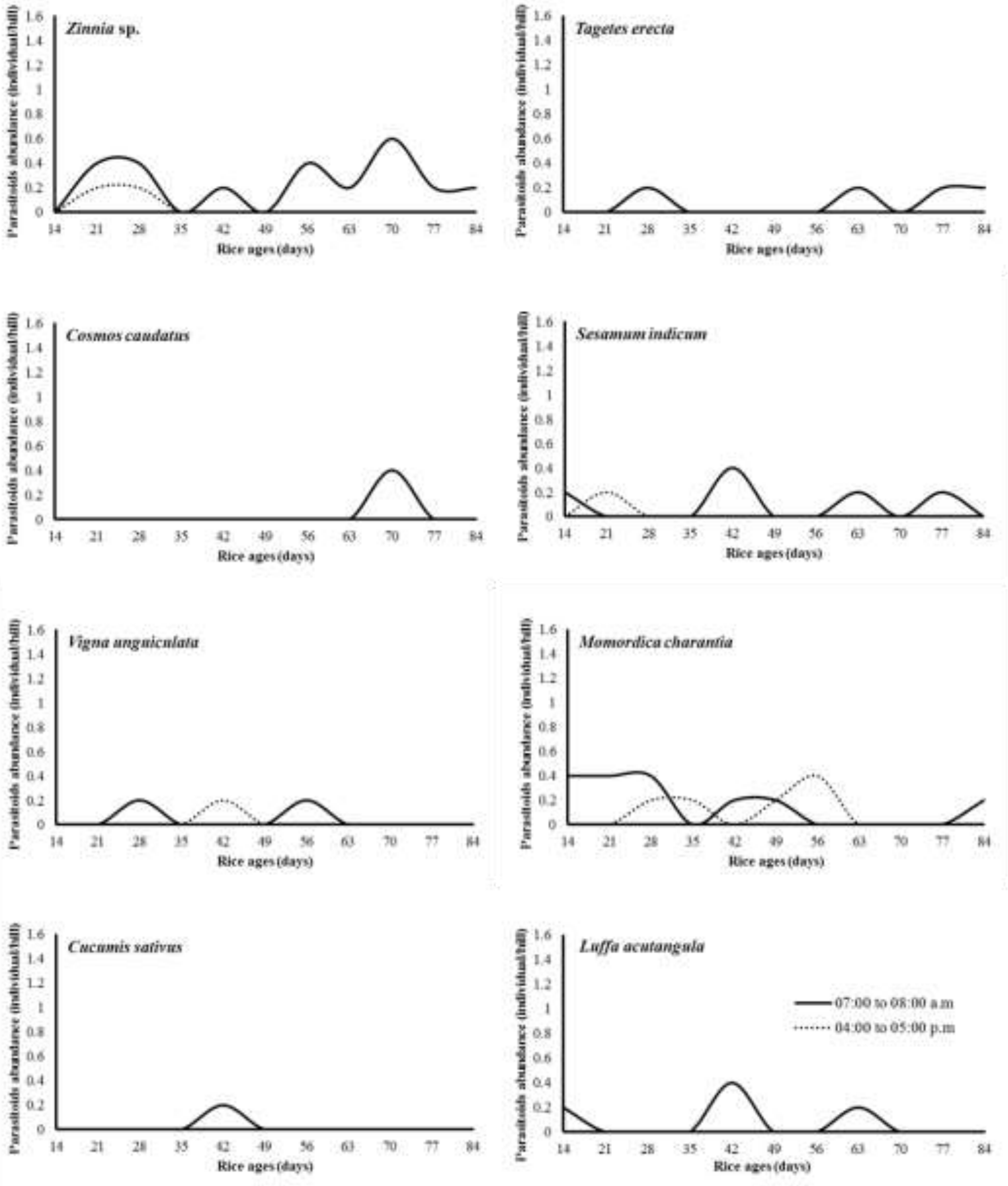


Fig. 4. Parasitoid abundance found on refugia and vegetables in the period of 14-84 days after rice transplanting or during a rice season

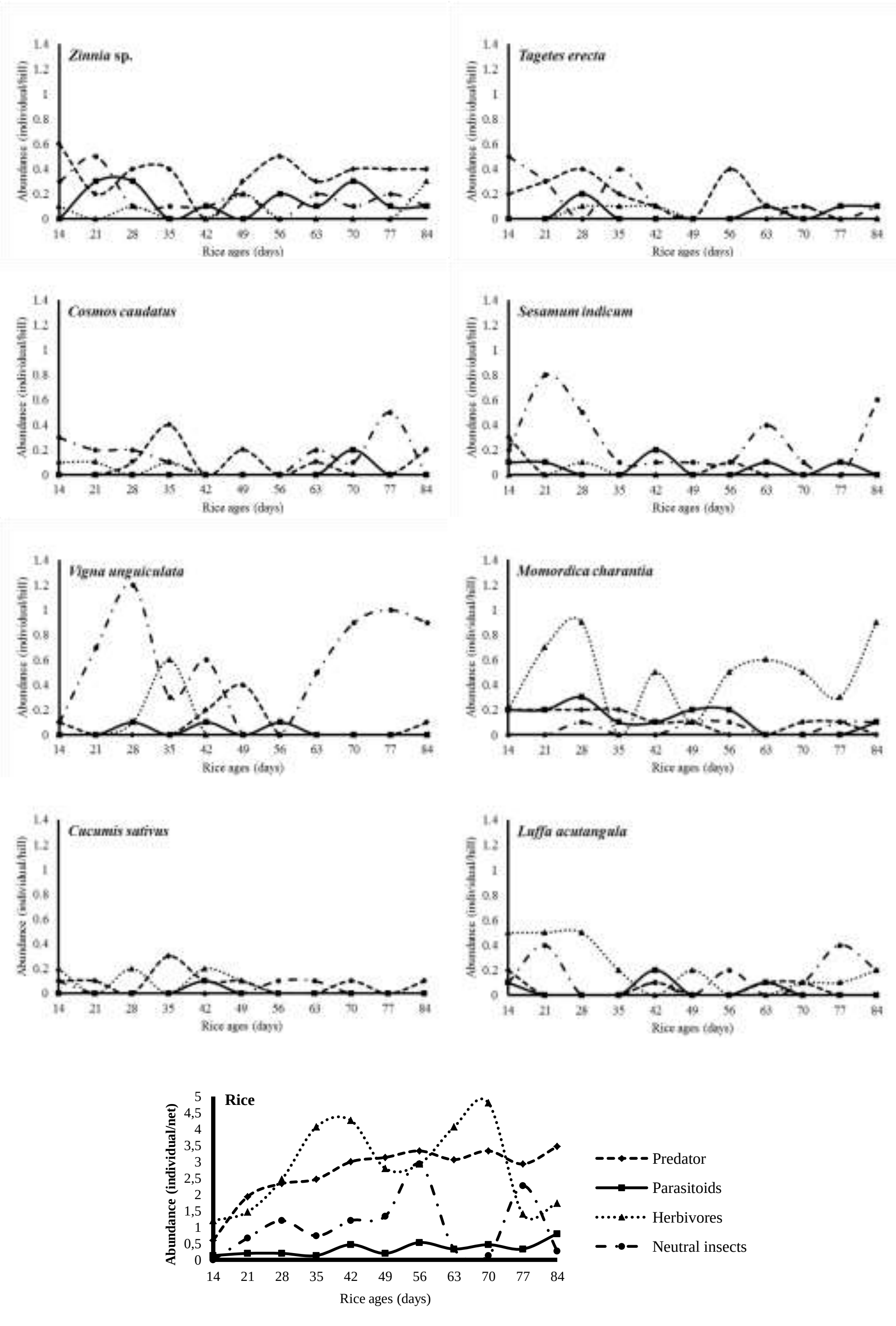


Fig. 5. Arthropod abundance found on refugia, vegetables, and rice in the period of 14-84 days after rice transplanting or during a rice season

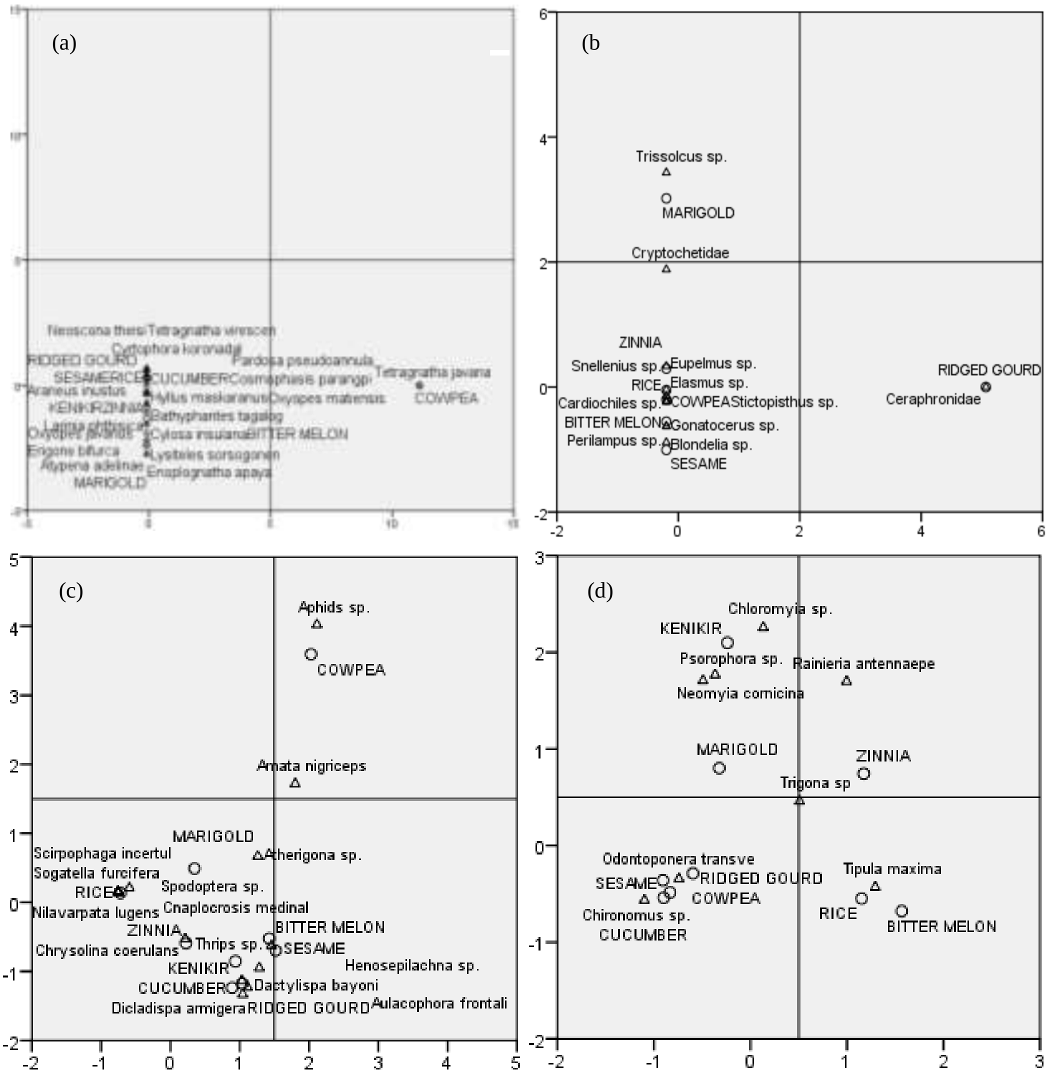


Fig. 6. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice vegetative stage; arthropods (o); plant (Δ)

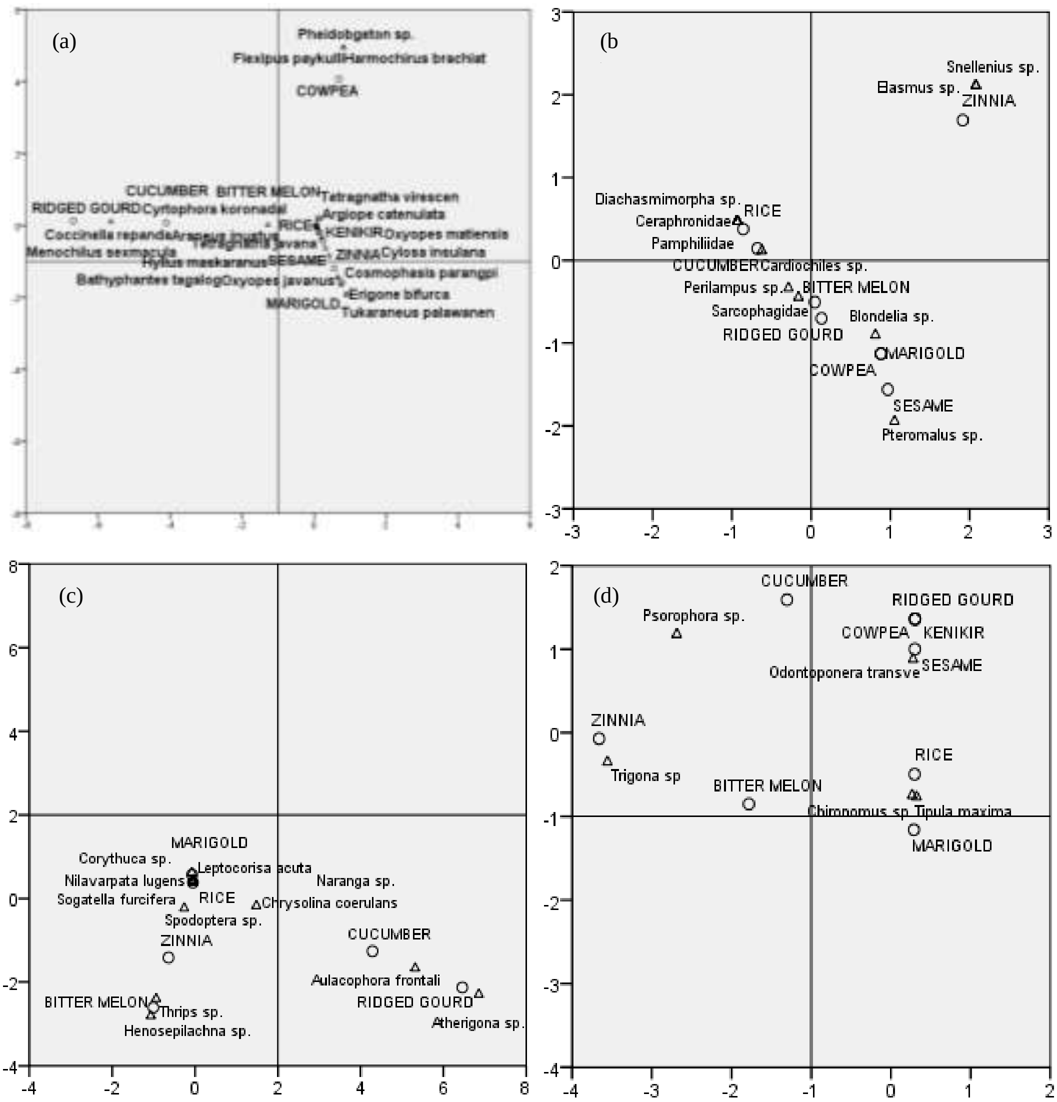


Fig. 7. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice milky stage; arthropods (o); plant (Δ)

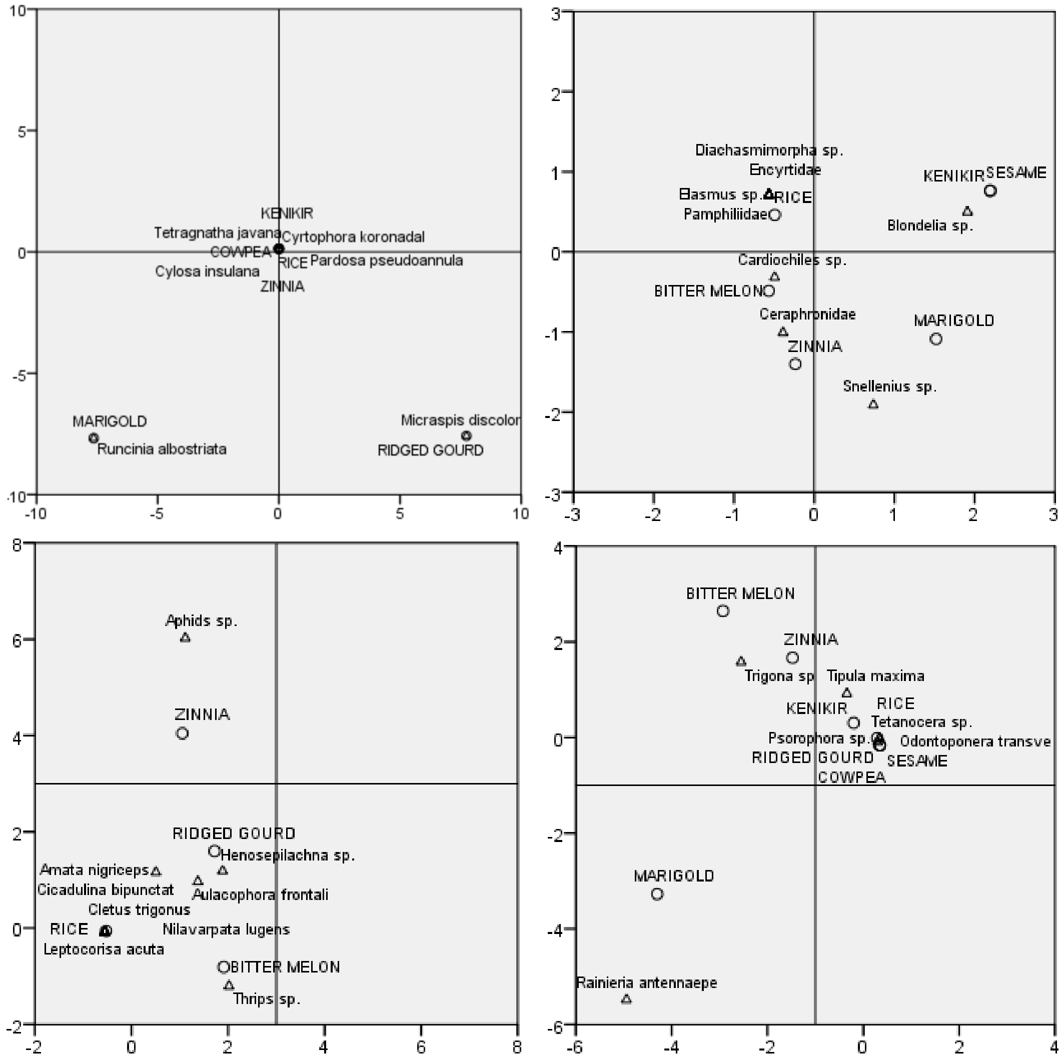


Fig. 8. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice ripening stage; arthropods (o); plant (Δ)

Table 1. Species composition of predatory arthropods found in rice, refugia, and vegetables

