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Refugia effect on arthropods in an organic paddy field in Malang District, East Java, Indonesia

ZAINAL ABIDIN[1,2,♥], AMIN SETYO LEKSONO[2,♥♥], BAGYO YANUWIADI[2,♥♥♥], MANGKU PURNOMO[3,♥♥♥♥]

[1]Department of Agrotechnology, Faculty of Science and Technology, Universitas Islam Negeri Raden Rahmat. Jl. Mojosari 2, Malang 65163, East Java, Indonesia. Tel./fax.: +62-341-399099, ♥email: zainal.abidin@uniramalang.ac.id

[2]Departement of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia. Tel.: +62-341-554403, ♥♥email: amin28@ub.ac.id, ♥♥♥yanuwiadi60@ub.ac.id

[3]Departement of Socio-Economic, Faculty Agriculture, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia. Tel.: +62-341-580054, ♥♥♥♥email: mangku@ub.ac.id

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Abstract. *Abidin Z, Leksono AS, Yanuwiadi B, Purnomo M. 2020. Refugia effect toward arthropods in an organic paddy field in Malang District, East Java, Indonesia. Biodiversitas 21: 1415-1421.* This study aims to determine the abundance, community structure, and diversity of arthropod visitors of refugia in organic paddy fields in the Malang District of East Java, Indonesia. This research was conducted in 2019 from February to June and covered the stages from planting to harvest. The paddy fields were divided into 12 plots consisting of six refugia plots and six control plots. Sampling was carried out in two five-day phases, specifically in the vegetative phase (February) and the generative phase (June) of paddy plants. The results showed that 28.184 species consisting of nine orders and 40 families were observed. The abundance of common predator families, such as the Aleyrodidae, Formicidae, Libellulidae, and Tetragnatidae, in organic paddy. The average arthropod taxa richness in the refugia was 20.59 ± 12.24 species, while in the control it was 13.16 ± 8.95 species. Statistical analysis showed that the difference was significant ($p < 0.05$). The average arthropod diversity in the refugia was 2.39 ± 0.78 species, while in control was 2.35 ± 0.15 species. In conclusion, the population of arthropods was the highest in the refugia. Therefore, organic paddy surrounded by refugia with wild plants was the most appropriate habitat and niche for predatory arthropods.

Keywords: Arthropods, organic paddy, refugia effect

INTRODUCTION

Paddy is an important cereal crops in Asia and nearly 90 percent of the area production and consumption of paddy are confirmed to Southeast Asian countries (Parasappa et al. 2017). Indonesia is the third-largest producer of rice in the world, after China and India. Rice is an important food crop in Indonesia. It is the staple food of the Indonesian people, and the Indonesian food system has a high dependence on it (Azmi et al. 2014). In farming practice, farmers often use pesticides to control pests because they do not want to take the risk of losing their yield.

The use of pesticides a large scale reduces biodiversity, especially of arthropods and other natural microorganisms in paddy fields. The insect community provides valuable ecosystem services and can help maintain the integrity of an ecosystem in a human-altered landscape, such as paddy fields (Withaningsih et al. 2019). Arthropod distribution in a habitat can be influenced by several things, such as refugia that function as microhabitats and are expected to contribute to natural enemy conservation efforts (Wulan et al. 2016).

One effort to improve biodiversity is through organic farming. Organic agriculture promotes a natural environment and sustains the health of the soil ecosystem and people. It also keeps the soil strong and fertile, so it can produce well and maintain diversity. Furthermore, most of the research was focused on the use of arthropods more environmentally friendly methods such as biological control and the use of refugia (Leksono 2017).

Refugia are areas in farmland that grow local plants that provide shelter, food sources, and other resources specifically to natural enemies such as predators and parasitoids. The local plants, also known as weeds and grasses, can serve as an alternative habitat for the survival of natural enemies. The planting of cultivation plants, such as chili (*Capsicum annuum*) and; eggplant (*Solanum melongena*) in a narrow area on the edge of an organic paddy field aims to increase the diversity and abundance of arthropods, especially predators, parasitoids, and pollinators. The organic farming system has been known to support the diversity of arthropods in Arthropods wide range of taxa, including microorganisms, arable flora, invertebrates, birds, and mammals, which benefit from organic management that leads to increases in abundance and in the richness of the species (Abidin et al. 2019).

