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

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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,

2
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Tili Karenina et al.: *Arthropods Inhabiting Adaptive Vegetables and Refugia*.....

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, & Tab, 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 septempunctata*, *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/m² and 21 hill/m², 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 ($\varnothing = 7$ 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 $\varnothing = 30$ 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.

Tili Karenina *et al.*: *Arthropods Inhabiting Adaptive Vegetables and Refugia*.....**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.	Coccinellidae	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.	Formicidae	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.	Pteromalidae	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 & Tschamtker (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, Yanuwadi, Sulistyowati, & Green, 2011). *O. javanus* effectively

Tili Karenina et al.: *Arthropods Inhabiting Adaptive Vegetables and Refugia*.....

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, Garipey, 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, Hernández-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.

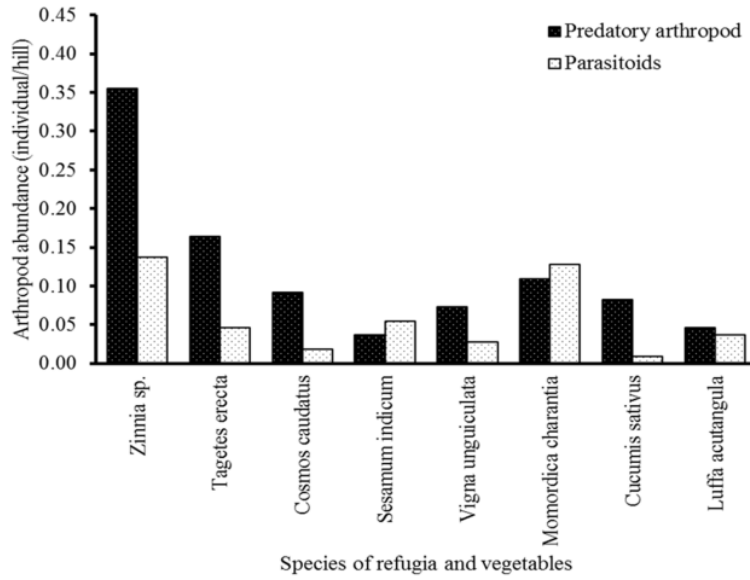


Fig. 1. Abundance of predatory arthropods and parasitoids inhabiting refugia and vegetables

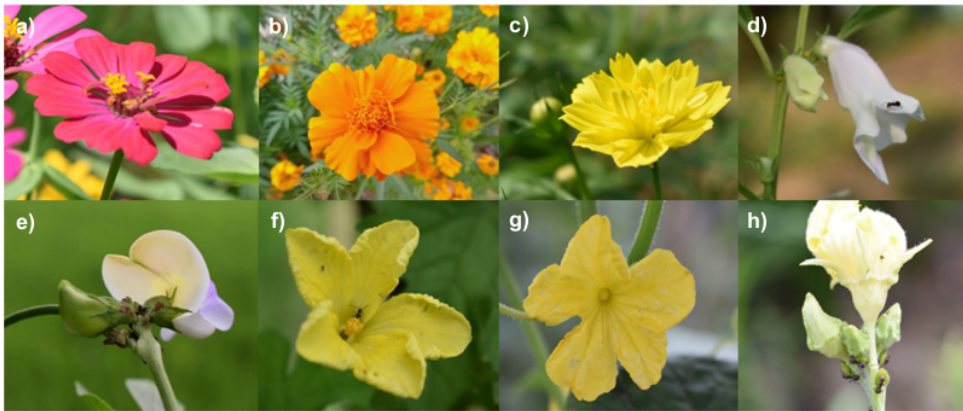


Fig. 2. Flower of refugia and vegetables: zinnia (a), marigold (b), yellow ray flower (c), sesame (d), cowpea (e), bitter melon (f), cucumber (g), ridged gourd (h)

Tili Karenina et al.: Arthropods Inhabiting Adaptive Vegetables and Refugia.....