No.	Species	Habitat (individual/net or individual/flower)								
		A	B	C	D	E	F	G	H	I
1.	*Pardosa pseudoannulata*	0.04	0	0	0	0	0	0	0	0
2.	*Araneus inustus*	0.01	0	0	0.01	0	0	0	0	0
3.	*Cylosa insulana*	0.05	0.02	0.02	0.01	0	0	0	0	0
4.	*Cyrtophora koronadalensis*	0.02	0	0	0	0	0	0	0	0
5.	*Neoscona theisi*	0.01	0	0	0	0	0	0	0	0
6.	*Argiope catenulate*	0.04	0	0	0	0	0	0	0	0
7.	*Larinia phthisica*	0	0.01	0.01	0	0	0	0	0	0
8.	*Tukaraneus palawanensis*	0	0	0.01	0	0	0	0	0	0
9.	*Tetragnatha javana*	0.17	0.02	0	0	0	0.01	0	0	0
10.	*Tetragnatha virescens*	0.68	0.01	0.01	0	0	0.03	0.02	0	0
11.	*Tetragnatha mandibulata*	0.24	0.01	0	0.01	0	0	0	0	0
12.	*Tetragnatha maxillosa*	0.10	0	0	0	0	0	0	0	0
13.	*Tetragnatha vermiformis*	0.12	0	0	0	0	0	0	0	0
14.	*Tetragnatha Okumae n. Sp.*	0.01	0	0	0	0	0	0	0	0
15.	*Tetragnatha iwahigensis*	0.01	0	0	0	0	0	0	0	0
16.	*Tetragnatha natans*	0.01	0	0	0	0	0	0	0	0
17.	*Bathyphantes tagalogensis*	0.07	0.01	0.01	0	0	0	0	0	0
18.	*Bathyphantes sp.*	0.02	0	0	0	0	0	0	0	0
19.	*Erigone bifurca*	0	0	0.02	0	0	0	0.01	0	0
20.	*Enoplognatha sp.*	0.02	0	0	0	0	0	0	0	0
21.	*Linyphiidae (unknown species)*	0.01	0	0	0	0	0	0	0	0
22.	*Atypena adelinae*		0	0.01	0	0	0	0	0	0
23.	*Oxyopes javanus*	0.02	0.05	0.01	0	0	0	0.01	0	0
24.	*Oxyopes matiensis*	0.09	0.05	0.00	0.03	0.01	0	0.01	0	0
25.	*Oxyopes pingasus*	0.01	0	0	0	0	0	0	0	0
26.	*Theridion sp.*	0.01	0	0	0	0	0	0	0	0
27.	*Enoplognatha apaya*	0	0	0.01	0	0	0	0	0	0
28	*Lysiteles sorsogonensis*	0	0	0.01	0	0	0	0	0	0
29.	*Thomisus ilocanus*	0	0	0.01	0	0	0	0	0	0
30.	*Thomisus italongus*	0	0	0	0	0	0	0.02	0	0
31.	*Runcinia albostriata*	0	0	0.01	0	0	0	0	0	0
32.	*Myrmarachne bidentata*	0.01	0	0	0	0	0	0	0	0
33.	*Hyllus maskaranus*	0.03	0.05	0	0	0.01	0	0	0	0
34.	*Myrmarachne onceana*	0	0	0.02	0	0	0	0.01	0	0
35.	*Cosmophasis parangpilota*	0.01	0.05	0.02	0.01	0	0	0	0	0
36.	*Cosmophasis sp.*	0.02	0.02	0	0.01	0	0	0	0	0
37.	*Flexipus paykulli*	0	0.02	0	0	0	0.01	0	0	0
38.	*Harmochirus brachiatus*	0.01	0	0	0	0	0.01	0	0	0
39.	*Bianor hotingchiehi*	0.01	0	0	0	0	0	0	0	0
40.	*Emathis sp.*	0.01	0	0	0	0	0	0	0	0
41.	*Hahnia tuybaana*	0.02	0	0	0	0	0	0	0	0
42.	*Cyrtorhinus lividipennis*	0.02	0	0	0	0	0	0	0	0
43.	*Orthotylus sp.*	0.02	0	0	0	0	0	0	0	0
44.	*Ophionea nigrofasciata*	0.01	0	0	0	0	0	0	0	0
45.	*Paederus fuscipes*	0.18	0.04	0	0	0.01	0	0	0	0.01
46.	*Micraspis inops*	0.24	0	0	0	0	0	0.01	0.02	0.01
47.	*Verania lineata*	0.01	0	0	0	0	0	0	0	0
48.	*Micraspis vincta*	0.02	0	0	0	0	0	0	0	0
49.	*Harmonia octomaculata*	0.01	0	0	0	0	0	0	0	0
50.	*Coccinella repanda*	0.03	0	0	0	0	0	0	0.01	0

Remarks: A= rice; B= *Zinnia* sp.; C= *Tagetes erecta*; D= *Cosmos caudatus*;E= *Sesamum indicum*; F=*Vigna unguiculata*; G=*Momordica charantia*; H=*Cucumis sativus*; I=*Luffa acutangula*

Table 1. Continued

No.	Species	Habitat (individual/net or individual/flower)								
		A	B	C	D	E	F	G	H	I
51.	*Brumoides suturalis*	0.02	0	0	0	0	0	0	0	0
52.	*Menochilus sexmaculatus*	0.01	0	0	0	0.01	0	0	0.03	0.02
53.	*Propylaea japonica*	0	0.01	0	0	0	0	0	0	0
54.	*Coccinella septempunctata*	0	0	0	0	0	0	0	0.01	0
55.	*Micraspis discolor*	0	0	0	0	0	0	0	0	0.01
56.	*Larva Coccinellidae*	0.16	0	0	0.02	0	0	0.02	0.02	0
57.	Elateridae (unknown species)	0.01	0	0	0	0	0	0	0	0
58.	*Formicomus* sp.	0.01	0.01	0	0	0	0	0.01	0	0
59.	*Agriocnemis* sp.	0.03	0	0	0	0	0	0	0	0
60.	*Pyrrhosoma* sp.	0.01	0	0	0	0	0	0	0	0
61.	*Argia* sp.	0.01	0	0	0	0	0	0	0	0
62.	*Pantala* sp.	0.01	0	0	0	0	0	0	0	0
63.	*Conocephalus longipennis*	0.02	0	0	0	0	0	0	0	0
64.	*Monomorium destructor*	0	0	0	0	0	0.02	0	0	0
65.	*Solenopsis* sp.	0.01	0	0	0	0	0	0	0	0
66.	*Volucella* sp.	0.01	0	0	0	0	0	0	0	0
67.	Mantidae (unknown species)	0.01	0	0	0	0	0	0	0	0
	Total Abundance (N)	2.74	0.38	0.18	0.1	0.04	0.08	0.12	0.09	0.05
	Number of Species (S)	51	15	14	7	4	5	9	5	4

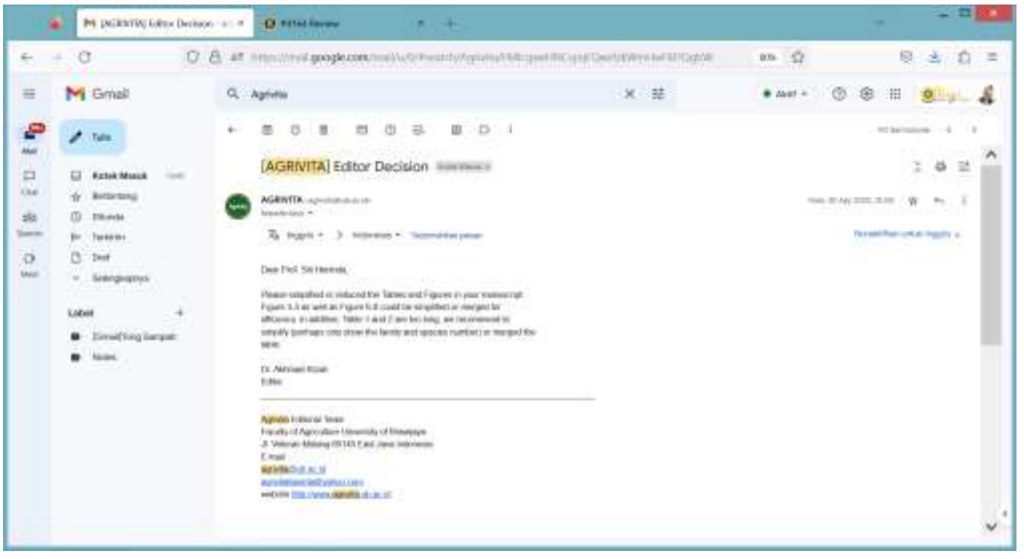
Remarks: A= rice; B= *Zinnia* sp.; C= *Tagetes erecta*; D= *Cosmos caudatus*;E= *Sesamum indicum*; F=*Vigna unguiculata*; G=*Momordica charantia*; H=*Cucumis sativus*; I=*Luffa acutangula*

Table 2. Species composition of parasitoid found on rice, refugia, and vegetables

No.	Species	Habitat (individual/net or individual/flower)								
		A	B	C	D	E	F	G	H	I
1	*Stictopisthus* sp.	0.01	0	0	0	0	0	0	0	0
2	*Elasmus* sp.	0.02	0.03	0	0	0	0	0.01	0	0
3	*Trissolcus* sp.	0	0	0.01	0	0	0	0	0	0
4	*Snellenius* sp.	0.02	0.03	0.01	0	0	0.01	0	0	0
5	*Cardiochiles* sp.	0.09	0.04	0	0	0	0	0.05	0.01	0
6	*Diachasmimorpha* sp.	0.02	0	0	0	0	0	0	0	0
7	*Gonatocerus* sp.	0	0	0	0	0	0	0.01	0	0
8	*Perilampus* sp.	0.01	0	0	0	0	0	0.01	0	0.01
9	Ceraphronidae (unknown species)	0.04	0.02	0	0	0	0	0	0	0.01
10	Pamphiliidae (unkown species)	0.02	0	0	0	0	0	0	0	0
11	Encyrtidae (unknown species)	0.02	0	0	0	0	0	0	0	0
12	*Eupelmus* sp.	0.01	0.01	0	0	0	0	0	0	0
13	*Helorus* sp.	0.02	0	0	0	0	0	0	0	0
14	*Pteromalus* sp.	0.01	0	0	0	0.01	0	0	0	0
15	*Netomocera* sp.	0.02	0	0	0	0	0	0	0	0
16	*Haltichella* sp.	0.01	0	0	0	0	0	0	0	0
17	*Tetramesa* sp	0.01	0	0	0	0	0	0	0	0
18	*Eurytomidae* sp.	0.01	0	0	0	0	0	0	0	0
19	*Athrycia* sp.	0.01	0	0	0	0	0	0	0	0
20	*Blondelia* sp.	0.01	0.01	0.02	0.02	0.05	0.02	0.04	0	0.01
21	Cryptochetidae (unknown species)	0	0.01	0.01	0	0	0	0	0	0
22	Sarcophagidae (unknown species)	0.01	0	0	0	0	0	0.01	0	0.01
	Total Abundance (N)	0.37	0.15	0.05	0.02	0.06	0.03	0.13	0.01	0.04
	Number of Species (S)	19	7	4	1	2	2	6	1	4

Remarks: A= rice; B= *Zinnia* sp.; C= *Tagetes erecta*; D= *Cosmos caudatus*;E= *Sesamum indicum*; F=*Vigna unguiculata*; G=*Momordica charantia*; H=*Cucumis sativus*; I=*Luffa acutangula*

3. Bukti konfirmasi review kedua dan hasil revisi kedua



Arboreal Entomophagous Arthropods of Rice Insect Pests Inhabiting Adaptive Vegetables and Refugia in Freshwater Swamps of South Sumatra

ABSTRACT

Plants growing around the rice fields can be used as a habitat and niche for entomophagous arthropods. This study aimed to identify the species of entomophagous arthropods of rice insect pests and to analyze their abundance and community in adaptive vegetables and refugia in freshwater swamps. The field was surrounded by 4 species of refugia (*Zinnia* sp., *Tagetes erecta, Cosmos caudatus,* and *Sesamum indicum*) and 4 species of vegetables (*Vigna unguiculata, Momordica charantia, Cucumis sativus,* and *Luffa acutangula*). Arthropods were sampled using nets. The results showed that entomophagous arthropods found consisted of 67 species of predatory arthropods and 22 species of parasitoids. The predatory arthropods species were mostly found in rice (51 species), *Zinnia* sp. (15 species), and *M. charantia* (9 species). Parasitoid species were dominantly found in rice (19 species), *Zinnia* sp. (7 species), and *M. charantia* (6 species). The predatory arthropods dominantly found were *Tetragnatha javana, Tetragnatha virescens,* and *Paederus fuscipes*, while the dominant parasitoids were *Cardiochiles* sp., *Elasmus* sp., and *Snellenius* sp. The parasitoid species composition in rice was more similar to the species composition in bitter melon and zinnia. However, predatory arthropod species composition in rice was similar to the species composition in all vegetables and refugia, except the species composition in cowpea. *Zinnia* sp. and *M. charantia* were the most chosen habitat by entomophagous arthropods besides rice fields. However, *M. charantia* is more beneficial than *Zinnia* sp. due to its function not only for the conservation of natural enemies and also for land productivity.

KEYWORDS

Habitat, niche, parasitoid, predator, refugia, and vegetable

INTRODUCTION

Wetland is a land saturated with water, both year-round and seasonal. Wetland in Indonesia generally consists of freshwater (non-tidal) swamp and tidal lowland. The freshwater swamp is a wetland that is flooded due to the flow of river water or rain, while the lowland tidal is inundated due to the tides. According to Margono et al. (2014), the wetland area in Indonesia is around 39.6 Mha, 77% of them are spread in Sumatra Island (11.9 Mha), Kalimantan (12.2 Mha), and Papua (11.8 Mha), while the remaining 23% are spread in Java (1.9 Mha), Sulawesi (1.2 Mha), Maluku (0.5 Mha), and Bali-Nusa Tenggara (0.2 Mha).

Freshwater swamps in South Sumatra are generally inundated from November to April, or May depend on the lowland typology, and in the dry season the land often drought (based on direct observation in the center of freshwater swamps, Ogan Ilir District, South Sumatra since 2012 up to now). When they are inundated, some local farmers raise swamp fish or local duck, alabio duck (*Anas platyrhynchos*), while in the dry season, they grow rice (Lakitan et al., 2018) or adaptive vegetables (Lakitan et al., 2019). Another local habit is when they grow rice, they also grow adaptive vegetables in rice fields. Some adaptive vegetables in freshwater swamps are cowpea (*Vigna unguiculata*) (Bhaskar et al., 2010), cucumber (*Cucumis sativus*) (Baptiste & Smardon, 2012), ridged gourd (*Luffa acutangula*) and bitter melon (*Momordica charantia*) (Widuri et al., 2016), chili pepper (*Capsicum annum L.*) (Siaga et al., 2018) common bean (*Phaseolus vulgaris*) (Lakitan, 2019), and tomatoes (Emile et al., 2012). The vegetables which planted around the rice fields have multiple functions, but it is not realized by the local farmers. Besides being able to increase land productivity, these vegetables can provide natural habitat and niche for natural enemies of the rice insect pest.

Cowpeas are inhabited by 21 insect species of 12 families and 5 orders (Coleoptera, Hemiptera, Orthoptera, Homoptera, and Lepidoptera) (Niba, 2011). Cucumbers are visited by 11 insect species of 7 families and 3 orders (Hymenoptera, Diptera, and Coleoptera) (Hossain et al., 2018). Ridged gourds are inhabited by 6 insect species of 3 families and 2 orders (Hymenoptera and Diptera), while bitter melons are visited by 4 insect species of 3 families and 2 orders (Bodlah & Waqar, 2013). Chili pepper is visited by 41 species of arthropods consisting of 14 species of pests and natural enemies, 12 species of visitors, and 1 species of pollinator (Kaur & Sangha, 2016).

The diversity of arthropods in freshwater swamps is also supported by the presence of wild flowering plant or non-crop plant as refugia around the rice field. Non-crop plants and refugia provide niche, additional food, and other resources for natural enemies of rice pests (Zhu et al., 2014; Hasan et al., 2016; Benvenuti & Bretzel, 2017; Lopes et al., 2017; McCabe et al., 2017). Grassy rice fields in ecosystems have a higher number of arthropods than those in non-weed ecosystems (Hu et al., 2012). The existence of refugia, sunflower plants (*Helianthus annuus*), indian mustard (*Brassica juncea*), sesame (*Sesamum indicum*), marigold (*Tagetes erecta*), yellow ray flower (*Cosmos caudatus*), and Zinnia (*Zinnia* sp.) is known to be effective in reducing the attack of leaf-rolling pests

(*Cnaphalocrocis medinalis*) in several rice varieties in India (Desai et al., 2017). Marigold is reported to be associated with several species of predatory arthropods such as *Oxyopes javanus, Coccinella septumpunctata, Syrphus* spp., and *Geocoris* spp. (Ganai et al., 2017). Zinnia is also reported to be associated with several species of spiders, including *Argiope aemula, Oxyopes* sp., and *Perenethis* sp. (Desai et al., 2017). Consequently, vegetables and refugia are beneficial as habitat and niche for entomophagous arthropods (parasitoid and predatory arthropods) which are natural enemies of insect pests. There is little information available the entomophagous arthropods that are associated with vegetables and refugia in freshwater swamps of South Sumatra. This study aimed to identify the species of entomophagous arthropods of rice insect pests and to analyze their abundance and community in adaptive vegetables and refugia in freshwater swamps of South Sumatra.

MATERIALS AND METHODS

The field experiment was carried out in the center of freshwater swamps in Pelabuhan Dalam Village of Pemulutan Subdistrict, Ogan Ilir District, South Sumatra Province, from May to September 2018. The area of the rice field is around 7.1 Mha. The species identification was carried out in the laboratory from September 2018 to May 2019.

Rice, Vegetables, and Refugia Planting

The rice plot area used was 1 ha, surrounded by 4 species of refugia and 4 vegetable species with the distance between plots was around 100 m, and 1 ha of plot area was divided into three sub-plots and used as replications. Each rice subplot was surrounded by 4 species of refugia (*Zinnia* sp., *T. erecta, C. caudatus,* and *S. indicum*), as well as other rice subplots were surrounded by 4 vegetable species (*V. unguiculata*, *M. charantia*, *C. sativus*, and *L. acutangula*). The position of 4 refugia species or the 4 species of vegetables in each rice sub-plot was in four embankments surrounding the sub-plot, and each embankment was planted with one plant species. In consequence, the four embankments surrounding the rice subplots were planted with different species of refugia or vegetables. This position was to give a freedom for entomophagous arthropods to choose the alternative habitat other than rice. The planting of refugia and vegetables was carried out 30 days before rice planting so that when it was in the vegetative phase of 14 days after transplanting (DAT), the refugia would have been blooming. The plant spacing of vegetables followed the habit of the local farmers (30 cm); meanwhile, the refugia were planted closer (15 cm) and containing 5 seeds per hole.

The rice was planted according to planting system of 2:1 "jajar legowo" spacing (50 cm x 25 cm x 12.5 cm) and did not use synthetic pesticides; the fertilizing used manure at a dose of 1 ton/ha and 2 L of extract liquid compost made following the method of Suwandi et al. (2012). The rice planting began with land preparation by cultivating the soil and applying the manure at the same time. Then, the rice seeds were sown according to the traditions of local farmers, using the "Samir" method, i.e., the seeds of 7-10 days old were transplanted into the field. When the rice plant was in 2 weeks after planting, the fertilization was applied using extract liquid compost every 2 weeks.

Sampling the arboreal arthropods inhabiting refugia and vegetables

Arthropod sampling that was inhabiting refugia and vegetables surrounding the rice field was conducted once a week started from 14 to 84 DAT. The sampling was carried out twice for every observation, i.e., at 07:00 to 08:00 a.m. and at 04:00 to 05:00 p.m. The sampling was carried out by randomly picking 5 flowers for each species of refugia and vegetables. The flowers were cut from their stalks and put them in a 150 ml plastic container (Ø = 7 cm and height = 6.5 cm) perforated on the lid with a diameter of 2 cm and covered with gauze glued together. Each flower was separately put into a plastic container and labeled. The flowers were incubated and observed until the arthropods were released from the flower. The arthropods were separated from the flowers and put into a 10 ml glass bottle containing 80% ethanol. The glass bottles containing arthropods were labeled and then identified in Entomology Laboratory, Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Sriwijaya. The identification of spiders referred to Barrion & Litsinger (1995) and the identification of insects referred to Heinrichs (1994), Kalshoven (1981), and McAlpine et al. (1987).

The Sampling of Arboreal Arthropods in Rice

Observation of the arthropods was conducted weekly started when the rice in 14 to 84 DAT. The sampling of the arboreal arthropods for the observations used nets (net handle length = 100 cm, net length = 75 cm, and net Ø = 30 cm) at five points scattered in four corners of the land and one in the middle of the land for each subplot study (3 subplots as a repetition). The sampling was carried out at 06.00 to 07.00 a.m. in good weather conditions with no rain. The arthropods collection with nets was carried out based on the modification of Janzen method (2013), i.e., the arthropods were collected by swinging a net of one double swing in a straight line in 30 cm depth in the canopy of the plants. The net coverage was based on the modified methods of Masika et al. (2017) by swinging a net that tied on a plant stem. The nets were intentionally applied on the rice stem to obtain the insects on the stems and leaves of the rice plants. The obtained arthropods were sorted, put into the vial bottles containing 80% ethanol, labeled, and then identified in the laboratory. The identification of the spiders referred to Barrion and Litsinger (1995), and identification of insects referred to Heinrichs (1994), Kalshoven (1981), and McAlpine et al. (1987).

Data Analysis

The data on species composition and abundance of entomophagous arthropods inhabiting refugia and vegetables were presented in tables and charts. Their subsequent abundance data were also grouped according to the guild, i.e., predator, parasitoid, herbivore, and neutral insect, to be displayed in graphical form. Correspondence analysis was used to investigate how species of arthropods and plants (refugia, vegetables, and rice) were grouped based on the arthropod species they interacted with (Raffaelli & Hall 1992) and the species of data analyzed were grouped in species community of predators, parasitoid, herbivore, and neutral insects. The calculation of correspondence analysis used the software of SAS University Edition 2.7 9.4 M5.