There are many studies on the component and effectiveness of herbaceous plants, and crop species such as *Ageratum conyzoides, Bidens pilosa, Capsicum annuum, Commelina difussa, Ipomea crassicaulis, Mimosa pudica, Vetiveria zizaniodes, Vigna unguiculata*, and *Zea mays* to attract natural enemies such predators and parasitoids (Azmi et al. 2014). The utilization of refugia plants for predatory arthropod conservation in organic paddy in Indonesia has not yet been done. Therefore, this study aims to determine the abundance, community structure, and diversity of arthropod visitors in the refugia of the organic paddy fields in the Malang District, East Java, Indonesia.

MATERIALS AND METHODS

Place and time research

This research was carried out in an organic paddy field in Sumberngepoh Village, Lawang Sub-district, Malang District, East Java Province, Indonesia (Figure 1). This site was located at 7º50’7” S and 112º41’41” E in altitude. The research was carried out in 2019 from February to June and covered the stages from planting to harvest. The statistical analyses of arthropods and abiotic factors were carried out in July 2019.

Equipment

The equipment used in this study was organized into three groups; field tools, laboratory instruments, and supporting tools. The field equipment consisted of raffia, wood, a thermo hygrometer, a lux meter, a knives, a notebook, and a pencil. The laboratory equipment consisted of stereo microscopes, specimen bottles, and Petri dishes. The supporting tools included identification books, such as Borror et al. (1996), Siwi (1991), and Internet literature, as well as; stationery; and cameras.

Arthropods sampling

Arthropods sampling was carried out twice, on in the vegetative phase (February) and generative phase (June) of paddy plants. Each phase lasted five days. Sampling was carried out simultaneously at three times a day; in the morning (08:00 to 09:30 a.m), afternoon (12:00 to 1:30 p.m), and evening (3:00 to 4.30 p.m) on the 12 plots (Abidin et al. 2013). The arthropods were collected using sweep nets (net handgrip length of 110 cm, length of 80 cm, and diameter of 35 cm) based on the methods of Jayakumar and Sankari (2010) and Janzen (2013). The swinging net was purposively touched on the paddy stem according to the method of Masika et al. (2017), to drag arthropods attached to their stems and leaves in the paddy lower canopy of the paddy. The arthropods were collected by swinging the net once by using double swings that form a straight line at a depth of 30 cm toward the paddy canopy interior (Karenina et al. 2019). When a species’ identity could not be determined at the time of the sweep and observation, the specimens were collected and taken for detailed identification in the base laboratory of Universitas Islam Raden Rahmat, Malang, Indonesia. Identification was done by Arief Lukman Hakim, M.Agr, an insect taxonomist. The arthropod’s visual identification was conducted by referencing Borror et al. (1996), Siwi (1991), and Internet literature. All the identified arthropods were grouped into guilds, and the number of individuals from each species was counted.

The paddy fields were divided into 12 plots consisting of six refugia plots and six control plots with the area of each plot being 0.5 x 2.5 square meters. Habitat modification was carried out on refugia plots by having farmers plant wild plants. The refugia plants that were planted included the chili (*Capsicum annum*), the eggplant (*Solanum melongena*), the taro (*Colocasia esculenta*), the *bandotan* (*Ageratum conyzoides*), and the *awar-awar* (*Ficus septica*). These refugia was chosen because it has flowers and leaves that attract the presence of natural enemy insects. The abiotic factor was measured light intensity, which was measured using a lux meter, while temperature and humidity were measured using a thermo hygrometer.