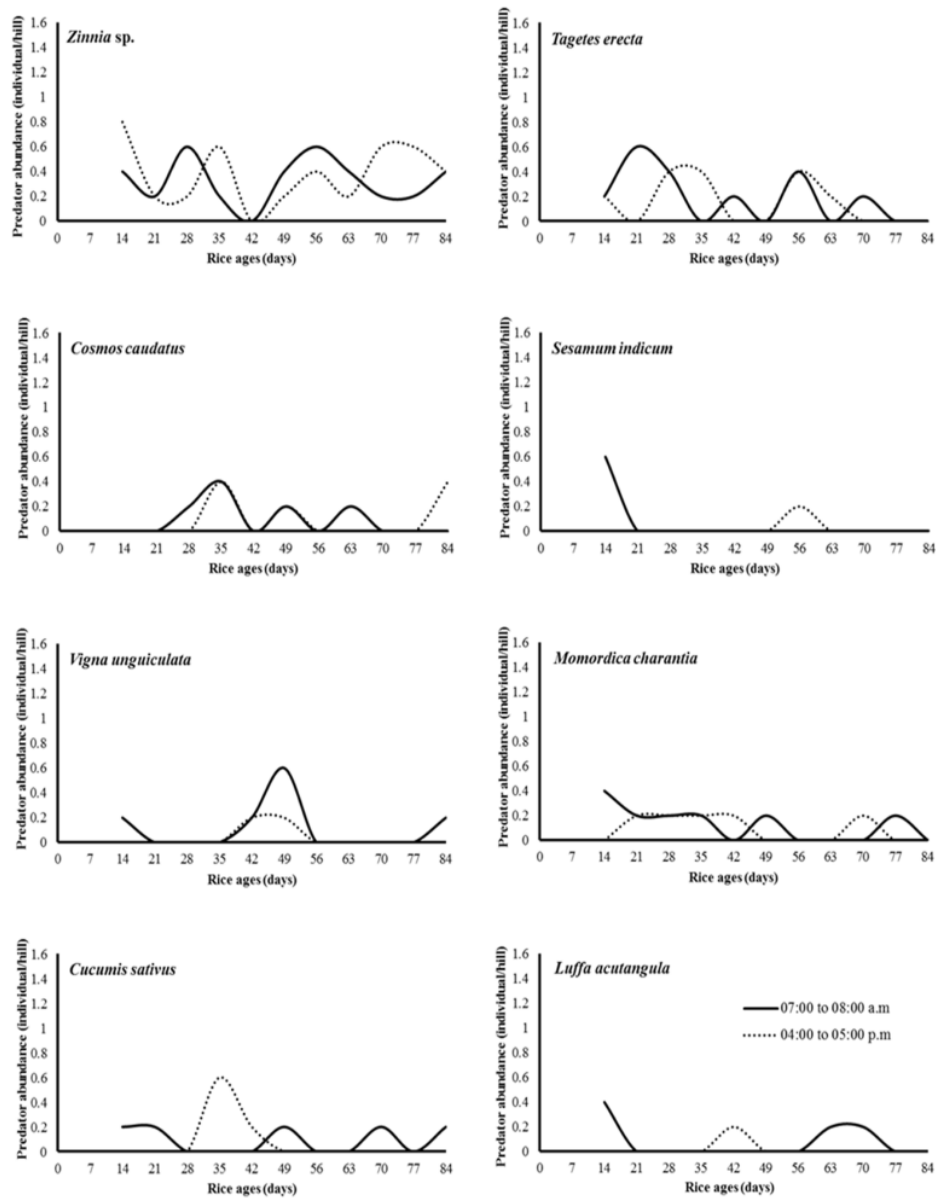


Fig. 3. Predatory abundance found on refugia and vegetables in the period of 14-84 days after rice transplanting