RESULTS AND DISCUSSION

Species Composition of Arboreal Entomophagous Arthropods

Arboreal entomophagous arthropods are arthropods that act as predators and parasitoids for natural enemies of insect pests. In this study, arboreal entomophagous arthropods found in rice were grouped into predatory arthropods and parasitoids. Predatory arthropods consisted of groups of spiders and predatory insects, while parasitoid was a group of insects that were parasite to insects or other arthropods. The total species number of predatory arthropods and parasitoids were 67 species with 21 families (Table 1) and 22 species with 17 familes (Table 2), respectively. In the rice field, the number of predatory arthropods species was dominant (51 species) compared to refugia and vegetables. In refugia, the predatory arthropods species were dominantly found in *Zinnia* sp. (15 species), while in vegetables were mostly found in *M. charantia* (9 species). *S. indicum* was a refugia less chosen as the predatory arthropod habitat, while *L. acutangula* was a vegetable plant less chosen as the habitat by the predatory arthropods. The five species of arboreal predatory arthropods which dominantly found in rice were *Tetragnatha javana, Tetragnatha virescens, Tetragnatha mandibulata, Paederus fuscipes,* and *Micraspis inops*. Four of five species that found in rice (*T. javana, T. virescens, T. mandibulata,* and *P. fuscipes*) were found in *Zinnia* sp. In contrast, in *M. charantia,* two species of predatory arthropods were found (*T. virescens* and *M. inops*). In addition, there were other predatory arthropods found in rice, refugia, and vegetables, i.e., *O. javanus, Oxyopes matiensis, Menochilus sexmaculatus,* and *Coccinella septempunctata*.

In this study, the arboreal predatory arthropods species found in rice, refugia, and vegetables were the important predators attacking insect pests of rice. *T. javana, T. virescens,* and *T. mandibulata* are family spiders of Tetragnathidae that can prey on orders of Homoptera and Lepidoptera in rice (Tahir et al., 2009). Betz and Tscharntke (2017) stated that the Tetragnathidae also preys on order of Homoptera (leafhoppers) on rice. *P. fuscipes* is a predator of *Nilaparvata lugens* (Meng et al., 2016), and *M. inops* is an insect pest of rice generalist predator (Karindah et al., 2011). *O. javanus* effectively preys on *Hieroglyphus banian, Sogetella furcilera, Marasmia patnalis,* and *Scripophaga innotata* on rice in Pakistan (Tahir & Butt, 2009). *T. virescens* effectively controls *S. furcifera* on rice in India (Prasad, Prabhu, & Balikai, 2015). Coccinellidae prey on *N. virescens*, *N. lugens,* and *S. furcifera* on rice in India (Shanker et al., 2018).

Number parasitoid species were mostly found in rice (19 species) compared to refugia and vegetables. In refugia, the parasitoids were mostly found in *Zinnia* sp. (7 species), whereas in vegetables were mostly found in *M. charantia* (6 species) (Table 2). The most abundant parasitoids found in rice were *Cardiochiles* sp. (0.09 individual/flower), and this species was also found in *Zinnia* sp. (0.04 individual/flower), *M. charantia* (0.05 individual/flower), and *C. sativus* (0.01 individual/flower). *Cardiochiles* sp. is an effective parasitoid to control *C. medinalis* in rice (Behera 2012). In addition, *Snellenius* sp. and *Elasmus* sp. were found at Zinnia sp., while in *M. charantia* was found *Blondelia* sp. *Snellenius* sp. is a parasitoid of *Spodoptera litura* larvae (Javier & Ceballo 2018). *Elasmus* sp. is a parasitoid of *dominulus polystes* (Gumovsky et al., 2007), while *Blondelia* sp. is generally attacked the Lepidoptera of the Geometridae family (Cutler et al., 2015).

If only comparing refugia and vegetables without rice, the abundance of predatory arthropods was higher in these following three habitats, i.e., *Zinnia* sp., *T. erecta,* and *M. charantia*. At the same time, parasitoid was higher in *Zinnia* sp*., S. indicum,* and *M. charantia* (Fig. 1). Refugia and vegetables were preferred by both entomophagous arthropods because they had a good morphological attraction, long flower blooms (Jennings et al., 2017), and the availability of floral nectar and pollen (Eggs & Sanders, 2013; Foti et al., 2017). In this study, the flower of *T. erecta, S. indicum,* and *M. charantia* was preferred by the entomophagous arthropods (Fig. 2) compared to other colors because of their yellow flower. The data were in line with the study of Rocha-Filho & Rinaldi (2011), stated that yellow flower was preferred for arthropods compared to the white and pink flower. Despite having the red color, *Zinnia* sp. was the most preferred due to its longest blooming period compared to other flowers because its flower blooms for 23.67 days (Wahocho et al., 2016). The form of *Zinnia* sp. flower was rosette-shaped*. T. erecta* and *M. charantia* is also had a high attraction for predator and parasitoid, and rosette-shaped flowers are longer visited by arthropods (Jennings et al., 2017). Pollen and nectar of the refugia and vegetable flowers become the high attraction for arthropods, such as spiders (Eggs & Sanders, 2013) and parasitoids (Foti et al., 2017).

Based on the time visiting flowers, there was an interesting phenomenon. Predators, especially spiders, their visiting time to refugia and vegetables was high at 7:00 a.m. to 08:00 a.m. and 4:00 p.m. to 5:00 p.m. (Fig. 3), while the parasitoid generally visited the flowers at 7:00 a.m. to 08:00 p.m. (Fig. 4). *Zinnia* sp*., T. erecta,* and *M. charantia* were visited by the predators in the morning and evening, and more often than other refugia or vegetable species. This is related to the longest blooming period of *Zinnia* sp. Predators generally visit refugia and vegetables in the morning and evening since the predators are looking for the prey. The prey that needed by predator is more than host need by parasitoid, for example, spiders periods of predation ranging from 5 a.m. to 10 p.m. (Arango et al. 2012). As for parasitoids, their activity of visiting refugia and vegetables is generally carried out in the morning due to parasitoid looking for pollen and nectar, while the direct observation result showed that the host finding activity by parasitoid was generally conducted at 7:00 a.m. in rice. Similarly with Schmidt et al. (2012) stated that parasitoid is generally looking for plants that produce nectar and pollen for their feed in the morning. The availability of nectar and pollen generally occurs in the morning because many flowers are blooming in the morning. Therefore, the existence of refugia and vegetables around the rice field is useful in providing alternative habitat and niche for the parasitoid and predator of rice pest insects.

The Community of Arboreal Arthropods in One Rice Growing Season

Arthropods can be grouped into the guilds, i.e., predators, parasitoids, herbivores, and neutral insects. The data showed that the four species of refugia were generally dominated by predators and parasitoids, while the four vegetable species were dominated by parasitoids and herbivores. The rice was dominated by herbivores, and predators followed the development of the herbivores population. The higher the population of herbivores, the higher the abundance of predators would be. These data showed that predators played a role in suppressing herbivores compared to the parasitoid population in rice, and this is in line with the study of Settle et al. (1996) and Herlinda et al. (2018). From the data, an interesting phenomenon was found in refugia, especially in *Zinnia* sp., parasitoid and predator were found to be more abundant at the beginning of the rice-growing season. At the same time, when the rice was at 35 DAT, the abundance of both entomophagous arthropods at *Zinnia* sp. began to decrease. In contrast, in the early rice planting, the abundance of the parasitoid began to increase at 42 DAT, and the predator abundance began to increase at 21 DAT. According to Settle et al. (1996) the population dynamics in rice is affected by the flow of the entomophagous arthropods from surrounding non-crop plants and vegetables to rice, and vice versa and this can occur if habitat and other niches are available around the rice fields that are appropriate for the arthropods.

When the rice was at the vegetative stage, the species of predatory arthropods inhabiting rice, vegetables, and refugia generally have the similar high community, except the arthropod that inhabits cowpea (Fig. 5a). The found predatory arthropods gathered in these plants, including *Pardosa pseudoannulata, Cyrtophora koronadalensis,* and *Neoscona theisi* which were the hunting spiders. Species composition in rice, refugia, and vegetables had high similarity, and this was showed that predatory arthropods were actively migrated from rice to vegetables and refugia or vice versa. Their movement was caused by the herbivores inhabited in rice, such as *N. lugens, Sogatella furcifera,* and *Spodoptera* sp*.* (Fig. 5c) which were the main preys for the predatory arthropods, while the alternative prey was neutral insects in rice, such as *Tetanocera* sp*., Tipula maxima,* and *Psorophora* sp. (Fig. 5d). The parasitoid species composition in rice was highly similar to the parasitoid in zinnia and bitter melon (Fig 5b). Thus, zinnia and bitter melon were preferred by parasitoids as habitat and alternative niche beside rice. In line with Settle et al. (1996), the movement of spiders among habitats was due to generalist predators on hunting prey in alternative habitat. The species of parasitoid composition in rice were generally similar to those in the vegetable and refugia species, except those that inhabiting marigolds and ridged gourd. The species of neutral insects in rice were mostly similar to the neutral species in bitter melon.

When the rice was in the milky stage, the predatory arthropod species composition in rice was quite similar to the arthropods that inhabited in bitter melon, sesame, zinnia, yellow ray flower, and marigold. The arthropod species grouped in these plants were *Coccinella repanda, T. virescens, Bathyphantes tagalogensis*, and *O. javanus* (Fig. 6a). The parasitoid species composition inhabiting rice such as *Cardiochiles* sp*.* and *Sarcophagidae* (Fig. 6b) was quite similar to the parasitoid inhabiting cucumber and bitter melon. The herbivore composition species in rice were most similar to those of herbivores inhabiting zinnia and marigolds, particularly *Leptocorisa acuta*. The species of herbivores found in rice were *N. lugens, S. furcifera,* and *L. acuta* (Fig. 6c). The predatory arthropods found in bitter melon, sesame, zinnia, yellow ray flower, marigold were the predators of *N. lugens, S. furcifera,* and *L. acuta* in rice*.* The neutral insect species (*Chironomus* sp. and *Tipula maxima*) (Fig. 6d) in rice and marigolds were preys for these predatory generalists. Thus, the movement of species from refugia and vegetables to rice occur if in the rice field is available a lot of preys for predatory generalists. This result is quite similar to Settle et al. (1996) and Herlinda et al. (2018). The parasitoid species composition in rice was more similar to the parasitoid species composition in bitter melon and zinnia. The results of this study showed that the predator and parasitoid of rice pests were found in refugia and vegetables. The refugia species that more frequently chosen by the predators and parasitoid of rice pest as an alternative habitat were *Zinnia* sp. Still, for the vegetables, they were most fond of bitter melon.

CONCLUSIONS AND SUGGESTION

Of the 4 species of refugia (*Zinnia* sp*., T. erecta, C. caudatus,* and *S. indicum*), which were mostly chosen by the entomophagous arthropods as an alternative habitat in addition to rice, it was *Zinnia* sp. Of the 4 species of vegetables (*V. unguiculata, M. charantia, C. sativus,* and *L. acutangula*), the most preferred habitat alternative for the entomophagous arthropods was *M. charantia*. However, economically *M. charantia* was more beneficial than *Zinnia* sp. to be used as the conservation of entomophagous arthropods because it does not only provide alternative habitat and niche for the entomophagous arthropods but also it is used as land productivity.

ACKNOWLEDGEMENT

This research was supported financially by the Program of Professor Research Grant (Penelitian Unggulan Profesi Profesor) of Universitas Sriwijaya, Ministry of Research, Technology and Higher Education, the Republic of Indonesia with a 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, a postgraduate student.

REFERENCES

Arango, A. M., López-Portillo, J., Parra-Tabla, V., Hernández-Salazar, L. T., Morales-Mávil, J. E., Rico-Gray, V. (2012). Effect of the spider *Peucetia viridans* (Oxyopidae) on floral visitors and seed set of *Cnidoscolus multilobus* (euphorbiaceae). *Acta Botanica Mexicana*, 100, 1–14. http://www.scielo.org.mx/pdf/abm/n100/n100a1.pdf

Baptiste, A. K., & Smardon, R. (2012). A review of wetland use and management of the Nariva Swamp, Trinidad. *Caribbean Geography*, 17(1–2), 73–91. https://www.researchgate.net/publication/273001155

Barrion, A., & Litsinger, J. (1995). *Riceland spiders of South and Southeast Asia*. Entomology Division International Rice Research Institute Philippines.

Behera, K. S. (2012). Biology of *Cardiochiles nigricollis* Cameron, a larval endo-parasitoid of *Cnaphalocrocis medinalis* (Guen.) and *Marasmia exigua* Butler. *Journal of Biological Control*, *26*(4), 376–379. http://www.informaticsjournals.com/index.php/jbc/article/download/3485/2570

Benvenuti, S., & Bretzel, F. (2017). Agro-biodiversity restoration using wildflowers: what is the appropriate weed management for their long-term sustainability?. *Ecological Engineering*, 102, 519–526. https://doi.org/10.1016/j.ecoleng.2017.02.062

Betz, L., & Tscharntke, T. (2017). Enhancing spider families and spider webs in Indian rice fields for conservation biological control, considering local and landscape management. *Journal of Insect Conservation*, 21(3), 495–508. https://link.springer.com/article/10.1007/s10841-017-9990-2

Bhaskar, B. P., Baruah, U., Vadivelu, S., Raja, P., Sarkar, D. (2010). Remote sensing and GIS in the management of wetland resources of Majuli Island, Assam, India. *Tropical Ecology*, 51(1), 31–40. https://www.researchgate.net/publication/280251875

Bodlah, I., & Waqar, M. (2013). Pollinators visiting summer vegetables ridge gourd (*Luffa acutangula*), bitter gourd (*Momordica charantia* L.) and brinjal (*Solanum melongena*). *Asian Journal of Agriculture and Biology*, 1(1), 8–12. https://www.researchgate.net/publication/311644274

Cutler, G. C., Gariepy, T. D., De Silva, E. C. A., Hilier, N. K. (2015). High rates of parasitism of blueberry spanworm (Lepidoptera: Geometridae) by Ichneumonidae and Tachinidae in commercial lowbush blueberry fields High rates of parasitism of blueberry spanworm (Lepidoptera: Geometridae) by Ichneumonidae and Tachinidae. *Journal of Pest Science*, 88, 219–223. https://link.springer.com/article/10.1007/s10340-015-0650-6

Desai, S. D., Swaminathan, R. Desai, V. S. (2017). Effect of habitat manipulation on infestation of paddy leaf folder, *Cnaphalocrocis medinalis* (Guenee). *Int.J.Curr.Microbiol.App.Sci*, 6(10), 1469–1477. https://doi.org/10.20546/ijcmas.2017.610.174

Eggs, B., & Sanders, D. (2013). Herbivory in spiders: The importance of pollen for orb-weavers. *PLoS ONE*, 8(11), 1–5. https://doi.org/10.1371/journal.pone.0082637

Emile, T., Honorine, N.T., Thomas N., Marie-Anne, S. (2012). Vegetable production systems of swamp zone in urban environment in west cameroon: case of Dschang city. *Universal Journal of Environmental Research and Technology All*, 2(2), 83–92. http://www.environmentaljournal.org/2-2/ujert-2-2-9.pdf

Foti, M. C., Rostás, M., Peri, E., Park, K. C., Slimani, T., Wratten, S. D., Colazza, S. (2017). Chemical ecology meets conservation biological control: identifying plant volatiles as predictors of floral resource suitability for an egg parasitoid of stink bugs. *Journal of Pest Science*, 90(1), 299–310. https://link.springer.com/article/10.1007/s10340-016-0758-3

Ganai, S. A., Ahmad, H., Sharma, D., Sharma, S. (2017). Diversity of arthropod fauna associated with marigold (*Tagetes erecta* L.) in Jammu. *Journal of Entomology and Zoology Studeis*, *5*(5), 1940–1943. http://www.entomoljournal.com/archives/2017/vol5issue5/PartY/5-5-193-255.pdf

Gumovsky, A., Rusina, L., Firman, L. (2007). Bionomics and morphological and molecular characterization of *Elasmus schmitti* and *Baryscapus elasmi* (Hymenoptera: Chalcidoidea, Eulophidae), parasitoids associated with a paper wasp, *Polistes dominulus* (Vespoidea, Vespidae). *Entomological Science*, 10, 21–34. https://doi.org/10.1111/j.1479-8298.2006.00195.x

Hasan, K., Pervin, M., Manda, F., Mala, M. (2016). Habitat management: a key option to enhance natural enemies of crop pest. *Universal Journal of Plant Science*, 4, 50–57. http://www.hrpub.org/journals/article_info.php?aid=5517

Heinrichs, E. A. (1994). *Biology and management of rice insect*. International Rice Research Intitute.

Herlinda, S., Yudha, S., Thalib, R., Khodijah, Suwandi, Lakitan, B., Verawaty, M. (2018). Species richness and abundance of spiders inhabiting rice in fresh swamps and tidal lowlands in South Sumatera, Indonesia. *J. ISSAAS*, 24, 82–93. https://www.cabdirect.org/cabdirect/abstract/20183221277

Hossain, M. S., Yeasmin, F., Rahman, M. M., Akhtar, S., Hasnat, M. A. (2018). Role of insect visits on cucumber (*Cucumis sativus* L.) yield. *J. biodivers. conserv. bioresour. manag.*, 4(2), 81–88. https://doi.org/10.3329/jbcbm.v4i2.39854

Hu, S., Fu, D. Y., Liu, X. J., Zhao, T., Han, Z. L., Lu, J. P., Wan, H. L., Ye, H. (2012). Diversity of planthoppers associated with the winter rice agroecosystems in Southern Yunnan, China. *Journal of Insect Science*, 12(29), 1–11. https://doi.org/10.1673/031.012.2901

Janzen, D. H. (2013). Differences in insect abundance and diversity between wetter and drier sites during a tropical dry season. *Ecology*, 49(1), 96–110. https://www.jstor.org/stable/1933565

Javier, A. M. V. (2018). Life history and biological control potential of *Snellenius manilae* Ashmead (Hymenoptera: Braconidae), a parasitoid of *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae). *Philipp Agric Scientist*, 101(2), 148–157. https://www.researchgate.net/publication/326981932_Life_History_and_Biological_Control_Potential_of_Snellenius_manilae_Ashmead_Hymenoptera_Braconidae_a_Parasitoid_of_Spodoptera_litura_Fabricius_Lepidoptera_Noctuidae

Jennings, D. T., Longcore, J. R., Bird, J. E. (2017). Spiders (Araneae) inhabit Lepidopteran-feeding shelters on ferns. *J. Acad. Entomol. Soc.* 13, 5–14. http://acadianes.org/journal/papers/jennings_16-3.pdf

Kalshoven, L. G. (1981). The pest of crops in Indonesia. Van Hoeve, Jakarta : PT. Ichtiar Baru.

Karindah, S., Yanuwiadi, B., Sulistyowati, L., Green, P. T. (2011). Abundance of *Metioche vittalicollis* (Orthoptera: Gryllidae) and natural enemies in a rice agroecosystem as influenced by weed species. *Agrivita*, 33(2), 133–141. http://doi.org/10.17503/agrivita.v33i2.55

Kaur, G., & Sangha, K. S. (2016). Evaluation of yellow sticky trap shapes for capturing alate insects in chilli agroecosystem. *Journal of Insect Science*, 29(1), 67–72. https://www.researchgate.net/publication/305771775

Lakitan, B., Alberto, A., Lindiana, L., Kartika, K., Herlinda, S., Kurnianingsih, A. (2018). The benefits of biochar on rice growth and yield in tropical riparian wetland, South Sumatra, Indonesia. *Chiang Mai University Journal of Natural Sciences*, 17(2), 111–126. http://cmuj.cmu.ac.th/ns/full/2120180410110810.pdf

Lakitan, B. 2019. Cultivation of common bean (*Phaseolus vulgaris* L.) subjected to shallow water table at riparian wetland in South Sumatra, Indonesia. *Australian journal of crop science*, 13(1), 98–104. https://www.researchgate.net/publication/332009012_Cultivation_of_common_bean_Phaseolus_vulgaris_L_subjected_to_shallow_water_table_at_riparian_wetland_in_South_Sumatra_Indonesia

Lakitan, B., Lindiana, L., Widuri, L. I., Kartika, K., Siaga, E., Meihana, M. (2019). Inclusive and Ecologically-Sound Food Crop Cultivation at Tropical Non-Tidal. *AGRIVITA*, 41(1), 1–9. http://doi.org/10.17503/agrivita.v40i0.1717

Lopes, S. de F., Ramos, M. B., de Almeida, G. R. (2017). The role of mountains as refugia for biodiversity in Brazilian Caatinga: Conservationist implications. *Tropical Conservation Science*, 10: 1–12. https://doi.org/10.1177%2F1940082917702651

Margono, B. A., Bwangoy, J. R. B., Potapov, P. V., Hansen, M. C. (2014). Mapping wetlands in Indonesia using landsat and PALSAR data-sets and derived topographical indices. *Geo-Spatial Information Science*, 17(1), 60–71. https://doi.org/10.1080/10095020.2014.898560

Masika, F. B., Masanza, M., Aluana, G., Barrigossi, A. F., Kizito, E. B. (2017). Abundance, distribution and effects of temperature and humidity on arthropod fauna in different rice ecosystems in Uganda. *Journal of Entomology and Zoology Studies*, 5(5), 964–973.

https://www.researchgate.net/publication/321676101_Abundance_distribution_and_effects_of_temperature_and_humidity_on_arthropod_fauna_in_different_rice_ecosystems_in_Uganda

McAlpine, J. F., Peterson, B. V., Shewel, G. E., Teskey, H. J., Vockeroth, J. R., Wood, D. M., (1987). *Manual of Neartic Diptera*. Agriculture Canada, Research Branch.

