Asian Journal of Crop Science

ISSN 1994-7879

OPEN ACCESS Asian Journal of Crop Science

ISSN 1994-7879
DOI: 10.3923/ajcs.2018.134.140

Research Article
Effect of Refugia on Spatial and Temporal Distribution of Arthropods on Rice Agroecosystem (*Oryza sativa* Linn.)

Bambang Tri Rahardjo, Silvi Ikawati, Muhammad Redy Prasdianata and Hagus Tarno

Laboratory of Plant Pest, Department of Plant Pest and Disease, Faculty of Agriculture, University of Brawijaya, Jl. Veteran Malang, 65145, East Java, Indonesia

Abstract
Background and Objective: The arthropods distribution is influenced by several factors i.e., vegetations (refugia). Spatial and temporal distributions can be observed to determine the arthropod's abundance on fields. The research aimed to determine the effect of refugia on the spatial and temporal distribution of arthropods on rice fields. **Materials and Methods:** From February-April, 2016, farmers' fields in Watugede, Singosari, Malang was observed to collect data and arthropod identification was conducted in Plant Pest Laboratory, Department of Plant Pest and Disease, Faculty of Agriculture, University of Brawijaya. The spatial and temporal distributions of arthropods on rice agroecosystem were investigated by using several observation methods such as visual methods, pit-fall and yellow sticky traps. Observation of spatial distribution was divided into 6 points with 3 replications. The points were 3, 6, 9, 12, 15 and 18 m from refugia. The observation of temporal distribution was done at four periods: Vegetative I, vegetative II, generative I (reproduction) and generative II (ripening) with 18 points of observation in total. **Results:** The results showed that the spatial distribution of arthropods on the field at the 3 m observation point which is the closest observation point to the refugia has the highest abundance of arthropods. While, the lowest found at the 15 m observation point from the refugia. Temporal distribution of arthropods on the field showed that the highest number occurred in the vegetative II and the lowest in the vegetative I. **Conclusion:** Based on temporal and spatial distributions on rice farm, the highest abundance of arthropods are determined in the vegetative II and 3 m observation point.

Key words: Arthropods, refugia, rice agroecosystem, spatial, temporal distribution

Citation: Bambang Tri Rahardjo, Silvi Ikawati, Muhammad Redy Prasdianata and Hagus Tarno, 2018. Effect of refugia on spatial and temporal distribution of arthropods on rice agroecosystem (*Oryza sativa* Linn.). Asian J. Crop Sci., 10: 134-140.

Corresponding Author: Bambang Tri Rahardjo, Laboratory of Plant Pest, Department of Plant Pest and Disease, Faculty of Agriculture, University of Brawijaya, Jl. Veteran Malang, 65145, East Java, Indonesia Tel: +62-341-575843

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rice is staple food for Indonesian. Rice production centers spread throughout provinces in Indonesia. One of the provinces in Indonesia that became one of the rice production centers was East Java Province with 13,054,511 t in total production in 2015[1]. Rice cultivation is never separated from two important factors, namely, biotic and abiotic factors. In the biotic factor, arthropods are important component that is always a special concern in doing the cultivation. As one of the biggest ecosystems in the tropics, rice fields include diverse insect pests and natural enemies[2]. Pentatomidae, orthoptera and planthoppers were main herbivores and predatory mites, spiders, Hymenoptera and Odonata were the major natural enemies[3]. There were several reports related to spatial and temporal distributions of arthropods in agroecosystems, storages and landscapes[4-6].

Arthropod distribution in a habitat can be influenced by several things, one of which is a refugia that functions as a microhabitat and is expected to contribute to natural enemy conservation efforts[7-10]. In rice agroecosystems, predatory arthropods are dominated by Insecta and Arachnida with the total of 142 species[11]. Two families of Insecta and Arachnida such as Carabidae and Staphylinidae for Insecta and Theridiidae and Lycosidae for Arachnida dominated in rice agroecosystem[11].

Related to the refugia and distribution of arthropods on rice agroecosystem, it's important to confirm the relationship between both to manipulate the habitat of natural enemies on rice agroecosystem. The spatial and temporal distributions will be the most important variables to determine the distribution of arthropods on rice ecosystem.