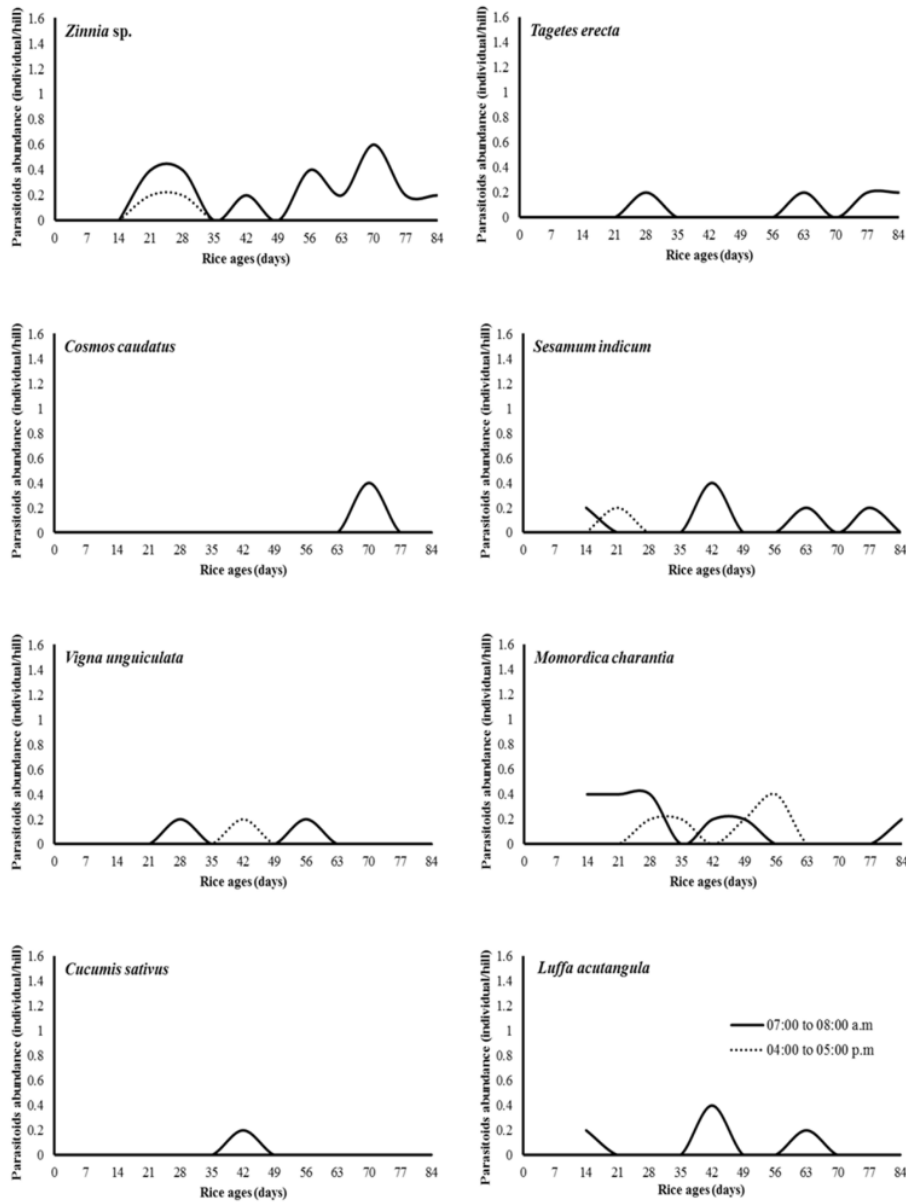


Fig. 4. Parasitoid abundance found on refugia and vegetables in the period of 14-84 days after rice transplanting or during a rice season

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).