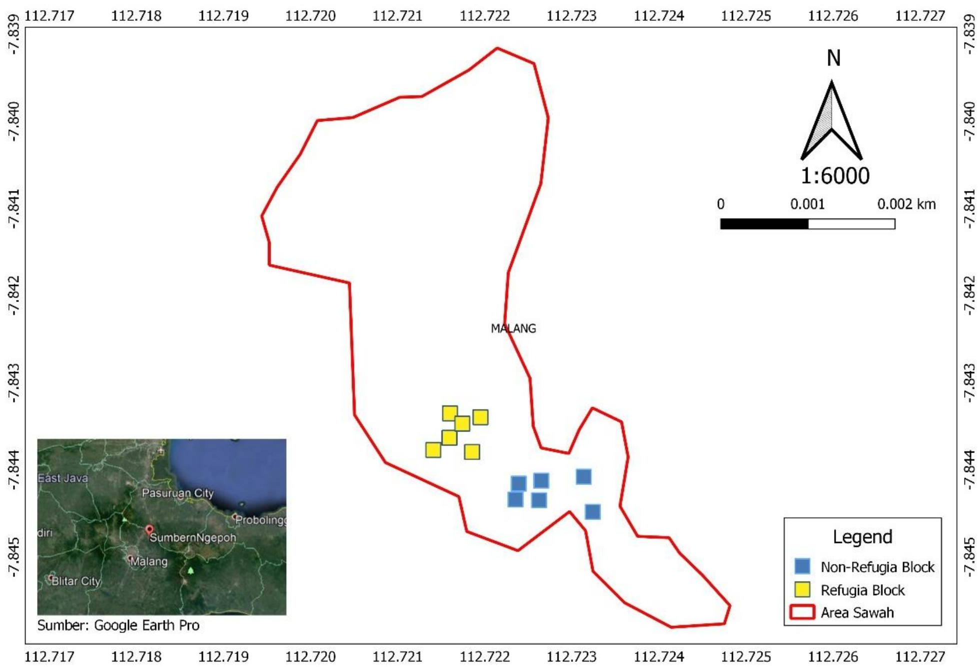

Figure 1. Study sites of arthropods study at organic paddy, Lawang Sub-district, Malang District, East Java Province, Indonesia

Data analysis

Arthropod community

The differences in abundance and diversity were analysis of variance (ANOVA) with treatment (plot adjacent to refugia and plots far from refugia), as main factors during phase and time periods (observation periods) as covariates. The data concerning abundance, taxa richness, and the Shannon-Wiener Diversity Index ware tested for normal distribution and the result showed that abundance of each family was normally distributed. The tests were performed using SPSS version 16 (SPSS Inc. Chicago, IL, USA), and the F-statistic test was considered significant when $p \geq 0.05$ (Krebs and Kenney 2011).

The arthropod abundance data were also used to analyze the species' diversity using the Shannon index (H'). The diversity level was also evaluated by the Evenness index (J') derived from the Shannon function, and the Berger-Parker dominance biodiversity indices.

RESULTS AND DISCUSSION

Habitat condition

The environmental characteristics of each period organic paddy field are different. The average air temperature, air humidity, and light intensity varied during each period (Table 1). Air temperature and air humidity increased with an increase in the period of time. The increase in light intensity along with an increasing period. Air temperature, air humidity, and light intensity in the organic paddy field had a positive correlation to the number of arthropods, while the range of tolerated temperature for arthropods was 15º to 45ºC with an optimum of 25ºC (Farikhah et al. 2019). In this current study, the air temperature ranged from 29.3ºC to 31.1ºC and was favorable to the arthropods. Furthermore, we found that the fluctuation in the air temperature affected the diversity and groups of arthropods. Overall, the abundance of arthropod visitors to the organic paddy field was as many as 28.184 species collected from six plots and consisted of 18.308 species in refugia and 9.876 species in the control.

Air humidity had a strong negative correlation to the arthropods biodiversity in the organic paddy field. The absence of canopy shade affected the change in species diversity. Air humidity plays Arthropods vital role in the internal moisture content and the life cycle, activity, and distribution of insects (Resh and Carde 2009; Budiadi et al. 2020).

Arthropods abundance

Overall the abundance of arthropod visitors to the organic paddy field was as many as 28.184 species of arthropods collected from six plots and consisted of 18.308 species in the refugia and 9.876 species in the control. There were samples that showed that the refugia were visited by nine orders and 40 families were observed. The abundance of common predator families such as Aleyrodidae, Formicidae, Acrididae, Libellulidae, and Tephritidae was higher in the organic paddy.

The Aleyrodidae haves dominated the sample both in the refugia 9.42 ± 7.29 and the control 5.05 ± 3.08. The other dominant families were the Formicidae, Acrididae, Libellulidae, and Tephritidae. The mean of arthropod abundance was higher in an organic paddy field with refugia 40.16 ± 25.55 than in control 24.69 ± 13.69, as seen in Table 2. Taxa richness and diversity were found to be higher in the refugia. The family richness in the refugia species 20.59 ± 12.14 was higher than that in the control species 13.16 ± 8.95. The diversity of arthropod visitors in the refugia species 2.39 ± 0.78 was also higher than in control species 2.35 ± 0.15, as seen in Table 2.