McCabe, E., Loeb, G., Grab, H. (2017). Responses of crop pests and natural enemies to wildflower borders depends on functional group. *Insects*, 8(73), 1–8. https://doi.org/10.3390/insects8030073

Meng, J., Mabubu, J. I., Han, Y., He, Y., Zhao, J., Hua, H., Feng, Y., Wu, H. (2016). No impact of transgenic cry1C rice on the rove beetle *Paederus fuscipes*, a generalist predator of brown planthopper *Nilaparvata lugens*. *Scientific reports*. https://www.nature.com/articles/srep30303

Niba, A. 2011. Arthropod assemblage dynamics on cowpea (*Vigna unguiculata* L. Walp) in a subtropical agro-ecosystem, South Africa. *African Journal of Agricultural Research*, 6(4), 1009–1015. https://doi.org/10.5897/AJAR10.751

Prasad, R., Prabhu, S. T., Balikai, R. A. (2015). Incidence of white backed plant hopper on rice and its predators under rainfed ecosystems and their correlation with weather parameters. *Research Journal of Agricultural Sciences*, 1(4), 322–326. https://www.researchgate.net/publication/264846092_Incidence_of_White_Backed_Plant_Hopper_on_Rice_and_its_Predators_under_Rainfed_Ecosystems_and_their_Correlation_with_Weather_Parameters

Raffaelli, D. & Hall, S.J. (1992). Compartments and predation in an estuarine food web. *Journal of Animal Ecology*, 61, 551–560. https://www.jstor.org/stable/5610?seq=1#page_scan_tab_contents

Rocha-Filho, L. C., & Rinaldi, I. M. P. (2011). Crab spiders (Araneae: Thomisidae) in flowering plants in a Brazilian "Cerrado" ecosystem. *Brazilian journal of biology*, 71(2), 359–364. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1519-69842011000300004

Schmidt, K., Orosz-Kovacs, Z. Farkas, A. (2012). Nectar secretion dynamics in some raspberry and blackberry cultivars. *The International Journal of Plant Reproductive Biology*, 4(2), 147–150. https://www.researchgate.net/publication/233808478_Nectar_secretion_dynamics_in_some_raspberry_and_blackberry_cultivars

Settle, W. H., Ariawan, H., Astuti, E. T., Cahyana, W., Hakim, A. L., Hindayana, D., Lestari, A. S., Pajarningsih. (1996). Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. *Ecology*, 77(7), 1975–1988. https://www.jstor.org/stable/2265694

Shanker, C., Chintagunta, L., Muthusamy, S., Vailla, S., Srinivasan, A., Katti, G. (2018). Flora surrounding rice fields as a source of alternative prey for coccinellids feeding on the pests of rice. *European Journal of Entomology*, 115, 364-371. https://doi.10.14411/eje.2018.036. https://www.eje.cz/pdfs/eje/2018/01/36.pdf

Siaga, E., Lakitan, B., Hasbi., Bernas, S. M., Wijaya, A., Lisda, R., Ramadhani, F., Widuri, L. I., Kartika, K., Meihana, M. 2018. Application of floating culture system in chili pepper (*Capsicum annum* L.) during prolonged flooding period at riparian wetland in Indonesia. *Australian Journal of Crop Science*, 12(5), 808–816. http://www.cropj.com/siaga_supp_12_5_2018_808_816.pdf

Suwandi, Ammar, M., Irsan, C. (2012). Application of extract compost increased yield and suppressed the diseases of ratoon rice crop in tidal swamp of Banyuasin Regency. *J. Lahan Suboptimal*, 1, 116–122. [Indonesian]. http://www.jlsuboptimal.unsri.ac.id/index.php/jlso/article/download/15/13

Tahir, H. M., & Butt, A. (2009). Predatory potential of three hunting spiders inhabiting the rice ecosystems. *J Pest Sci*, 82, 217–225. https://link.springer.com/article/10.1007/s10340-008-0242-9

Wahocho, S. A., Miano, T. F., Memon, N. U. N., Wahocho, N. A. (2016). Photoperiodic effect on vegetative growth and flower quality of zinnia (*Zinnia elegans* Jacq.). *Sarhad Journal of Agriculture*, 32(4), 316–324. http://dx.doi.org/10.17582/journal.sja/2016.32.4.316.324

Widuri, L. I., Lindiana, L., Kartika, K., Siaga, E., Meihana, M., Hasmeda, M., Sodikin, E., Lakitan, B. (2016). Identification of farmer's needs and vegetable cultivation constraints in riparian wetlands using grounded theory. *Prosiding seminar nasional lahan suboptimal*, 587–594. [Indonesian]. http://pur-plso.unsri.ac.id/userfiles/71_%20HAL%20587-594%20%20Laily-ilman-widuri-identifikasi-kebutuhan-petani-lahan-rawa-lebak.pdf

Zhu, P., Wang, G ., Zheng, X., Tian, J., Lu, Z., Heong, K. K., Xu, H., Chen, G., Yang, Y., Gurr, G. M. (2014). Selective enhancement of parasitoids of rice Lepidoptera pests by sesame (*Sesamum indicum*) flowers. *BioControl*, 1-11. https://link.springer.com/article/10.1007/s10526-014-9628-1

Figures and Tables

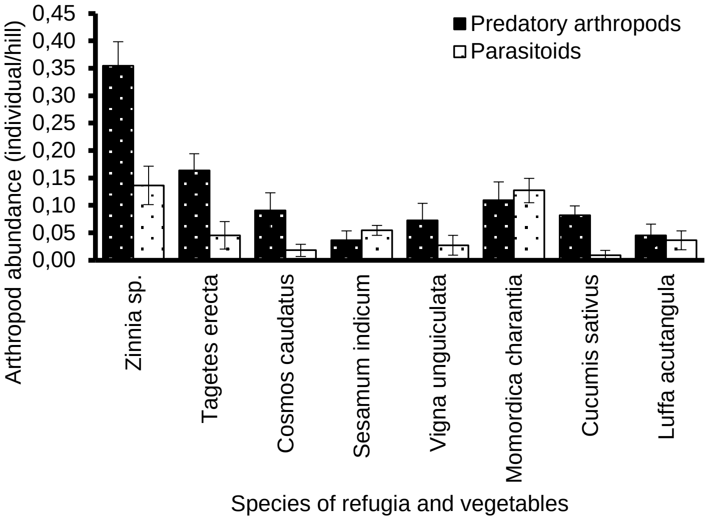


Fig. 1. Abundace of predatory arthropods and parasitoids inhabiting refugia and vegetables

Fig. 2. Flower of refugia and vegetables: zinnia (a), marigold (b), yellow ray flower (c), sesame (d), cowpea (e), bitter melon (f), cucumber (g), ridged gourd (h)

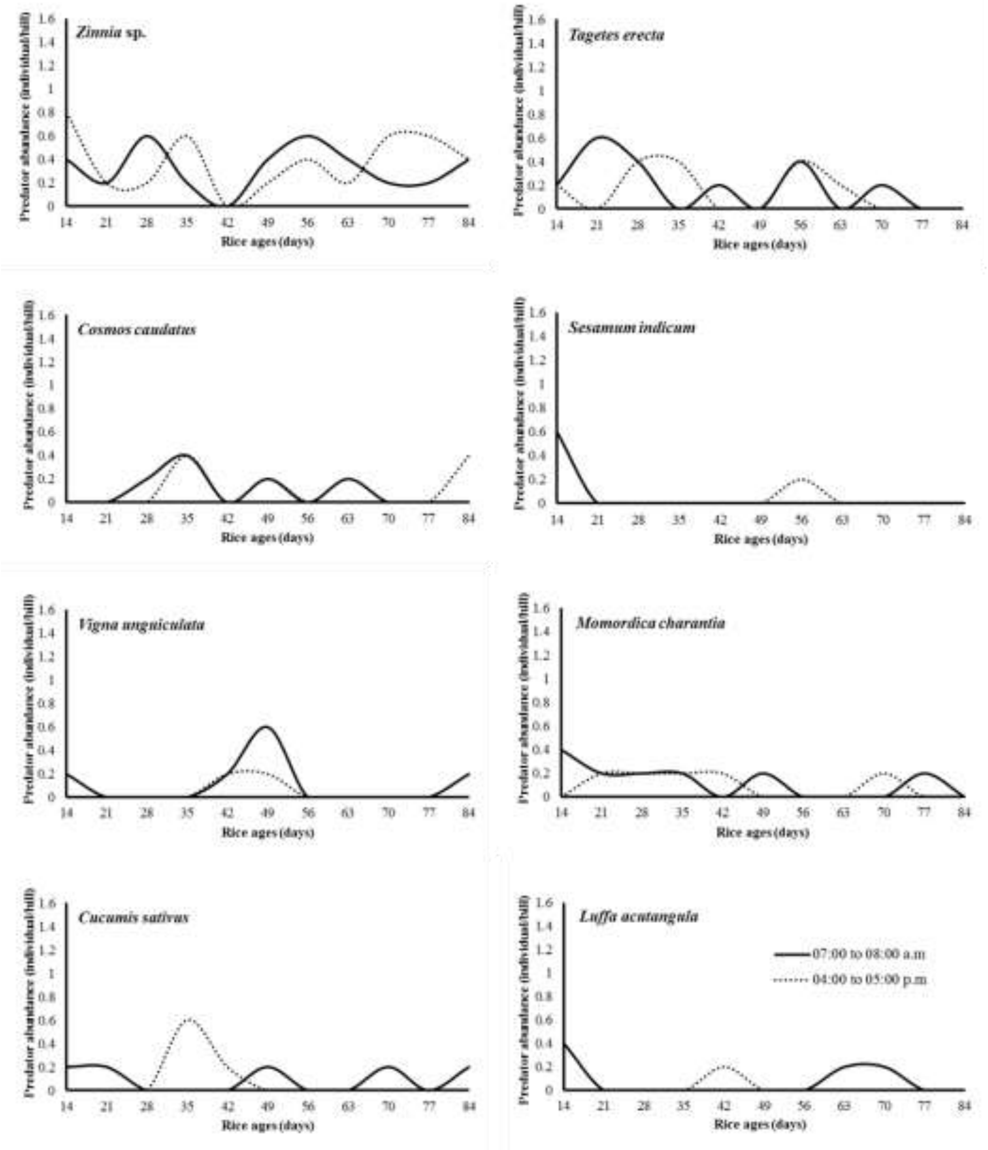


Fig. 3. Predatory abundance found on refugia and vegetables in the period of 14-84 days after rice transplanting

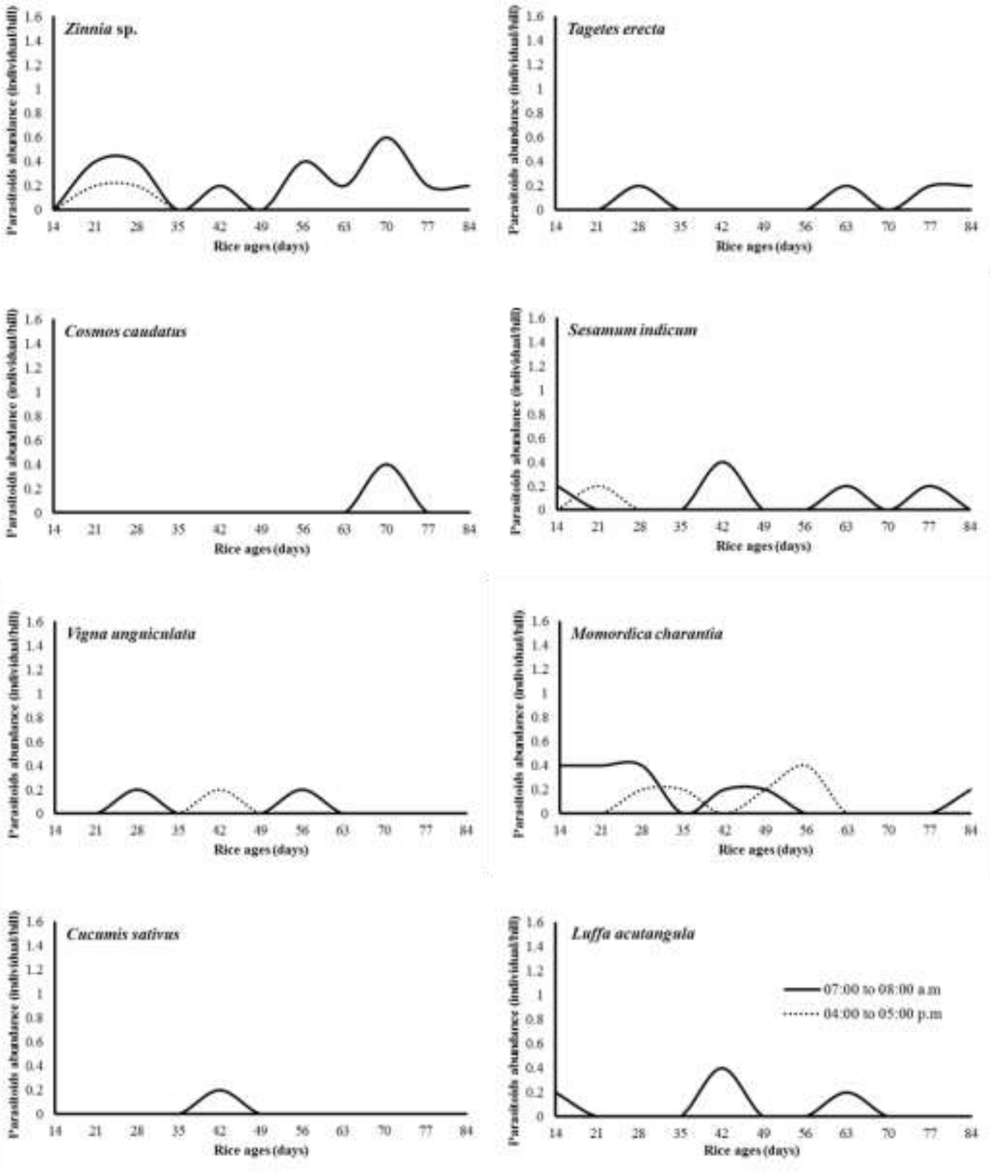


Fig. 4. Parasitoid abundance found on refugia and vegetables in the period of 14-84 days after rice transplanting or during a rice season

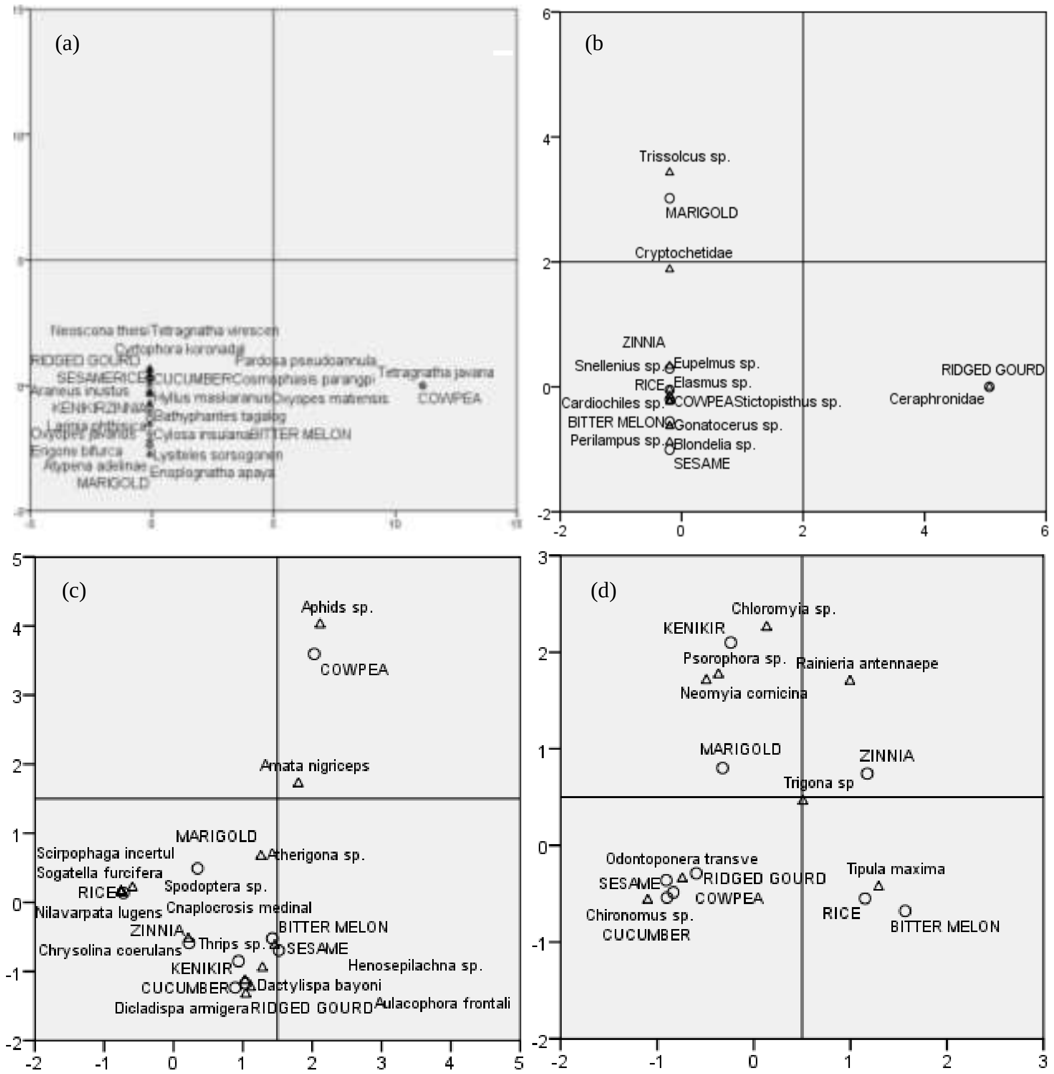


Fig. 5. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice vegetative stage; arthropods (o); plant (Δ)