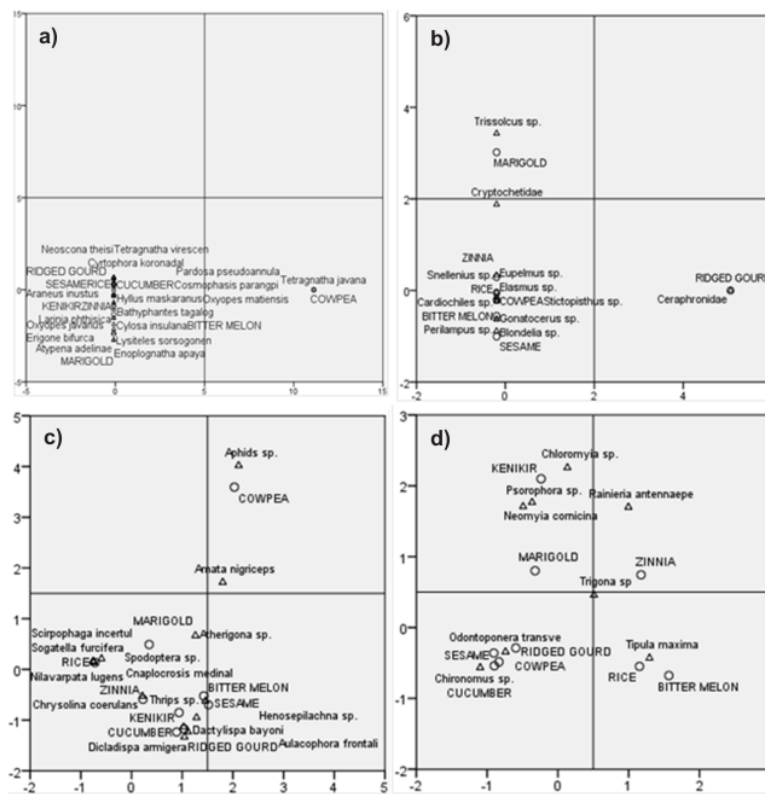


Fig. 5. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice vegetative stage; arthropods (o); plant (Δ)

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 *Leptocoris* *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.

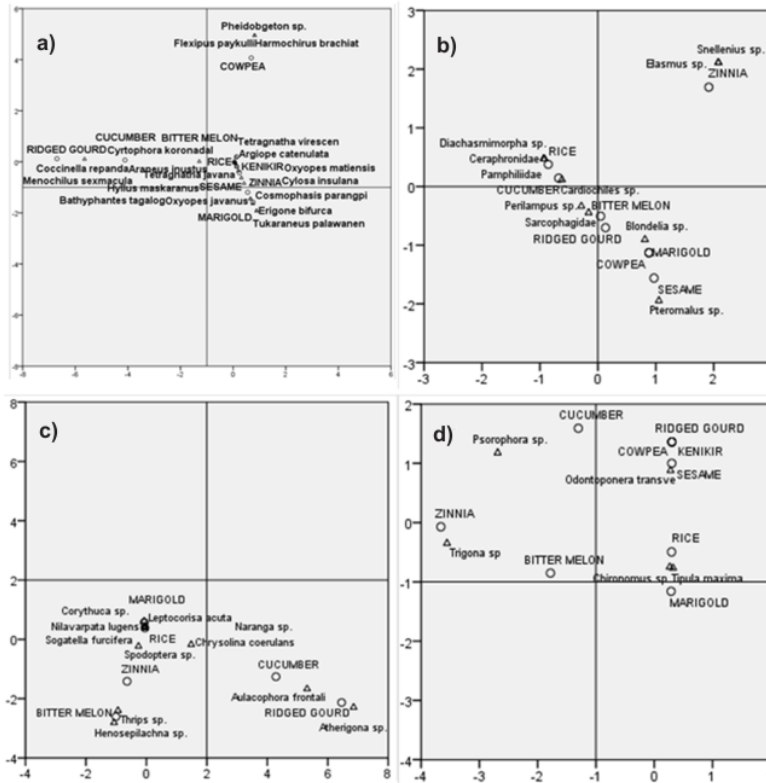


Fig. 6. Composition of predatory arthropods (a), parasitoids (b), herbivores (c), and neutral insects (d) found during rice milky stage; arthropods (o); plant (Δ)

Tili Karenina *et al.*: *Arthropods Inhabiting Adaptive Vegetables and Refugia*.....

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.

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