Aleyrodidae comprises a single hemipterous insect group called 'whiteflies' and is an economically important group of sap-sucking insects infesting a wide range of host plants. These creatures are often found attached to the leaf surfaces or tender twigs but can be spotted with careful observation. They are not true flies but are referred to as 'whiteflies' because of their ability to fly and the white floury appearance of their wings, which are dusted with wax (Sundararaj 2019). These whiteflies may cause indirect damage to plants by transmitting of viruses. Furthermore, opportunistic fungi such as sooty mold may develop in the honeydew of these insects, which may affect photosynthesis and depreciate the fruits (Lourencăo et al. 2015).

Table 1. Average measurements of the environmental conditions of the vegetative and generative phase in the organic paddy field

Time	Air temperature (ºC)	Air humidity (%)	Light intensity (lux)
First period	29.3	53	5.321
Second period	31.1	50.3	5.749
Third period	30	57.3	5.471

Table 2. Mean (± SE) of the dominant families, abundance, taxa richness and diversity of arthropods on an organic paddy field with in the refugia and controls

Family	Refugia	Control
Aleyrodidae	(9.42 ± 7.29)	(5.05±3.08)
Formicidae	(7.37 ± 5.37)	(4.12 ± 2.28)
Acrididae	(6.63 ± 4.11)	(3.11 ± 2.04)
Libellulidae	(4.61 ± 2.13)	(3.4 ± 1.9)
Tephritidae	(3.63 ± 2.63)	(2.53 ± 1.53)
Aphididae	(2.55 ± 2.48)	(4.5± 2.53)
Lycosidae	(2.46 ± 1.14)	(1.27 ± 0.1)
Reduviidae	(1.38 ± 0.17)	(0.2 ± 0.12)
Coccinellidae	(1.65 ± 0.13)	(0.51 ± 0.11)
Sarcophagidae	(0.46 ± 0.1)	0
Abundance	(40.16 ± 25.55)	(24.69 ± 13.69)
Taxa richness	(20.59 ± 12.14)	(13.16 ± 8.95)
Diversity	(2.39 ± 0.78)	(2.35 ± 0.15)

Some factors that result in whiteflies being so widespread and causing a lot of damage include: (i) a wide host range, (ii) a resistance to many insecticides, (iii) a high reproductive capacity, and (iv) a capacity to transmit viruses. The life cycle of whiteflies consists of an egg stage, four nymphal stages, and an adult's stages (both sexes). Adult female whiteflies can start laying eggs one to three days after emerging. They can oviposit up to 800 eggs and live about 25 to 30 days, depending on environmental conditions (Kirk et al. 2000).

The families are all predatory arthropods that inhabit habitats close to water. In East Java, the paddy field is one of the suitable habitats for this group (Leksono et al. 2017). Formicidae occupies several functional roles in the ecosystem including nectar feeder, predator, scavenger, and seed feeder (Widyastuti et al. 2018). A study conducted in rice fields in the Philippines showed that 14 species of Formicidae were identified as potential predators of which the very aggressive. Those included *Solenopsis geminata* and *Tapinoma*. Other ant species act as soil engineers. For example, the nest mounds constructed by ants can improve nutrient enrichment for the plant (Wilby et al. 2001).

This effort can be achieved by applying the refugia blocks. A refugia block is an area on farmland that is planted with a local plant that provides shelter, food, sources, and other resources especially for natural enemies such as predators and parasitoids (Woodmansee 2015). Local wild plants, also known as weed and grass may serve as an alternative habitat for the survival of a particular organism. The plant abundance enhances regulating services by ensuring the survival of Formicidae, honeybees (in the absence of oilseed crops), and pollination services (Bretagnolle and Gaba 2015).

Based on observation, the refugia planted by organic paddy farmers include chili (*Capsicum annuum*), eggplant (*Solanum melongena*), *bandotan* (*Ageratum conyzoides*), *talas* (*Colocasia esculenta*), *awar-awar* (*Ficus septic*). This refugia plant can be agents' biologically integrated pest control insects herbivore in an organic paddy field. Furthermore, the effect of the refugia block on visitor arthropods is quite substantial because, in all treatments, an increase in the number of individual arthropods occurs in the generative season. The generative stage covers the beginning of development and flower formation.