MATERIALS AND METHODS

Research location and period: The research was conducted on rice field in Watugede Village, Singosari Sub-district, Malang Regency from February-April, 2016. The collected arthropod's samples were identified in the Plant Pest Laboratory, Department of Plant Pest and Disease, Faculty of Agriculture, University of Brawijaya, Malang.

Research design: The research method used was descriptive explorative design. Exploration was done on rice field which applies conventional cultivation method and without insecticide application. The cultivation techniques included the soil tillage, preparing Cibogo rice variety, planting various plants as refugia, transplanting, fertilizing, irrigating and weeding.

Variables and tools of observation: Arthropods observation was done directly by determining the observation points and then observing them until all arthropods observed for 3 min. The observation point was used as a basis for observation of the arthropods spatial and temporal distributions. The observation was done at 7 days after transplanting (25 days after planting). Observation was done once a week. For the spatial distribution, observations used a visual method by determining the observed point of the sample. The observed points of the sample were six observation points with three replications. The distance for each observation point was three meters. Each sample point was placed further away from the refugia plant. One sample point was a single clump of rice. Observation of each sample point was performed until all arthropods observed.

Pitfall trap method used plastic cups (7 cm in diameter, 9 cm in height) filled with detergent solution. The number of pit fall trap used were 18. Each Pit fall trap was settled at three meters away from refugia and it was placed 3 m apart in accordance with the predetermined point.

Yellow plastic pan with 20 cm in diameter and was filled with a detergent solution in which 1 m height of timber as holder were settled up as Yellow Pan Traps. Eighteen yellow pan traps were mounted at a 3 m away from refugia. Each trap was placed 3 m apart in accordance with the predetermined point.

For the temporal distribution, observations were divided into four periods. Vegetative I, vegetative II, generative I (reproduction) and generative II (ripening) were chosen as period of observations. Observation points used as observation point of spatial distribution were observed. There were six points with three replications, therefore there were 18 observation points in total. Observations of temporal distribution were also done using traps. The trap used was pit fall traps and yellow pan traps. The procedure of using those traps was the same as spatial observation. Observation time for each period was 3 times observation for the temporal distribution of arthropods.

Arthropod identification: Arthropods that can be directly identified their species in the field were noted directly during observation. While species that cannot be identified from the observation were brought to Plant Pest Laboratory, Department of Plant Pests and Diseases, Faculty of Agriculture, University of Brawijaya, Malang. Each arthropod was identified based on morphological features using a book Taxonomy of Rice Insect Pests and their Arthropod Parasites and Predators[12].

Data analysis: Sigmaplot was used to create all bar charts. The bar chart was made according to the observation point for the spatial distribution and rice growth stages for the temporal distribution. In addition to bar charts, the data of arthropod diversity obtained were also measured using the Shannon-Wienner's (H') diversity index, Margalef's (R) richness index, Piellou's (e') evenness index and Simpson's (C) dominance index. Simpson Index (D), Shannon-Wiener Indices (H`), Species Evenness Indices and Simpson's dominance index were calculated based on Tarno *et al.*[13].

RESULTS AND DISCUSSION

Arthropod diversity: Based on arthropod's diversity, result showed that there are 13 orders consisting of 49 families and 82 species of arthropods found in the field (Fig. 1). Arthropods obtained were derived from direct observation by visual method, yellow pan traps and pitfall trap.

Based on the functional role of arthropods in agro-ecosystems, population of arthropods were grouped into detritivore, herbivore, parasitoid, predator and pollinator (Fig. 2). Arthropods belonging to detritivores included three orders, five families and five species. The herbivores included seven orders, 19 families and 22 species. The predator included seven orders, 27 families and 42 species. The parasitoid included one order, seven families and 12 species. The pollinator included one order, one family and 2 species.

Based on a diversity index (Table 1), the results of diversity index show as follows: (a) The arthropod diversity index (H') is 2.795 which includes in moderate category, (b) The evenness index (e') is 0.634 which includes in high evenness category, (c) The dominance index (C) is 0.105 which means the species is not dominant on the field and (d) The richness index is 10,590 which means arthropod species are high.

From Table 1, the absence of dominance of existing species on the field due to the diversity of arthropod in the field can maintain the stability of agroecosystems through potentially dominant species suppression mechanisms. They claimed that a natural enemy is able to optimally act as a predator from the beginning, so the pest population is at equilibrium level position or the fluctuations in the population of pests and natural enemies are balanced[14]. Therefore, there will be no pest explosion.