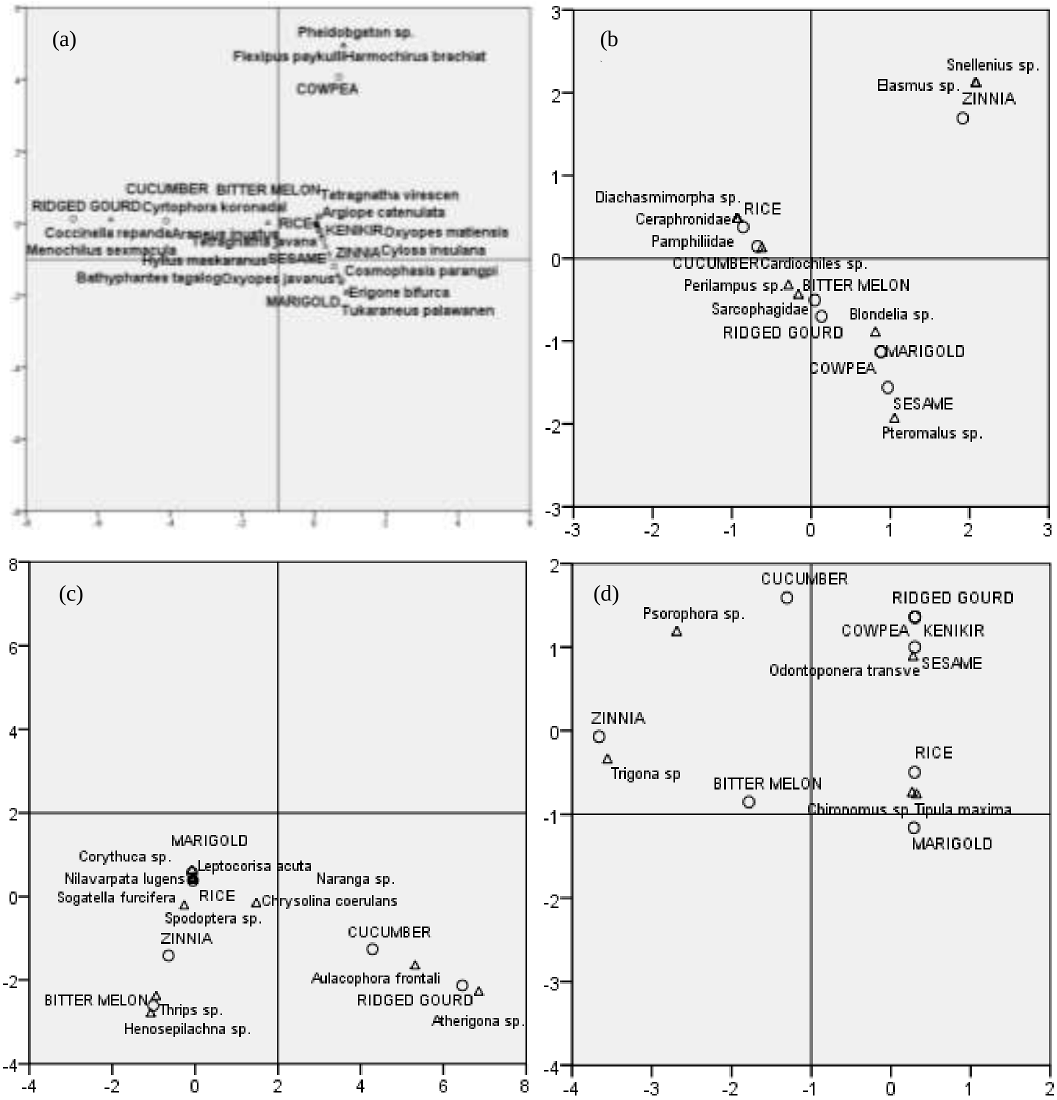


Fig. 6. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice milky stage; arthropods (o); plant (Δ)

Table 1. Species composition of predatory arthropods found in rice, refugia, and vegetables

No.	Class/ Ordo/ Family	Habitat (individual/net or individual/flower)								
		A	B	C	D	E	F	G	H	I
	Arachnida	1.88	0.32	0.18	0.08	0.02	0.06	0.08	0	0
	Araneae	1.88	0.32	0.18	0.08	0.02	0.06	0.08	0	0
1.	Lycosidae	0.04	0	0	0	0	0	0	0	0
2.	Araneidae	0.13	0.03	0.04	0.02	0	0	0	0	0
3.	Tetragnathidae	1.34	0.04	0.01	0.01	0	0.04	0.02	0	0
4.	Linyphiidae	0.12	0.01	0.04	0	0	0	0.01	0	0
5.	Oxyopidae	0.12	0.1	0.01	0.03	0.01	0	0.02	0	0
6.	Theridiidae	0.01	0	0.01	0	0	0	0	0	0
7.	Thomisidae	0	0	0.03	0	0	0	0.02	0	0
8.	Salticidae	0.1	0.14	0.04	0.02	0.01	0.02	0.01	0	0

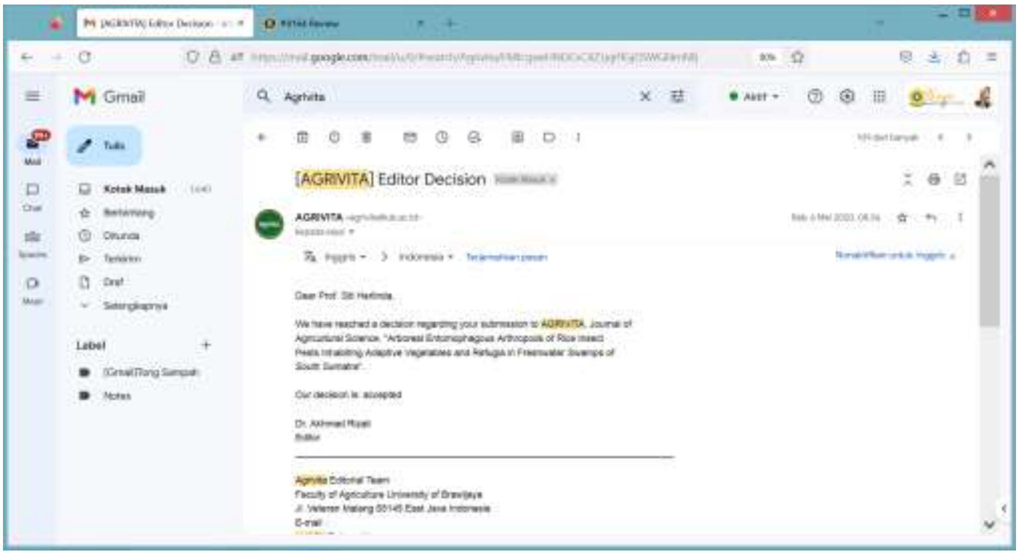
No.	Class/ Ordo/ Family	Habitat (individual/net or individual/flower)								
		A	B	C	D	E	F	G	H	I
9.	Hahniidae	0.02	0	0	0	0	0	0	0	0
	Insecta	0.86	0.06	0	0.02	0.02	0.02	0.04	0.09	0.05
	Hemiptera	0.04	0	0	0	0	0	0	0	0
10.	Miridae	0.04	0	0	0	0	0	0	0	0
	Coleoptera	0.71	0.06	0	0.02	0.02	0	0.04	0.09	0.05
11.	Carabidae	0.01	0	0	0	0	0	0	0	0
12.	Staphylinidae	0.18	0.04	0	0	0.01	0	0	0	0.01
13.	Coccinelidae	0.5	0.01	0	0.02	0.01	0	0.03	0.09	0.04
14.	Elateridae	0.01	0	0	0	0	0	0	0	0
15.	Anthicidae	0.01	0.01	0	0	0	0	0.01	0	0
	Odonata	0.06	0	0	0	0	0	0	0	0
16.	Coenagrionidae	0.05	0	0	0	0	0	0	0	0
17.	Libellulidae	0.01	0	0	0	0	0	0	0	0
	Orthoptera	0.02	0	0	0	0	0	0	0	0
18.	Tettigonidae	0.02	0	0	0	0	0	0	0	0
	Hymenoptera	0.01	0	0	0	0	0.02	0	0	0
19.	Formichidae	0.01	0	0	0	0	0.02	0	0	0
	Diptera	0.01	0	0	0	0	0	0	0	0
20.	Syrphidae	0.01	0	0	0	0	0	0	0	0
	Mantodea	0.01	0	0	0	0	0	0	0	0
21.	Mantidae	0.01	0	0	0	0	0	0	0	0
	Total Abundance (N)	2.74	0.38	0.18	0.1	0.04	0.08	0.12	0.09	0.05
	Number of Species (S)	51	15	14	7	4	5	9	5	4

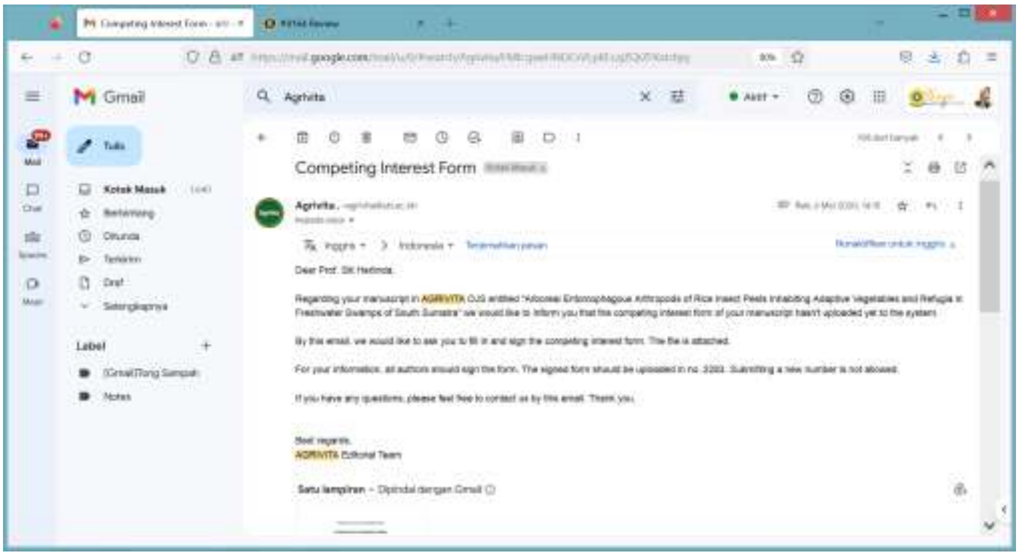
Remarks: A= rice; B= *Zinnia* sp.; C= *Tagetes erecta*; D= *Cosmos caudatus*;E= *Sesamum indicum*; F=*Vigna unguiculata*; G=*Momordica charantia*; H=*Cucumis sativus*; I=*Luffa acutangula*

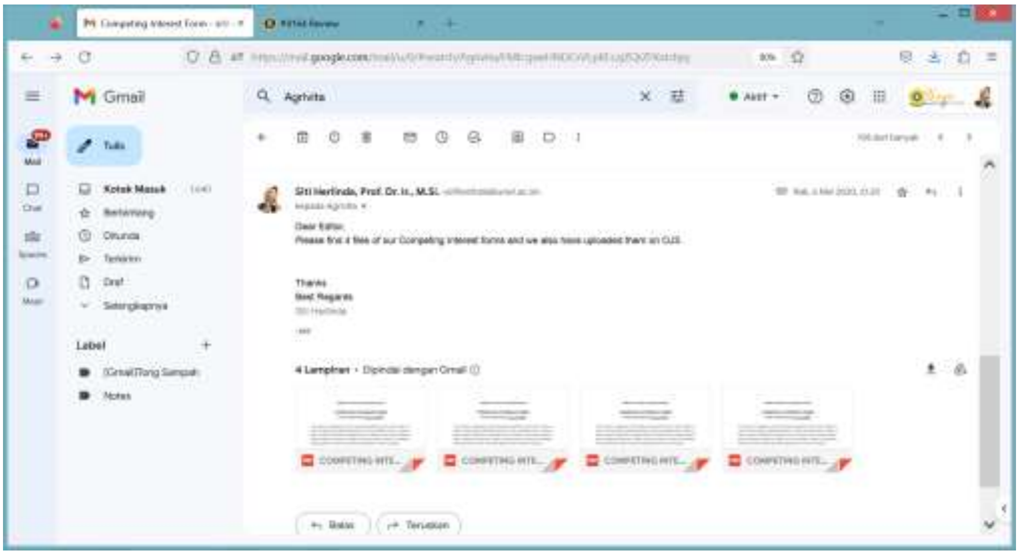
Table 2. Species composition of parasitoid found on rice, refugia, and vegetables

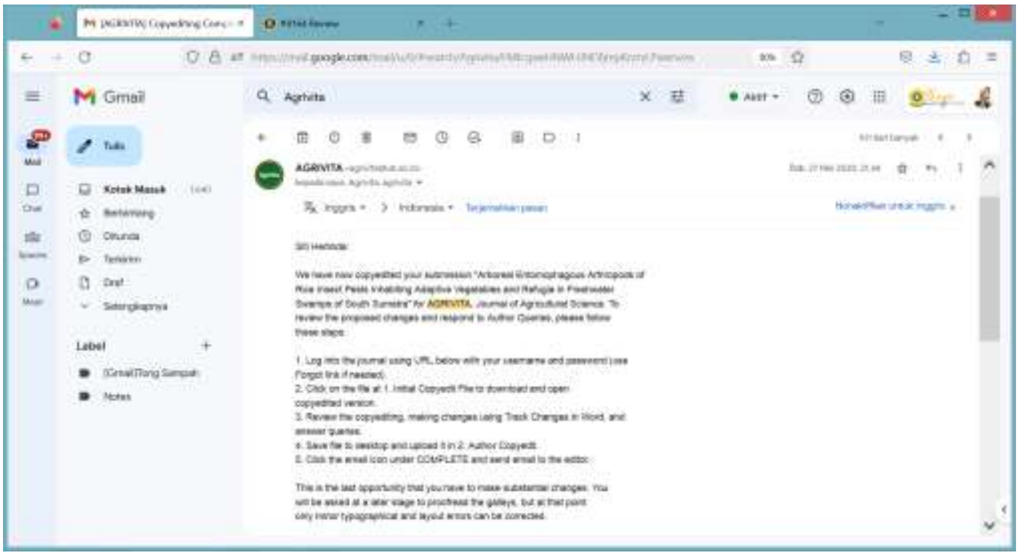
No.	Class/ Ordo/ Family	Habitat (individual/net or individual/flower)								
		A	B	C	D	E	F	G	H	I
	Insecta	0.37	0.15	0.05	0.02	0.06	0.03	0.13	0.01	0.04
	Hymenoptera	0.34	0.13	0.02	0	0.01	0.01	0.08	0.01	0.02
1.	Ichneumoidae	0.01	0	0	0	0	0	0	0	0
2.	Eulophidae	0.02	0.03	0	0	0	0	0.01	0	0
3.	Scelionidae	0	0	0.01	0	0	0	0	0	0
4.	Braconidae	0.13	0.07	0.01	0	0	0.01	0.05	0.01	0
5.	Trichogrammatidae	0	0	0	0	0	0	0.01	0	0
6.	Perilampidae	0.01	0	0	0	0	0	0.01	0	0.01
7.	Ceraphronidae	0.04	0.02	0	0	0	0	0	0	0.01
8.	Pamphiliidae	0.02	0	0	0	0	0	0	0	0
9.	Encyrtidae	0.02	0	0	0	0	0	0	0	0
10.	Eupelmidae	0.01	0.01	0	0	0	0	0	0	0
11.	Heloridae	0.02	0	0	0	0	0	0	0	0
12.	Ptreromalidae	0.03	0	0	0	0.01	0	0	0	0
13.	Chalcididae	0.01	0	0	0	0	0	0	0	0
14.	Eurytomidae	0.02	0	0	0	0	0	0	0	0
	Diptera	0.03	0.02	0.03	0.02	0.05	0.02	0.05	0	0.02
15.	Tachinidae	0.02	0.01	0.02	0.02	0.05	0.02	0.04	0	0.01
16.	Cryptochetidae	0	0.01	0.01	0	0	0	0	0	0
17.	Sarcophagidae	0.01	0	0	0	0	0	0.01	0	0.01
	Total Abundance (N)	0.37	0.15	0.05	0.02	0.06	0.03	0.13	0.01	0.04
	Number of Species (S)	19	7	4	1	2	2	6	1	4

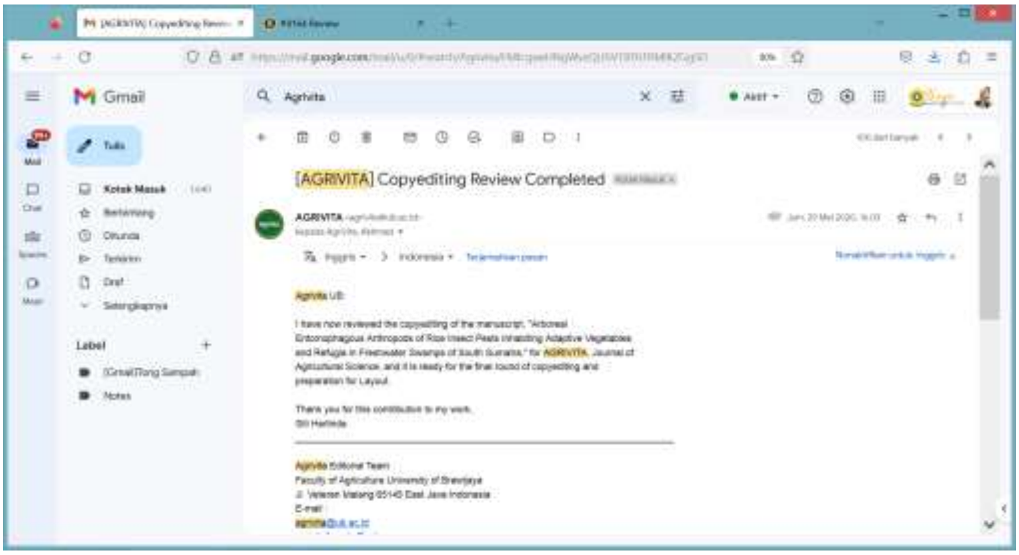
Remarks: A= rice; B= *Zinnia* sp.; C= *Tagetes erecta*; D= *Cosmos caudatus*;E= *Sesamum indicum*; F=*Vigna unguiculata*; G=*Momordica charantia*; H=*Cucumis sativus*; I=*Luffa acutangula*


Gmail
Agrivita
Kotak Masuk
Label
[AGRIVITA] Editor Decision
AGRIVITA
Dear Prof. Siti Herlinda
Our decision is: accepted
Agrivita Editorial Team
Faculty of Agriculture University of Brawijaya
E-mail

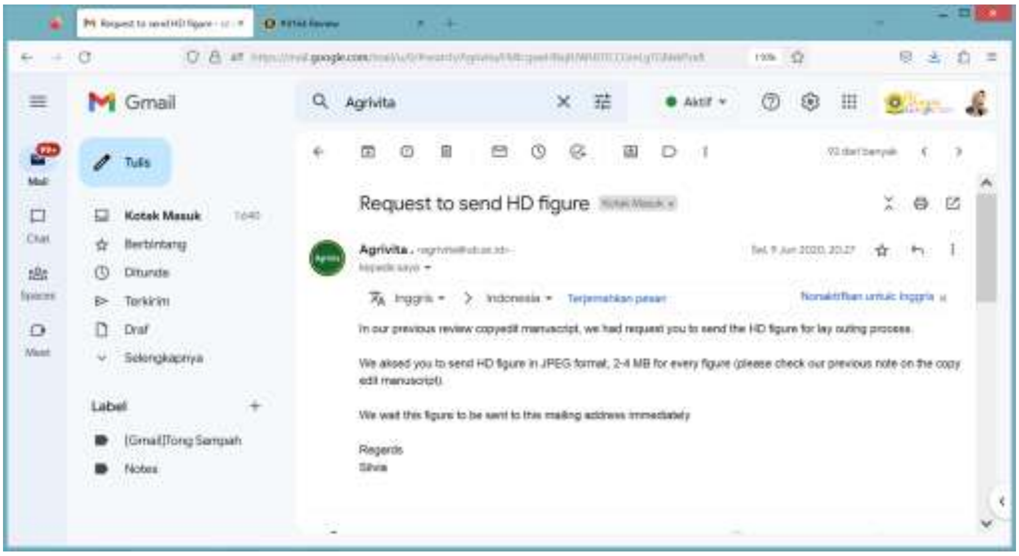

Gmail
Agrivita
Kotak Masuk
Label
Competing Interest Form
Agrivita
Dear Prof. Siti Herlinda
Best regards,
AGRIVITA Editorial Team
Satu lampiran • Dipindai dengan Gmail

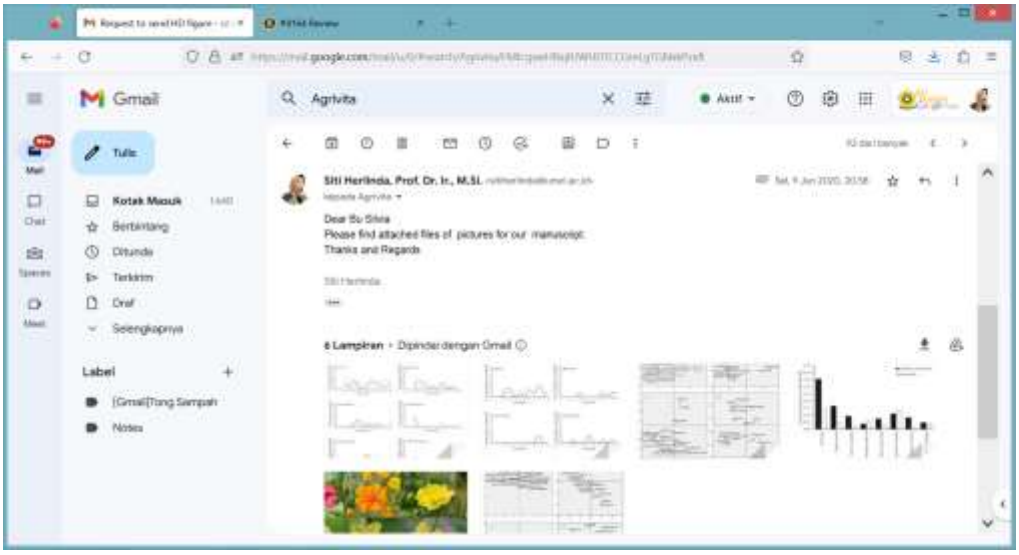

Gmail
Agrivita
Siti Herlinda, Prof. Dr. Ir., M.Si.
Thanks
Best Regards
4 Lampiran · Dipindai dengan Gmail
Balas
Teruskan

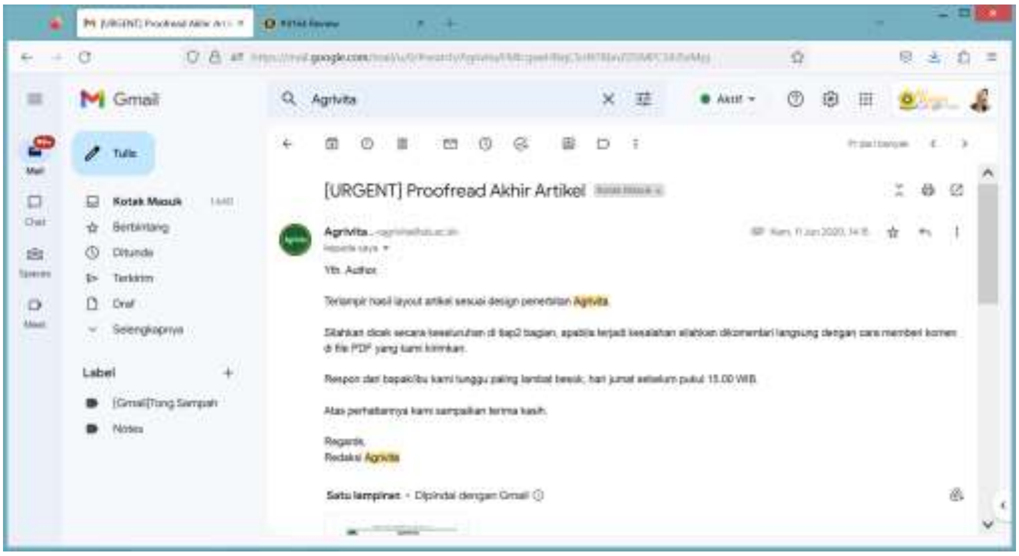

Gmail
Agrivita
AGRIVITA
Inggris
Indonesia
Terjemahkan pesan
1. Log into the journal using URL below with your username and password (use Forgot link if needed).
2. Click on the file at 1. Initial Copyedit File to download and open copyedited version.
3. Review the copyediting, making changes using Track Changes in Word, and answer queries.
4. Save file to desktop and upload it in 2. Author Copyedit.
5. Click the email icon under COMPLETE and send email to the editor.