A study conducted by Zhang et al. (2013) reported the existence of 77 species of predators in this system. Refugia may support diverse predatory arthropods such as the Carabidae, Coccinellidae, Staphylinidae, Carcinophoridae, Coenagrionidae, and Gryllidae which are among the common predators in the organic paddy field (Hendrival et al. 2017).

Statistical analysis of variance showed that the taxa richness (F= 4.7; P <0.05) and diversity (F= 2.9; P <0.01) of arthropod visitors were significantly higher in the refugia, while there were no significant differences in abundance between the refugia and control. The refugia also had arthropods significant effect on many groups. Formicidae, Libellulidae, Lycosidae, and Coccinellidae were more abundant in the refugia, while the Aleyrodidae and Aphididae were more abundant in control (Table 3). However, Sarcophagidae and Aphididae were not significantly different between the refugia and control.

The reproduction phase had a significant effect on many groups. The abundances of most taxa were also significantly higher in the refugia. These included several dominant groups such as the Reduviidae, Sarcophagidae, and Aphididae. However, the abundance of the Aleyrodidae, Formicidae, Libellulidae, Lycosidae, and Coccinellidae were not significantly different between vegetative and generative phase (Table 3).

The composition of the functional group was dominated by natural enemies (Aleyrodidae) in both the refugia and control. The proportion of predator species in the refugia was higher 79.73 than in the control 53.94. the number of scavenger species was higher in the refugia 19.79 than in the control 9.37. Arthropods small portion of the predator and herbivorous was has occurred in the study sites, both were higher in the refugia and the control (Figure 2). This result showed that parasitoids were more abundant in the refugia than in the control.

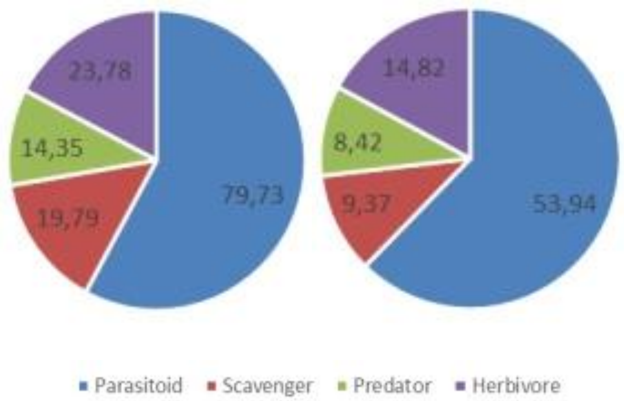

Figure 2. Comparison of the composition of arthropod functional groups in the refugia and the control plots. A. Refugia block, B. Control

Table 3. Summary of *F* value by the degree of significance using a General Linear Model Analysis of Variance (ANOVA) of the abundance, taxa richness and diversity of several arthropods visitor families

Family	Refugia	Control
Aleyrodidae	15.4***	4.2**
Formicidae	7.2**	3.9**
Aphididae	0.5	0.3
Lycosidae	5.1*	2.9*
Reduviidae	0	0.5
Coccinellidae	3.4	0
Sarcophagidae	1.6	1.9
Abundance	5.3*	7.1**
Taxa richness	4.7*	8.2**
Diversity	2.9	1.6