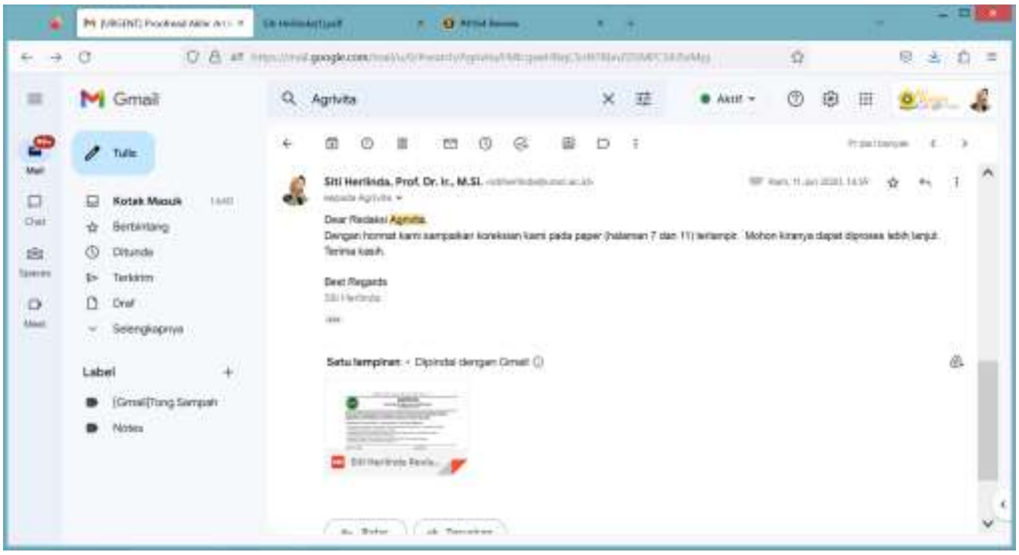

Gmail
Agrivita
Tulis
Kotak Masuk
Berbintang
Ditunda
Terkirim
Draf
Selengkapnya
Label
[Gmail]Tong Sampah
Notes
[AGRIVITA] Copyediting Review Completed
AGRIVITA
Inggris
Indonesia
Terjemahkan pesan
Agrivita UB
Thank you for this contribution to my work.
Agrivita Editorial Team
Faculty of Agriculture University of Brawijaya
Jl. Veteran Malang 65145 East Java Indonesia
E-mail:

6


Gmail
Agrivita
Aktif
Tulis
Kotak Masuk
Berbintang
Ditunda
Terkirim
Draf
Selengkapnya
Label
[Gmail]Tong Sampah
Notes
Request to send HD figure
Agrivita .
Inggris
Indonesia
Terjemahkan pesan
Nonaktifkan untuk Inggris
In our previous review copyedit manuscript, we had request you to send the HD figure for lay outing process.
We aksed you to send HD figure in JPEG format, 2-4 MB for every figure (please check our previous note on the copy edit manuscript).
We wait this figure to be sent to this mailing address immediately
Regards
Silvia


Gmail
Agrivita
Aktif
Tulis
Kotak Masuk
Berbintang
Ditunda
Terkirim
Draf
Selengkapnya
Label
[Gmail]Tong Sampah
Notes
Siti Herlinda, Prof. Dr. Ir., M.Si.
kepada Agrivita
Dear Bu Silvia
Please find attached files of pictures for our manuscript
Thanks and Regards
6 Lampiran • Dipindai dengan Gmail


Gmail
Agrivita
Aktif
Tulis
Kotak Masuk
Berbintang
Ditunda
Terkirim
Draf
Selengkapnya
Label
[Gmail]Tong Sampah
Notes
[URGENT] Proofread Akhir Artikel
Agrivita
Yth. Author
Terlampir hasil layout artikel sesuai design penerbitan Agrivita.
Silahkan dicek secara keseluruhan di tiap2 bagian, apabila terjadi kesalahan silahkan dikomentari langsung dengan cara memberi komen di file PDF yang kami kirimkan.
Respon dari bapak/ibu kami tunggu paling lambat besok, hari jumat sebelum pukul 15.00 WIB.
Atas perhatiannya kami sampaikan terima kasih.
Regards,
Redaksi Agrivita
Satu lampiran • Dipindai dengan Gmail



AGRIVITA
Journal of Agricultural Science
www.agrivita.ub.ac.id

Arboreal Entomophagous Arthropods of Rice Insect Pests Inhabiting Adaptive Vegetables and Refugia in Freshwater Swamps of South Sumatra

Tili Karenina[1], Siti Herlinda[2,3*)], Chandra Irsan[2,3] and Yulia Pujiastuti[2,3]

[1] Postgraduate Program of Agriculture Sciences, Faculty of Agriculture, Universitas Sriwijaya, Palembang 30139, South Sumatra, Indonesia
[2] Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Sriwijaya, Indralaya 30662, South Sumatra, Indonesia
[3] Research Center for Sub-optimal Lands (PUR-PLSO), Universitas Sriwijaya, Palembang 30139, South Sumatra, Indonesia

ARTICLE INFO

Keywords:
Habitat
Cardiochiles sp.
Momordica charantia
Paederus fuscipes
Tetragnatha javana
Zinnia sp.

Article History:
Received: July 6, 2019
Accepted: May 6, 2020

*) Corresponding author:
E-mail: sitiherlinda@unsri.ac.id

ABSTRACT

The plants surrounding rice field serve as a habitat and niche for entomophagous arthropods. This study aimed to identify the entomophagous arthropod species and to analyze their abundance and community in vegetables and refugia grown in the rice field. The field was surrounded by 4 species of refugia (*Zinnia* sp., *Tagetes erecta*, *Cosmos caudatus*, and *Sesamum indicum*) and 4 species of vegetables (*Vigna unguiculata*, *Momordica charantia*, *Cucumis sativus*, and *Luffa acutangula*). The arthropod found were 67 species of predatory arthropods and 22 species of parasitoids. The predatory arthropods were mostly found in rice (51 species) followed by *Zinnia* sp. (15 species), and *M. charantia* (9 species). Parasitoid species were dominantly found in rice (19 species), *Zinnia* sp. (7 species), and *M. charantia* (6 species). The predatory arthropods mostly found were *Tetragnatha javana*, *Tetragnatha virescens*, and *Paederus fuscipes*, while the dominant parasitoids were *Cardiochiles* sp., *Elasmus* sp., and *Snellenius* sp. The parasitoid species composition in rice was more similar to those in bitter melon and zinnia. The composition of predatory arthropod species in rice was similar to those in all vegetables and refugia, except in cowpea. *Zinnia* sp. and *M. charantia* were the most chosen habitat by entomophagous arthropods.

INTRODUCTION

Wetland is a land saturated with water, both year-round and seasonal. Wetland in Indonesia generally consists of freshwater (non-tidal) swamp and tidal lowland. The freshwater swamp is a wetland that is flooded due to the flow of river water or rain, while the lowland tidal is inundated due to the tides (Hanif et al., 2020). According to Margono, Bwangoy, Potapov, & Hansen (2014), the wetland area in Indonesia is around 39.6 Mha of which 77% are spread in Sumatra Island (11.9 Mha), Kalimantan (12.2 Mha), and Papua (11.8 Mha). The remaining 23% are spread in Java (1.9 Mha), Sulawesi (1.2 Mha), Maluku (0.5 Mha), and Bali-Nusa Tenggara (0.2 Mha).

Freshwater swamps in South Sumatra are generally inundated from November to April, or May depended on the lowland typology. During dry season, the area were often in drought condition (based on direct observation in the center of freshwater swamps, Ogan Ilir District, South Sumatra since 2012 up to now). When the land was inundated, the local farmers raise swamp fish or local duck and alabio duck (*Anas platyrhynchos*). During dry season, they grow rice (Lakitan et al., 2018) or adaptive vegetables (Lakitan et al., 2019) or mixed cropping between rice and adaptive vegetables. Some adaptive vegetables in freshwater swamps are cowpea (*Vigna unguiculata*) (Bhaskar,

ISSN: 0126-0537 Accredited First Grade by Ministry of Research, Technology and Higher Education of The Republic of Indonesia, Decree No: 30/E/KPT/2018

Cite this as: Karenina, T. Herlinda, S. Irsan, C. & Pujiastuti, Y. (2020). Arboreal Entomophagous Arthropods of Rice Insect Pests Inhabiting Adaptive Vegetables and Refugia in Freshwater Swamps of South Sumatra. *AGRIVITA Journal of Agricultural Science*, *42*(1), 37–44. https://doi.org/10.17503/agrivita.v42i1.2219

Baruah, Vadivelu, Raja, & Sarkar, 2010), cucumber (*Cucumis sativus*) (Baptiste & Smardon, 2012), ridged gourd (*Luffa acutangula*) and bitter melon (*Momordica charantia*) (Widuri et al., 2016), chili pepper (*Capsicum annum L.*) (Siaga et al., 2018) common bean (*Phaseolus vulgaris*) (Susilawati & Lakitan, 2019), and tomatoes (Emile, Honorine, Thomas, & Marie-Anne, 2012). The vegetables planted around the rice fields usually have multiple functions. These crops are not only directed to increase land productivity, yet provide natural habitat and niche for natural enemies of rice insect pests as well (Karenina, Herlinda, Irsan, & Pujiastuti, 2019).

Cowpeas are inhabited by 21 insect species of 12 families and 5 orders (Coleoptera, Hemiptera, Orthoptera, Homoptera, and Lepidoptera) (Niba, 2011). Cucumbers are visited by 11 insect species of 7 families and 3 orders (Hymenoptera, Diptera, and Coleoptera) (Hossain, Yeasmin, Rahman, Akhtar, & Hasnat, 2018). Ridged gourds are inhabited by 6 insect species of 3 families and 2 orders (Hymenoptera and Diptera), while bitter melons are visited by 4 insect species of 3 families and 2 orders (Bodlah & Waqar, 2013). Chili pepper is visited by 41 species of arthropods consisting of 14 species of pests and natural enemies, 12 species of visitors, and 1 species of pollinator (Kaur & Sangha, 2016).

The diversity of arthropods in freshwater swamps is also supported by the existence of wild flowering weeds or non-crop plants like refugia grown surrounding the rice field. These plants provide niche, additional food, and other resources for natural enemies of rice pests (Benvenuti & Bretzel, 2017; de Faria Lopes, Ramos, & de Almeida, 2017; Hassan, Pervin, Mondal, & Mala, 2016; McCabe, Loeb, & Grab, 2017; Zhu et al., 2015). Grassy rice fields in ecosystems have a higher number of arthropods than those in non-weed ecosystems (Hu et al., 2012). The existence of refugia, sunflower plants (*Helianthus annuus*), indian mustard (*Brassica juncea*), sesame (*Sesamum indicum*), marigold (*Tagetes erecta*), yellow ray flower (*Cosmos caudatus*), and Zinnia (*Zinnia* sp.) is known to be effective in reducing the attack of leaf-rolling pests (*Cnaphalocrocis medinalis*) on several rice varieties in India (Desai, Swaminathan, & Desai, 2017). Marigold is reported to be associated with several species of predatory arthropods such as *Oxyopes javanus*, *Coccinella septumpunctata*, *Syrphus* spp., and *Geocoris* spp. (Ganai et al., 2017). Zinnia is also reported to be associated with several species of spiders, including *Argiope aemula*, *Oxyopes* sp., and *Perenethis* sp. (Desai, Swaminathan, & Desai, 2017). Thus, vegetables and refugia are actually beneficial as habitat and niche for entomophagous arthropods (parasitoid and predatory arthropods) which act as natural enemies of insect pests. There is little information available the entomophagous arthropods that are associated with vegetables and refugia in freshwater swamps of South Sumatra. This study aimed to identify the species of entomophagous arthropods of rice insect pests and to analyze their abundance and community in adaptively grown vegetables and refugia in freshwater swamps in South Sumatra, Indonesia.

MATERIALS AND METHODS

The field experiment was carried out in the center of freshwater swamps at the village of Pelabuhan Dalam of Pemulutan Subdistrict, the district of Ogan Ilir, South Sumatra, Indonesia from May to September 2018. The area of the rice field covers around 7.1 Mha. The species identification was carried out in the laboratory from September 2018 to May 2019.

Rice, Vegetables, and Refugia Planting

The rice plot area used was 1 ha, surrounded by 4 species of refugia and 4 vegetable species with the distance between plots was around 100 m. One hectare of plot area was divided into three sub-plots and used as replications. Each rice subplot was surrounded by 4 species of refugia (*Zinnia* sp., *T. erecta*, *C. caudatus*, and *S. indicum*), as well as other rice subplots were surrounded by 4 vegetable species (*V. unguiculata*, *M. charantia*, *C. sativus*, and *L. acutangula*). This research used the randomized block design. The position of 4 refugia species or the 4 species of vegetables in each rice sub-plot was in four embankments surrounding the sub-plot, and each embankment was planted with one plant species. In consequence, the four embankments surrounding the rice subplots were planted with different species of refugia or vegetables. The plant spacing of vegetables followed the habit of the local farmers (30 cm); meanwhile, the refugia were planted closer (15 cm) and containing 5 seeds per hole. So, the density of vegetables and refugia were 9 hills/m^2 and 21 hill/m^2, respectively these arrangement gave entomophagous arthropods alternative of habitats aside from rice. The refugia and vegetables were planted 30 days prior to rice and these would bring the plants in flowering stage when the rice still in vegetative phase (14 days after transplanting, DAT). The rice seeds were sown according to the traditions of local farmers, using the "Samir" method, i.e., the seeds of 7-10 days old were transplanted into the field. The rice was planted according to planting system of 2:1 "jajar legowo" with the planting distance of 50 cm x 25 cm x 12.5 cm. Manure with the dosage of 1 t/ha, 2 l extract of liquid compost (Suwandi, Ammar, & Irsan, 2012) and no synthetic pesticide were given during the rice culture. The rice was transplanted in the same time with soil preparation and the application of manure. When the rice plant was in 2 weeks after transplanting, the fertilization was applied using extract liquid compost (Bahua & Gubali, 2020) every 2 weeks.

Sampling the Arboreal Arthropods Inhabiting Refugia and Vegetables

Arthropod sampling that was inhabiting refugia and vegetables surrounding the rice field was conducted once a week started from 14 to 84 DAT of the rice. In every observation, the sampling was carried out twice, at 07:00 to 08:00 am and at 04:00 to 05:00 pm. The sampling was carried out by randomly picking 5 flowers for each species of refugia and vegetables. The flowers were collected and put in a 150 ml plastic container (Ø = 7 cm and height = 6.5 cm) perforated on the lid with a diameter of 2 cm and covered with gauze glued together. Each flower was put in separate container and labelled. The flowers were incubated and observed until the arthropods were released from the flower. The arthropods were put into a 10 ml glass bottle containing 80% ethanol. The glass bottles containing arthropods were labeled and the arthropods were identified in Laboratory of Entomology, Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Sriwijaya. The identification of spiders was based to Barrion & Litsinger (1995) and the identification of insects was referred to Heinrichs (1994), Kalshoven (1981), and McAlpine et al. (1987).

The Sampling of Arboreal Arthropods in Rice Plants

Observation of the arthropods was conducted weekly started when the rice in 14 to 84 DAT. The sampling of the arboreal arthropods for the observations used nets (net handle length = 100 cm, net length = 75 cm, and net Ø = 30 cm) at five points arranged diagonally at the rice plot for each subplot (3 subplots as a repetition). The sampling was carried out at 06.00 to 07.00 am when the weather was in mild conditions and no rain. The arthropods collection with nets was carried out following the method of Janzen & Schoener (1968) with modification, i.e. the arthropods were collected by swinging a net of one double swing in a straight line in 30 cm depth in the canopy of the plants. The net coverage was based on the modified methods of Masika, Masanza, Aluana, Barrigossi, & Kizito (2017) by swinging a net that tied on a plant stem. The nets were intentionally applied on the rice stem to obtain the insects on the stems and leaves of the rice plants. The obtained arthropods were sorted, put into the vial bottles containing 80% ethanol, labeled, and then identified in the laboratory. The identification of the spiders referred to Barrion & Litsinger (1995), and identification of insects referred to Heinrichs (1994), Kalshoven (1981), and McAlpine et al. (1987).

Data Analysis

The data on species composition and abundance of entomophagous arthropods inhabiting refugia and vegetables were recorded. Their subsequent abundance data were also grouped according to the guild, i.e. predator, parasitoid, herbivore, and neutral insect. Correspondence analysis was used to investigate how species of arthropods and plants (refugia, vegetables, and rice) were grouped based on how they interacted with (Raffaelli & Hall, 1992) the analyzed species data were grouped into species community of predators, parasitoid, herbivore, and neutral insects. The calculation of correspondence analysis used the software of SAS University Edition 2.7 9.4 M5.

RESULTS AND DISCUSSION

Species Composition of Arboreal Entomophagous Arthropods

Arboreal entomophagous arthropods are arthropods that act as predators and parasitoids for natural enemies of insect pests. In this study, the arboreal entomophagous arthropods found in rice were grouped into predatory arthropods and parasitoids. Predatory arthropods consisted of spiders and predatory insects groups, while parasitoid was a group of insects that act as parasite to insects or other arthropods. The total number of predatory and parasitoids species were 67 species from 21 families (Table 1) and 22 species from 17 families (Table 2), respectively.

Table 1. Families of predatory arthropods found in rice, refugia, and vegetables

NO	Class/ Ordo/ Family	Habitat (individual/net or individual/flower)								
		A	B		C	D	F	G	H	I
	Arachnida	1.88	0.32	0.18	0.08	0.02	0.06	0.08	0	0
	Araneae	1.88	0.32	0.18	0.08	0.02	0.06	0.08	0	0
1.	Lycosidae	0.04	0	0	0	0	0	0	0	0
2.	Araneidae	0.13	0.03	0.04	0.02	0	0	0	0	0
3.	Tetragnathidae	1.34	0.04	0.01	0.01	0	0.04	0.02	0	0
4.	Linyphiidae	0.12	0.01	0.04	0	0	0	0.01	0	0
5.	Oxyopidae	0.12	0.1	0.01	0.03	0.01	0	0.02	0	0
6.	Theridiidae	0.01	0	0.01	0	0	0	0	0	0
7.	Thomisidae	0	0	0.03	0	0	0	0.02	0	0
8.	Salticidae	0.1	0.14	0.04	0.02	0.01	0.02	0.01	0	0
9.	Hahniidae	0.02	0	0	0	0	0	0	0	0
	Insecta	0.86	0.06	0	0.02	0.02	0.02	0.04	0.09	0.05
	Hemiptera	0.04	0	0	0	0	0	0	0	0
10.	Miridae	0.04	0	0	0	0	0	0	0	0
	Coleoptera	0.71	0.06	0	0.02	0.02	0	0.04	0.09	0.05
11.	Carabidae	0.01	0	0	0	0	0	0	0	0
12.	Staphylinidae	0.18	0.04	0	0	0.01	0	0	0	0.01
13.	Coccinelidae	0.5	0.01	0	0.02	0.01	0	0.03	0.09	0.04
14.	Elateridae	0.01	0	0	0	0	0	0	0	0
15.	Anthicidae	0.01	0.01	0	0	0	0	0.01	0	0
	Odonata	0.06	0	0	0	0	0	0	0	0
16.	Coenagrionidae	0.05	0	0	0	0	0	0	0	0
17.	Libellulidae	0.01	0	0	0	0	0	0	0	0
	Orthoptera	0.02	0	0	0	0	0	0	0	0
18.	Tettigonidae	0.02	0	0	0	0	0	0	0	0
	Hymenoptera	0.01	0	0	0	0	0.02	0	0	0
19.	Formichidae	0.01	0	0	0	0	0.02	0	0	0
	Diptera	0.01	0	0	0	0	0	0	0	0
20.	Syrphidae	0.01	0	0	0	0	0	0	0	0
	Mantodea	0.01	0	0	0	0	0	0	0	0
21.	Mantidae	0.01	0	0	0	0	0	0	0	0
		2.74	0.38	0.18	0.1	0.04	0.08	0.12	0.09	0.05
		51	15	14	7	4	5	9	5	4

Remarks: A = rice; B = *Zinnia* sp.; C = *Tagetes erecta*; D = *Cosmos caudatus*; E = *Sesamum indicum*; F = *Vigna unguiculata*; G = *Momordica charantia*; H = *Cucumis sativus*; I = *Luffa acutangula*

Table 2. Families of parasitoid found on rice, refugia, and vegetables

No.	Class/ Ordo/ Family	Habitat (individual/net or individual/flower)								
		A	B	C	D	E	F	G	H	I
	Insecta	0.37	0.15	0.05	0.02	0.06	0.03	0.13	0.01	0.04
	Hymenoptera	0.34	0.13	0.02	0	0.01	0.01	0.08	0.01	0.02
1.	Ichneumoidae	0.01	0	0	0	0	0	0	0	0
2.	Eulophidae	0.02	0.03	0	0	0	0	0.01	0	0
3.	Scelionidae	0	0	0.01	0	0	0	0	0	0
4.	Braconidae	0.13	0.07	0.01	0	0	0.01	0.05	0.01	0
5.	Trichogrammatidae	0	0	0	0	0	0	0.01	0	0
6.	Perilampidae	0.01	0	0	0	0	0	0.01	0	0.01
7.	Ceraphronidae	0.04	0.02	0	0	0	0	0	0	0.01
8.	Pamphiliidae	0.02	0	0	0	0	0	0	0	0
9.	Encyrtidae	0.02	0	0	0	0	0	0	0	0
10.	Eupelmidae	0.01	0.01	0	0	0	0	0	0	0
11.	Heloridae	0.02	0	0	0	0	0	0	0	0
12.	Ptreromalidae	0.03	0	0	0	0.01	0	0	0	0
13.	Chalcididae	0.01	0	0	0	0	0	0	0	0
14.	Eurytomidae	0.02	0	0	0	0	0	0	0	0
	Diptera	0.03	0.02	0.03	0.02	0.05	0.02	0.05	0	0.02
15.	Tachinidae	0.02	0.01	0.02	0.02	0.05	0.02	0.04	0	0.01
16.	Cryptochetidae	0	0.01	0.01	0	0	0	0	0	0
17.	Sarcophagidae	0.01	0	0	0	0	0	0.01	0	0.01
	Total Abundance (N)	0.37	0.15	0.05	0.02	0.06	0.03	0.13	0.01	0.04
	Number of Species (S)	19	7	4	1	2	2	6	1	4

Remarks: A = rice; B = *Zinnia* sp.; C = *Tagetes erecta*; D = *Cosmos caudatus*; E = *Sesamum indicum*; F = *Vigna unguiculata*; G = *Momordica charantia*; H = *Cucumis sativus*; I = *Luffa acutangula*

In rice field, the number of predatory arthropods species was dominant (51 species) compared to refugia and vegetables. In refugia, the predatory arthropods were merely found in *Zinnia* sp. (15 species) and *M. charantia* (9 species) on vegetables. While, the less preferred habitat of predatory arthropods was observed in *S. indicum* (refugia) and *L. acutangula* (vegetable). There are five species that were observed dominant in rice, i.e. *Tetragnatha javana*, *Tetragnatha virescens*, *Tetragnatha mandibulata*, *Paederus fuscipes*, and *Micraspis inops*. Four of the said species (*T. javana*, *T. virescens*, *T. mandibulata*, and *P. fuscipes*) were found in *Zinnia* sp. and only two species, i.e. *T. virescens* and *M. inops* were observed in *M. charantia*. Aside from the five species, several minor predatory arthropods were also in rice, refugia, and vegetables, like *O. javanus*, *Oxyopes matiensis*, *Menochilus sexmaculatus*, and *Coccinella septempunctata*.

The arboreal predatory arthropods species in rice, refugia, and vegetables found in this study were the important predators attacking insect pests of rice. *T. javana*, *T. virescens*, and *T. mandibulata* belong to the spider family of Tetragnathidae and they can prey on the insects pest from Homoptera and Lepidoptera in rice (Tahir & Butt, 2009). Betz & Tscharntke (2017) stated that the Tetragnathidae also preys on Homoptera (leafhoppers). *P. fuscipes* is reported to be a predator of *Nilaparvata lugens* (Meng et al., 2016), and *M. inops* is an insect pest of rice generalist predator (Karindah, Yanuwiadi, Sulistyowati, & Green, 2011). *O. javanus* effectively preys on *Hieroglyphus banian*, *Sogetella furcilera*, *Marasmia patnalis*, and *Scripophaga innotata* (Tahir & Butt, 2009). *T. virescens* effectively controls *S. furcifera* (Prasad, Prabhu, & Balikai, 2010). Coccinellidae preys on *N. virescens*, *N. lugens*, and *S. furcifera* (Shanker et al., 2018).

Number parasitoid species were merely found in rice (19 species) compared to refugia and vegetables. In refugia the highest parasitoid was found in *Zinnia* sp. (7 species), *M. charantia* (6 species) in vegetables (Table 2). The most abundant parasitoids found in rice were *Cardiochiles* sp. (0.09 individual/flower), and this species was also found in *Zinnia* sp. (0.04 individual/flower), *M. charantia* (0.05 individual/flower), and *C. sativus* (0.01 individual/flower). *Cardiochiles* sp. was reported to be an effective parasitoid for *C. medinalis* control in rice (Behera, 2012). Aside from the *Cardiochiles* sp., several parasitoids were also observed in Zinnia and *M. charantia*. Existed in Zinnia, *Snellenius* sp. was reported to be a parasitoid of *Spodoptera litura* larvae (Javier & Ceballo, 2018) and *Elasmus* sp. was a parasitoid of *Dominulus polystes* (Gumovsky, Rusina, & Firman, 2007). *Blondelia* sp. found in *M. charantia* generally attacked the Lepidoptera of the Geometridae family (Cutler, Gariepy, De Silva, & Hillier, 2015).

Between refugia and vegetables, the abundance of predatory arthropods was found higher in *Zinnia* sp., *T. erecta*, and *M. charantia*. At the same time, parasitoid was higher in *Zinnia* sp., *S. indicum*, and *M. charantia* (Fig. 1). Refugia and vegetables were preferred by both entomophagous arthropods because of their morphological features with a long flower opening (Jennings, Longcore, & Bird, 2017), and the availability of floral nectar and pollen (Eggs & Sanders, 2013; Foti et al., 2017). The yellow petal of *T. erecta*, *S. indicum*, and *M. charantia* was seemed to be an important factor of the entomophagous arthropods settlement (Fig. 2). These findings was in line with the report of Rocha-Filho & Rinaldi (2011), that yellow flower was merely preferred compared to white and pink flowers. Having red petals, *Zinnia* sp. was also found to be preferred due to its longest blooming period (23.67 days) compared to other planted refugia and vegetable crops (Wahocho, Miano, Memon, & Wahocho, 2016). The flower shape was also determined the arthropods preference. The rossete flower shape of *Zinnia* sp., *T. erecta* and *M. charantia* were reported to have high attraction for predator and parasitoid, thus longer to be visited by arthropods (Jennings, Longcore, & Bird, 2017). Pollen and nectar of the refugia and vegetable flowers also become other beneficial factor for arthropods, like spiders (Eggs & Sanders, 2013) and parasitoids (Foti et al., 2017) to stay longer.

The visiting periods between predators and parasitoids were also different. Predators, especially spiders, usually found in refugia and vegetables at 7-8 am and 4-5 pm (Fig. 3). While, the parasitoid generally visited the flowers at 7 am to 8 pm (Fig. 4).

Zinnia sp., *T. erecta*, and *M. charantia* were visited by the predators in the morning and evening, and more often than other refugia or vegetable species. This is related to the longer flower opening period in *Zinnia* sp. Predators generally visit refugia and vegetables in the morning and evening since it is related with the existence of preys. The duration needed by the predators for hunting their preys is more longer than those needed by the parasitoids, for example, spider periods of predation ranging from 5 a.m. to 10 p.m. (Arango, López-Portillo, Parra-Tabla, Hernàndez-Salazar, & Rico-Gray, 2012), but the parasitoid generally visited the plants in the morning and these related with the period of flower opening. Most of refugia and vegetables flowers open in the morning and the opening flower is an indication of nectar and pollen availability. According to Schmidt, Orosz-Kovács, & Farkas (2012), parasitoids feed flower nectar and pollen in the morning. Thus, the existence of refugia and vegetables around the rice field is useful in providing alternative habitat and niche for the parasitoid and predator of rice pest insects.

The Community of Arboreal Arthropods in One Rice Growing Season

Arthropods can be grouped into the guilds, i.e., predators, parasitoids, herbivores, and neutral insects. The data showed that predators and parasitoids were commonly found in all planted refugia species. While in all vegetables species, the parasitoids and herbivores were more dominant. In rice, the herbivores were more dominant, followed by predators and the developing herbivore population. The predators played a role in suppressing herbivores compared to the parasitoid population in rice (Herlinda et al., 2018; Settle et al., 1996). Since the herbivore is the predators prey, then the higher the herbivore population would induce the increase of the predators.

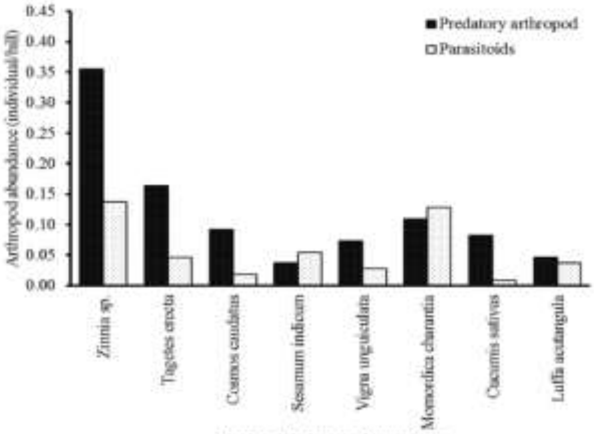


Fig. 1. Abundance of predatory arthropods and parasitoids inhabiting refugia and vegetables

Fig. 2. Flower of refugia and vegetables: zinnia (a), marigold (b), **yellow ray flower** (c), sesame (d), cowpea (e), bitter melon (f), cucumber (g), ridged gourd (h)

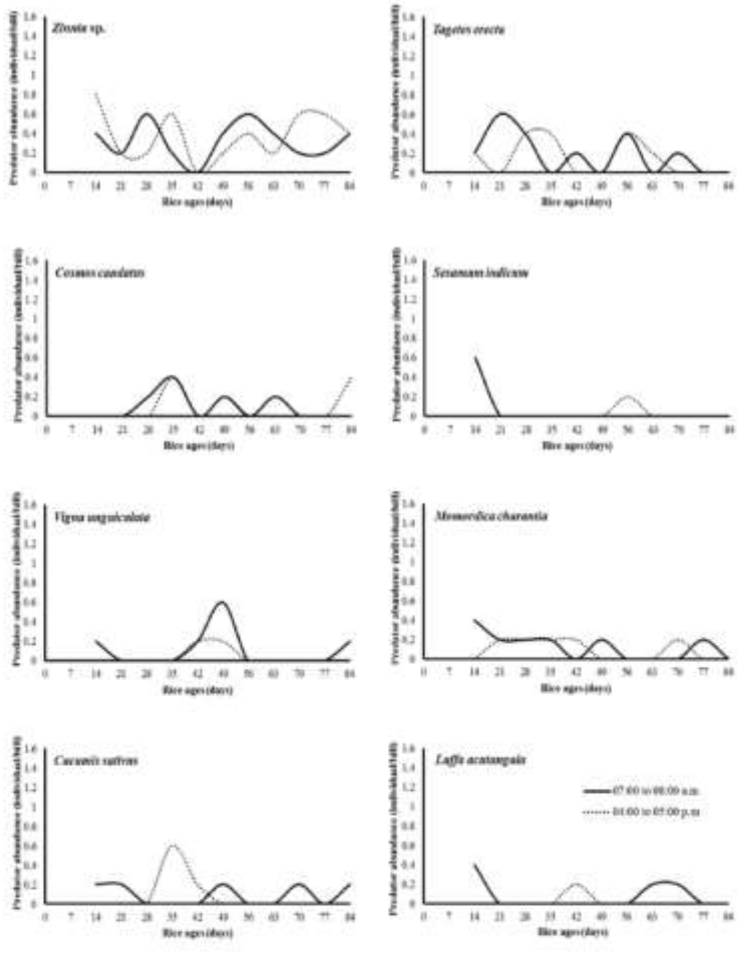


Fig. 3. Predatory abundance found on refugia and vegetables in the period of 14-84 days after rice transplanting

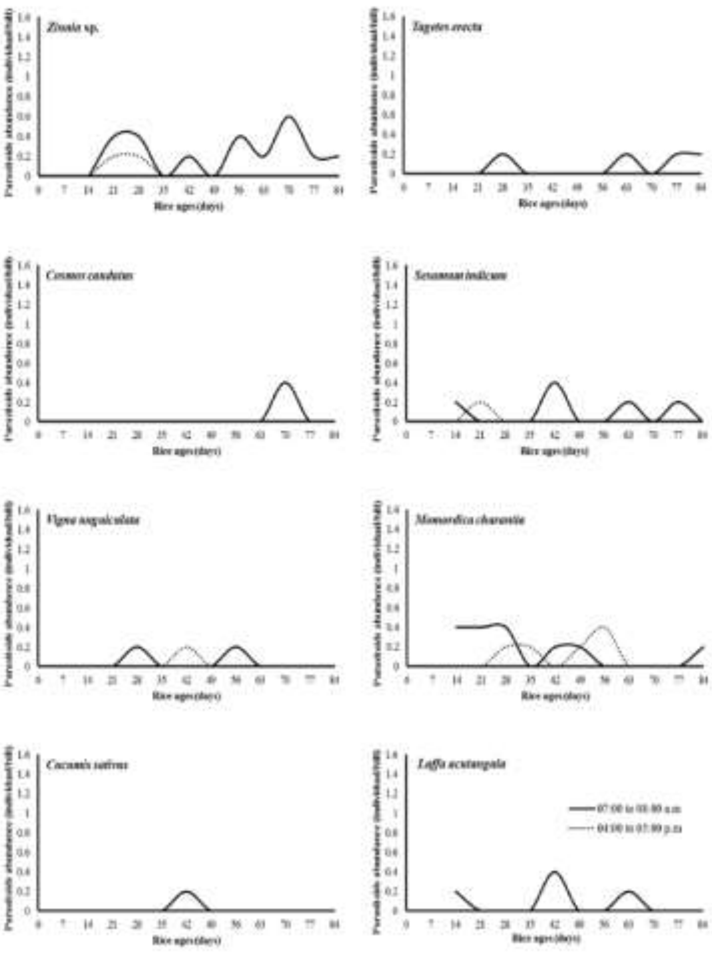


Fig. 4. Parasitoid abundance found on refugia and vegetables in the period of 14-84 days after rice transplanting or during a rice season

An interesting phenomenon was found in refugia, especially in *Zinnia* sp. Parasitoids and predators were found more abundant at the beginning of rice growth stage. At the same time, when the rice was at 35 DAT, the population of both entomophagous arthropods at *Zinnia* sp. began to decrease. In contrast, in the early rice planting, the parasitoid population began to increase at 42 DAT, and the predator began to increase at 21 DAT. According to Settle et al. (1996) the population of arthropods in rice is affected by the movement of the entomophagous arthropods from non-crop plants and vegetables to rice; and vice versa. This can occur if habitat and other niches are available around the rice fields that are appropriate for the arthropods.

When the rice was at the vegetative stage, the predatory arthropods inhabiting rice, vegetables, and refugia generally have the similar high community, except the arthropod that inhabits cowpea (Fig. 5a). The predatory arthropods gathered from these plants include *Pardosa pseudoannulata*, *Cyrtophora koronadalensis*, and *Neoscona theisi* that were categorized as hunting spiders. Species composition in rice, refugia, and vegetables had high similarity based on the observation on predatory arthropods migration from from rice to vegetables and refugia or vice versa. Their movement was caused by the herbivores inhabited in rice, such as *N. lugens*, *Sogatella furcifera*, and *Spodoptera* sp. (Fig. 5c) which were the main prey for the predatory arthropods, including their alternative preys like neutral insect, such as *Tetanocera* sp., *Tipula maxima*, and *Psorophora* sp. (Fig. 5d).

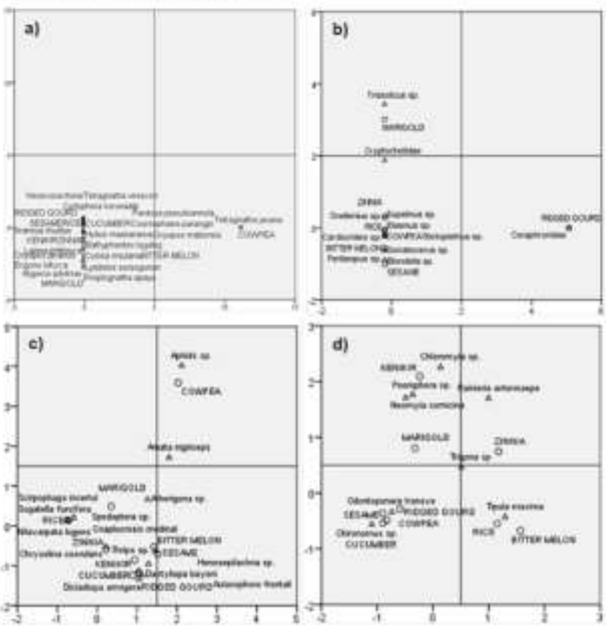


Fig. 5. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice vegetative stage; arthropods (o); plant (Δ)

The parasitoid species composition in rice was highly similar to the parasitoid in Zinnia sp. and bitter melon (Fig 5b) indicating that Zinnia and bitter melon were also preferred by parasitoids as habitat and alternative niche. In line with Settle et al. (1996), the movement of spiders among habitats was due to generalist predators on hunting prey in alternative habitat. The species of parasitoid composition in rice were generally similar to those in the vegetable and refugia species, except those that inhabiting marigolds and ridged gourd. The species of neutral insects in rice were mostly similar to the neutral species in bitter melon.