Table 4. Arthropod abundance in the vegetative and generative stage

Ordo	Family	Arthropods abundance			
		Vegetative stage		Generative stage	
		Refugia	Control	Refugia	Control
Araneae	Lycosidae	301	172	150	42
	Oxyopidae	77	29	40	11
	Salticidae	192	36	10	2
	Tetragnathidae	163	27	23	17
	Thomisidae	25	4	12	2
Coleoptera	Coccinnellidae	167	43	49	26
	Staphylinidae	88	32	416	278
Diptera	Asilidae	24	14	8	3
	Calliphoridae	56	21	21	13
	Ceratopogonidae	85	31	9	2
	Culicidae	125	38	51	20
	Drosophilidae	230	189	42	28
	Muscidae	153	52	31	19
	Sarcophagidae	69	25	142	14
	Simuliidae	60	48	166	95
	Sryphidae	30	13	45	29
	Tachinidae	89	47	12	4
	Tabanidae	106	62	22	11
	Tephritidae	56	39	546	438
	Tipulidae	231	210	40	21
Hemiptera	Aleyrodidae	6804	4120	507	495
	Alydidae	238	62	494	241
	Delphacidae	89	72	41	37
	Miridae	552	149	6	2
Hymenoptera	Reduviidae	130	73	79	38
	Aphididae	396	83	107	52
	Braconidae	21	2	10	3
	Crambidae	249	229	308	213
	Formicidae	1452	388	289	139
	Pteromalidae	20	12	27	14
Lepidoptera	Pompilidae	3	2	4	1
	Pieridae	89	51	35	18
	Spingidae	1	0	3	1
	Pyralidae	2	0	0	0
Mantodea	Papilionidae	4	0	9	2
Odonata	Mantidae	2	0	1	0
	Libelludidae	728	321	289	92
	Coenagrionidae	38	24	16	12
Orthoptera	Acrididae	823	612	180	63
	Gryllidae	71	39	29	7
	Grand total	14039	7371	4269	2505

Refugia supported changes in the composition of arthropods which affected the decrease in the proportion of herbivore. This was due to the existence of beneficial predators and parasitoids which can suppress herbivorous populations. Several studies in agricultural ecosystems have shown that increasing the diversity of arthropods predators and parasitoids can have an effect on the level of consumption of prey (Lopes et al. 2017).

The richness and diversity of taxa were greater in plots adjacent to the refugia than those of the control. Refugia support arthropods by providing shelter, food sources, and other resources. Interestingly, the abundance statistics showed a different situation. This could be because the appearance of predators and parasitoids causes the herbivorous population to decrease (Leksono et al. 2019). Furthermore, the refugia area also provides an alternative habitat for parasitoids, thus allowing for parasitic processes that suppress pest populations. Therefore, the presence of refugia areas can maintain the balance of arthropod composition and ultimately maintain the balance of the ecosystem (Leksono et al. 2019).

The taxa richness and diversity were greater in a plot adjacent to refugia areas than in a plot far from refugia (control). The presence of a modified habitat, created by planting refugia plants, increased habitat complexity. This may increase the natural enemy population that enables pest control in complex habitats compared to simple habitats. Pest repellents that are driven by complex landscapes can result in less plant injury. Enhanced natural enemy activity was associated with herbaceous habitats in 80% of the cases (Bianchi et al. 2006)

The presence of habitats modified by the farmer planting refugia plants can increase habitat complexity, which can increase natural enemy populations, such as parasitoids and predators, which make it possible to control pest (herbivore) populations in complex habitats. A pest that is driven by complex landscapes can cause lower crop injury. Each insect has arthropods a specific role in the ecosystem's stability and energy balance (Weisser and Siemann 2004).

In this current study, the dominant arthropods direct observation vegetative stage was different in that of direct observation at the generative stage. These arthropods, includes the Formicidae family of the Hymenoptera orders and the Alydidae family of the Hemiptera order that was the most dominant at refugia in the vegetative and generative stage (Table 4). In the control, the Acrididae family of the Orthoptera order was the most dominant of the vegetative and generative stage. the Formicidae family including predators of pests. The predator likes moist ecosystems such as the paddy field, and lives on rice stems, and footpaths (Herlinda et al. 2018). The grasshoppers of the Orthoptera order (a member of Acrididae, Tettigoniidae, and Gryllidae) as herbivores are dominant in most of the forest habitats, and therefore, have an important role in decomposing the litter produced from the arthropods' proliferating stand (Erawati et al. 2010).

In conclusion, the results showed that the abundance of arthropod visitors in the organic paddy field was as much as 28.184 species collected from six plots, which consisted of 18.308 species in refugia and 9.876 species in control. The samples showed that refugia were visited by nine orders, and 40 families were observed. The abundance of common predator families, such as the Formicidae, Acrididae, Libellulidae, and Tephritidae were higher in the organic paddy. The Aleyrodidae dominated the sample both in the refugia 9.42 ± 7.29 and control 5.05 ± 3.08. The composition of the functional group was dominated by natural enemies (Aleyrodidae) in both the refugia and control. The refugia supported a change in arthropod composition that affected the increase in the proportion of herbivores, predators, and parasitoids and created a functional and compositional group balance.

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