When the rice was in the milky stage, the predatory arthropod species composition in rice was quite similar to the arthropods that inhabited in bitter melon, sesame, zinnia, yellow ray flower, and marigold. The recorded arthropod species in these plants were *Coccinella repanda*, *T. virescens*, **Bathyphantes tagalogensis**, and *O. javanus* (Fig. 6a). The parasitoid species composition inhabiting rice such as *Cardiochiles* sp. and *Sarcophagidae* (Fig. 6b) was quite similar to the parasitoid inhabiting cucumber and bitter melon. The herbivore composition species in rice were similar to those of herbivores inhabiting zinnia and marigolds, particularly *Leptocorisa acuta*. The species of herbivores found in rice were *N. lugens*, *S. furcifera*, and *L. acuta* (Fig. 6c). The predatory arthropods found in bitter melon, sesame, zinnia, yellow ray flower, marigold were the predators of *N. lugens*, *S. furcifera*, and *L. acuta* in rice. The neutral insect species (*Chironomus* sp. and *Tipula maxima*) (Fig. 6d) in rice and marigolds were prey for these predatory generalists.

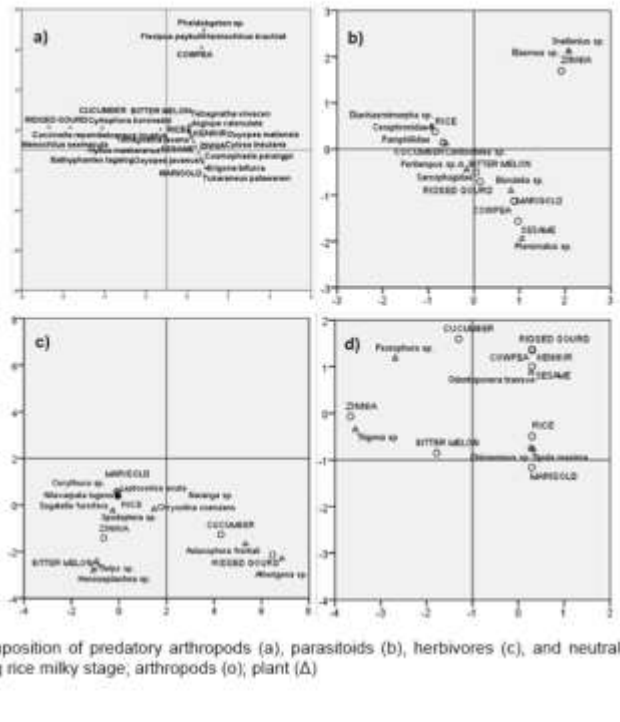


Fig. 6. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice milky stage; arthropods (o); plant (Δ)

Thus, the movement of species from refugia and vegetables to rice occur when the availability of preys in rice field was high for predatory generalists. This result is quite similar to Herlinda et al. (2018) and Settle et al. (1996). The parasitoid species composition in rice was more similar to that in bitter melon and zinnia. The results of this study also revealed that the predator and parasitoid of rice pests were also found in refugia and vegetables. The refugia species in that the predators and parasitoid were merely found was *Zinnia* sp. In vegetables, bitter melon were observed to give more conducive habitat for predators and parasitoids.

CONCLUSION

Among 4 species of refugia, *Zinnia* sp. had higher settlement of entomophagous arthropods as an alternative habitat in addition to rice. In vegetables, *M. charantia* was the most preferred habitat alternative for the entomophagous arthropods. *M. charantia* was considered more beneficial than *Zinnia* sp. for entomophagous arthropods the conservation. Aside from providing alternative habitat and niche for the entomophagous arthropods, *M. charantia* also increased land productivity.

ACKNOWLEDGEMENT

This research was financially supported by the Program of Professor Research Grant (Penelitian Unggulan Profesi Profesor) of Universitas Sriwijaya, Indonesian Ministry of Research, Technology and Higher Education, the Republic of Indonesia with a 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, Indonesian Ministry of Research, Technology, and Higher Education that has given a scholarship for Tili Karenina, a postgraduate student.

REFERENCES

Arango, A. M., López-Portillo, J., Parra-Tabla, V., Hernández-Salazar, L. T., & Rico-Gray, J. E. M. M. (2012). Effect of the spider *Peucetia viridans* (oxyopidae) on floral visitors and seed set of *Cnidoscolus multilobus* (euphorbiaceae). *Acta Botanica Mexicana, 100*, 1–14. Retrieved from http://www.scielo.org.mx/scielo.php?script=sci_abstract&pid=S0187-71512012000300001&lng=es&nrm=iso&tlng=en

Bahua, M. I., & Gubali, H. (2020). Direct seed planting system and giving liquid organic fertilizer as a new method to increase rice yield and growth (*Oryza sativa* L.). *AGRIVITA Journal of Agricultural Science, 42*(1), 68-77. https://doi.org/10.17503/agrivita.v42i1.2324

Baptiste, A. K., & Smardon, R. (2012). A review of wetland use and management of the Nariva Swamp, Trinidad. *Caribbean Geography, 17*(1&2), 73–91. Retrieved from https://www.researchgate.net/publication/273001155_A_review_of_wetland_use_and_management_of_the_Nariva_SwampTrinidad

Barrion, A. T., & Litsinger, J. A. (1995). *Riceland spiders of South and Southeast Asia.* Wallingford, UK: CAB International; Manila, Philippines: International Rice Research Institute. Retrieved from https://trove.nla.gov.au/work/21883244?q&versionId=46512183

Behera, K. S. (2012). Biology of *Cardiochiles nigricollis* Cameron, a Larval Endo-parasitoid of *Cnaphalocrocis medinalis* (Guen.) and Marasmia exigua Butler. *Journal of Biological Control, 26*(4), 376–379. Retrieved from http://www.informaticsjournals.com/index.php/jbc/article/view/3485

Benvenuti, S., & Bretzel, F. (2017). Agro-biodiversity restoration using wildflowers: What is the appropriate weed management for their long-term sustainability? *Ecological Engineering, 102*, 519–526. https://doi.org/10.1016/j.ecoleng.2017.02.062

Betz, L., & Tscharntke, T. (2017). Enhancing spider families and spider webs in Indian rice fields for conservation biological control, considering local and landscape management. *Journal of Insect Conservation, 21*, 495–508. https://doi.org/10.1007/s10841-017-9990-2

Bhaskar, B. P., Baruah, U., Vadivelu, S., Raja, P., & Sarkar, D. (2010). Remote sensing and GIS in the management of wetland resources of Majuli Island, Assam, India. *Tropical Ecology, 51*(1), 31–40. Retrieved from http://www.tropecol.com/pdf/open/PDF_51_1/Jour.05.pdf

Bodlah, I., & Waqar, M. (2013). Pollinators visiting summer vegetables ridge gourd (*Luffa acutangula*), bitter gourd (*Momordica charantia* L.) and brinjal (*Solanum melongena*). *Asian Journal of*

Agriculture and Biology, *1*(1), 8–12. Retrieved from https://www.asianjab.com/pollinators-visiting-summer-vegetables-ridge-gourd-luffa-acutangula-bitter-gourd-momordica-charantia-l-and-brinjal-solanum-melongena/

Cutler, G. C., Gariepy, T. D., De Silva, E. C. A., & Hillier, N. K. (2015). High rates of parasitism of blueberry spanworm (Lepidoptera: Geometridae) by Ichneumonidae and Tachinidae in commercial lowbush blueberry fields. *Journal of Pest Science*, *88*, 219–223. https://doi.org/10.1007/s10340-015-0650-6

de Faria Lopes, S., Ramos, M. B., & de Almeida, G. R. (2017). The role of mountains as refugia for biodiversity in Brazilian Caatinga: Conservationist implications. *Tropical Conservation Science*, *10*, 1–12. https://doi.org/10.1177/1940082917702651

Desai, S. D., Swaminathan, R., & Desai, V. S. (2017). Effect of habitat manipulation on infestation of paddy leaf folder, *Cnaphalocrocis medinalis* (Guenee). *International Journal of Current Microbiology and Applied Sciences*, *6*(10), 1469–1477. https://doi.org/10.20546/ijcmas.2017.610.174

Eggs, B., & Sanders, D. (2013). Herbivory in spiders: The importance of pollen for orb-weavers. *PLoS ONE*, *8*(11), e82637. https://doi.org/10.1371/journal.pone.0082637

Emile, T., Honorine, N., Thomas, N., & Marie-Anne, S. (2012). Vegetable production systems of swamp zone in urban environment in West Cameroon: Case of Dschang city. *Universal Journal of Environmental Research & Technology*, *2*(2), 83–92. Retrieved from https://www.environmentaljournal.org/2-2/ujert-2-2-9.pdf

Foti, M. C., Rostás, M., Peri, E., Park, K. C., Slimani, T., Wratten, S. D., & Colazza, S. (2017). Chemical ecology meets conservation biological control: Identifying plant volatiles as predictors of floral resource suitability for an egg parasitoid of stink bugs. *Journal of Pest Science*, *90*, 299–310. https://doi.org/10.1007/s10340-016-0758-3

Ganai, S. A., Ahmad, H., Sharma, D., Sharma, S., Khaliq, N., & Norboo, T. (2017). Diversity of arthropod fauna associated with marigold (*Tagetes erecta* L.) in Jammu. *Journal of Entomology and Zoology Studeis*, *5*(5), 1940–1943. Retrieved from http://www.entomoljournal.com/archives/2017/vol5issue5/PartY/5-5-193-255.pdf

Gumovsky, A., Rusina, L., & Firman, L. (2007). Bionomics and morphological and molecular characterization of *Elasmus schmitti* and *Baryscapus elasmi* (Hymenoptera: Chalcidoidea, Eulophidae), parasitoids associated with a paper wasp, *Polistes dominulus* (Vespoidea, Vespidae). *Entomological Science*, *10*(1), 21–34. https://doi.org/10.1111/j.1479-8298.2006.00195.x

Hanif, K.I., Herlinda, S., Irsan, C., Pujiastuti, Y., Prabawati, G., Hasbi, & Karenina, T. (2020). The impact of bioinsecticide overdoses of *Beauveria bassiana* on species diversity and abundance of not targeted arthropods in South Sumatra (Indonesia) freshwater swamp paddy. *Biodiversitas*, *21*(5), 2124-2136. https://doi.org/10.13057/biodiv/d210541

Hassan, K., Pervin, M., Mondal, F., & Mala, M. (2016). Habitat management: A key option to enhance natural enemies of crop pest. *Universal Journal of Plant Science*, *4*(4), 50–57. Retrieved from http://www.hrpub.org/journals/article_info.php?aid=5517

Heinrichs, E. A. (1994). *Biology and management of rice insects*. International Rice Research Institute. Retrieved from https://books.google.co.id/books/about/Biology_and_Management_of_Rice_Insects.html?id=wOtMTN2zcNYC&redir_esc=y

Herlinda, S., Yudha, S., Thalib, R., Khodijah, Suwandi, Lakitan, B., & Verawaty, M. (2018). Species richness and abundance of spiders inhabiting rice in fresh swamps and tidal lowlands in South Sumatra, Indonesia. *Journal of the International Society for Southeast Asian Agricultural Sciences*, *24*(1), 82–93. Retrieved from https://www.cabdirect.org/cabdirect/abstract/20183221277

Hossain, M., Yeasmin, F., Rahman, M., Akhtar, S., & Hasnat, M. (2018). Role of insect visits on cucumber (*Cucumis sativus* L.) yield. *Journal of Biodiversity Conservation and Bioresource Management*, *4*(2), 81–88. https://doi.org/10.3329/jbcbm.v4i2.39854

Hu, S., Fu, D., Liu, X., Zhao, T., Han, Z., Lü, J., ... Ye, H. (2012). Diversity of planthoppers associated with the winter rice agroecosystems in Southern Yunnan, China. *Journal of Insect Science*, *12*, 29. https://doi.org/10.1673/031.012.2901

Janzen, D. H., & Schoener, T. W. (1968). Differences in insect abundance and diversity between wetter and drier sites during a tropical dry season. *Ecology*, *49*(1), 96–110. https://doi.org/10.2307/1933565

Javier, A. M. V., & Ceballo, F. A. (2018). Life history and biological control potential of *Snellenius manilae* ashmead (Hymenoptera: Braconidae), a parasitoid of *Spodoptera litura* fabricius (Lepidoptera: Noctuidae). *Philippine Agricultural Scientist, 101*(2), 148–157.

Jennings, D. T., Longcore, J. R., & Bird, J. E. (2017). Spiders (Araneae) inhabit lepidopteran-feeding shelters on ferns in Maine, USA. *Journal of the Acadian Entomological Society, 13*, 5–14. Retrieved from https://acadianes.org/journal/papers/jennings_16-3.pdf

Kalshoven, L. G. E. (1981). *Pests of crops in Indonesia*. (P. A. van der Laan & G. H. L. Rothschild, Eds.). Jakarta: PT. Ichtiar Baru : Van Hoeve. Retrieved from https://www.worldcat.org/title/pests-of-crops-in-indonesia/oclc/964210647

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*(8), 2375-2387. https://doi.org/10.13057/biodiv/d200836

Karindah, S., Yanuwiadi, B., Sulistyowati, L., & Green, P. T. (2011). Abundance of *Metioche vittaticollis* (Orthoptera: Gryllidae) and natural enemies in a rice agroecosystem as influenced by weed species. *AGRIVITA Journal of Agricultural Science, 33*(2), 133–141. Retrieved from https://agrivita.ub.ac.id/index.php/agrivita/article/view/55

Kaur, G., & Sangha, K. (2016). Evaluation of yellow sticky trap shapes for capturing alate insects in chilli agroecosystem. *Journal of Insect Science, 29*(1), 67–72. Retrieved from http://www.insais.org/wp-content/themes/WTheme/manuscripts/48e59e109e03ff5ce71c8cdd0148809013.pdf

Lakitan, B., Alberto, A., Lindiana, L., Kartika, K., Herlinda, S., & Kurnianingsih, A. (2018). The benefits of biochar on rice growth and yield in tropical riparian wetland, South Sumatra, Indonesia. *Chiang Mai University Journal of Natural Sciences, 17*(2), 111–126. https://doi.org/10.12982/CMUJNS.2018.0009

Lakitan, B., Lindiana, L., Widuri, L. I., Kartika, K., Siaga, E., Meihana, M., & Wijaya, A. (2019). Inclusive and ecologically-sound food crop cultivation at tropical non-tidal wetlands in Indonesia. *AGRIVITA Journal of Agricultural Science, 41*(1), 23–31. https://doi.org/10.17503/agrivita.v40i0.1717

Margono, B. A., Bwangoy, J.-R. B., Potapov, P. V., & Hansen, M. C. (2014). Mapping wetlands in Indonesia using landsat and PALSAR data-sets and derived topographical indices. *Geo-Spatial Information Science, 17*(1), 60–71. https://doi.org/10.1080/10095020.2014.898560

Masika, F. B., Masanza, M., Aluana, G., Barrigossi, A. F., & Kizito, E. B. (2017). Abundance, distribution and effects of temperature and humidity on arthropod fauna in different rice ecosystems in Uganda. *Journal of Entomology and Zoology Studies, 5*(5), 964–973. Retrieved from http://www.entomoljournal.com/archives/2017/vol5issue5/PartM/5-4-120-357.pdf

McAlpine, J. F., Petersen, B. V., Shewell, G. E., Teskey, H. J., Vockeroth, J. R., & Wood, D. M. (1987). *Manual of Neartic Diptera*. Canada: Research Branch Agriculture. Retrieved from https://books.google.co.id/books/about/Manual_of_Nearctic_Diptera.html?id=KzIIAQAAMAAJ&redir_esc=y

McCabe, E., Loeb, G., & Grab, H. (2017). Responses of crop pests and natural enemies to wildflower borders depends on functional group. *Insects, 8*(3), 73. https://doi.org/10.3390/insects8030073

Meng, J., Mabubu, J. I., Han, Y., He, Y., Zhao, J., Hua, H., ... Wu, G. (2016). No impact of transgenic cry1C rice on the rove beetle *Paederus fuscipes*, a generalist predator of brown planthopper *Nilaparvata lugens*. *Scientific Reports, 6*, 30303. https://doi.org/10.1038/srep30303

Niba, A. S. (2011). Arthropod assemblage dynamics on cowpea (*Vigna unguiculata* L. Walp) in a subtropical agro-ecosystem, South Africa. *African Journal of Agricultural Research, 6*(4), 1009–1015. Retrieved from https://academicjournals.org/journal/AJAR/article-full-text-pdf/D7DF9B637246

Prasad, R., Prabhu, S. T., & Balikai, R. A. (2010). Incidence of white backed plant hopper on rice and its predators under rainfed ecosystems and their correlation with weather parameters. *Research Journal of Agricultural Sciences, 1*(4), 322–326. Retrieved from http://delphacid.s3.amazonaws.com/6679.pdf

Raffaelli, D., & Hall, S. J. (1992). Compartments and predation in an estuarine food web. *The Journal of Animal Ecology, 61*(3), 551–560. https://doi.org/10.2307/5610

Rocha-Filho, L., & Rinaldi, I. (2011). Crab spiders (Araneae: Thomisidae) in flowering plants in a Brazilian "Cerrado" ecosystem. *Brazilian Journal of Biology, 71*(2), 359–364. https://doi.org/10.1590/s1519-69842011000300004

Schmidt, K., Orosz-Kovács, Z., & Farkas, Á. (2012). Nectar secretion dynamics in some raspberry and blackberry cultivars. *The International Journal of Plant Reproductive Biology, 4*(2), 147–150. Retrieved from https://www.researchgate.net/publication/233808478_Nectar_secretion_dynamics_in_some_raspberry_and_blackberry_cultivars

Settle, W. H., Ariawan, H., Astuti, E. T., Cahyana, W., Hakim, A. L., Hindayana, D., ... Sartanto. (1996). Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. *Ecology, 77*(7), 1975–1988. https://doi.org/10.2307/2265694

Shanker, C., Chintagunta, L., Muthusamy, S., Vailla, S., Srinivasan, A., & Katti, G. (2018). Flora surrounding rice fi elds as a source of alternative prey for coccinellids feeding on the pests of rice. *European Journal of Entomology, 115*, 364–371. https://doi.org/10.14411/EJE.2018.036

Siaga, E., Lakitan, B., Hasbi, Bernas, S. M., Wijaya, A., Lisda, R., ... Meihana, M. (2018). Application of floating culture system in chili pepper (*Capsicum annum* L.) during prolonged flooding period at riparian wetland in Indonesia. *Australian Journal of Crop Science, 12*(05), 808–816. https://doi.org/10.21475/ajcs.18.12.05.PNE1007

Susilawati, & Lakitan, B. (2019). Cultivation of common bean (*Phaseolus vulgaris* L.) subjected to shallow water table at riparian wetland in South Sumatra, Indonesia. *Australian Journal of Crop Science, 13*(01), 98–104. https://doi.org/10.21475/ajcs.19.13.01.p1298

Suwandi, Ammar, M., & Irsan, C. (2012). Aplikasi ekstrak kompos meningkatkan hasil dan menekan penyakit padi sistem ratun di sawah pasang surut kabupaten Banyuasin. *Jurnal Lahan Suboptimal, 1*(2), 116–122. Retrieved from http://www.jlsuboptimal.unsri.ac.id/index.php/jlso/article/view/15

Tahir, H. M., & Butt, A. (2009). Predatory potential of three hunting spiders inhabiting the rice ecosystems. *Journal of Pest Science, 82*, 217–225. https://doi.org/10.1007/s10340-008-0242-9

Wahocho, S. A., Miano, T. F., Memon, N. U. N., & Wahocho, N. A. (2016). Photoperiodic effect on vegetative growth and flower quality of Zinnia (*Zinnia elegans* Jacq.). *Sarhad Journal of Agriculture, 32*(4), 258–423. Retrieved from http://researcherslinks.com/current-issues/Photoperiodic-Effect-on-Vegetative-Growth-and-Flower-Quality-of-Zinnia-Zinnia elegans Jacq/14/1/259/html

Widuri, L. I., Lindiana, L., Kartika, K., Siaga, E., Meihana, M., Hasmeda, M., ... Lakitan, B. (2016). Identifikasi kebutuhan petani dan permasalahan budidaya sayuran di lahan rawa lebak menggunakan grounded theory. In *Prosiding Seminar Nasional Lahan Suboptimal 2016* (pp. 587–594). Palembang: PUR-PLSO Universitas Sriwijaya. Retrieved from http://pur-plso.unsri.ac.id/userfiles/71_ HAL 587-594 Laily-ilman-widuri-identifikasi-kebutuhan-petani-lahan-rawa-lebak.pdf

Zhu, P., Wang, G., Zheng, X., Tian, J., Lu, Z., Heong, K. L., ... Gurr, G. M. (2015). Selective enhancement of parasitoids of rice Lepidoptera pests by sesame (*Sesamum indicum*) flowers. *BioControl, 60*, 157–167. https://doi.org/10.1007/s10526-014-9628-1

5. Bukti tagihan untuk penerbitan artikel