Spatial distribution of arthropods in rice fields: The observation results of spatial distribution of arthropod at several observation points (3, 6, 9, 12, 15 and 18 m) shows arthropod species and its population as presented in Fig. 3.

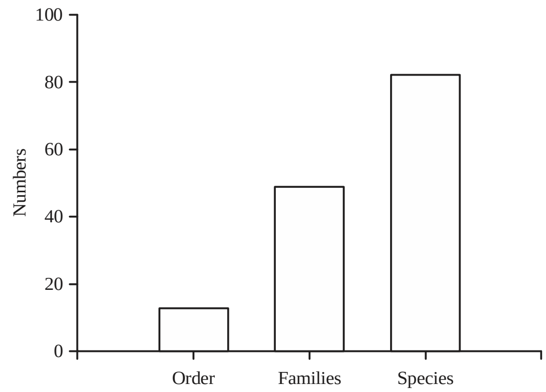

Fig. 1: Arthropods found based on taxonomic groups

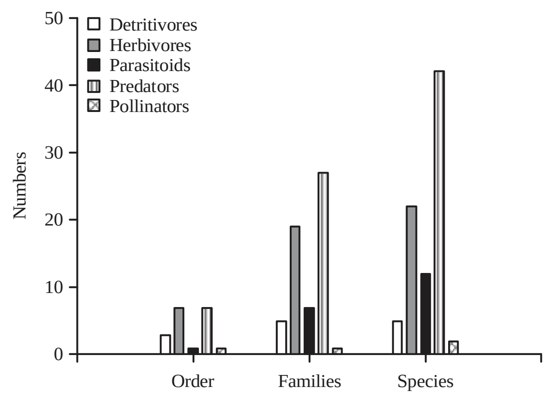

Fig. 2: Population of each functional group of arthropod on rice agro-ecosystem

Table 1: Results of arthropod diversity index

Index	Values	Category
Diversity (H')	2.795	Moderate
Evenness (e')	0.634	High
Dominance (C)	0.105	Not dominant
Richness (R)	10.590	High

In Fig. 3, the total number of arthropods found at 3 m observation point is the highest arthropod population (427 heads). While, the lowest (291 heads) is at 15 m observation point. Spatial distribution of arthropods at 3 m which is the closest to refugia has the highest number. Herlinda *et al.*[11] stated that the high level of dominance in an ecosystem means that there is a very high domination by certain species when compared to other species.

The data of spatial distribution of arthropods with arthropods that have been grouped according to their role in agro-ecosystem (Fig. 4) shows that the further observation point from the refugia, the number of predators found decreases.

The data for the number of herbivores showed that the further observation point from refugia, the number of herbivores found increases. Arthropods that act as detritivore, parasitoid and pollinator are more fluctuated and have less numbers than the predators and herbivores in the field.

Predators and herbivores are the dominant arthropods in the field both in terms of species diversity and the abundance of arthropods based on their spatial distribution. The closer to refugia and bunds, the number of predators is higher. However, at 18 m from the refugia, the number of predators increase at the beginning and then decrease. It is caused by the population of predators follow the higher growth of herbivores. The high population of herbivores is a good thing for the availability of prey for predators in the field. This condition is called density-dependent factor. Density-dependent factor such as predators of rice pests are a natural controlling factor that has a suppressive nature of the pest population[15].

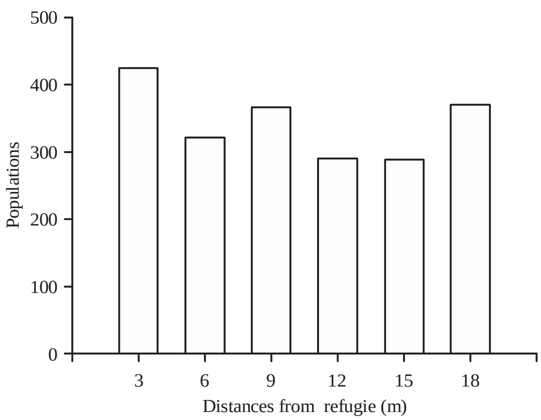

Fig. 3: Spatial distribution of arthropods based on population

Diversity and dominance indices of arthropod functional groups are significantly affected by the surrounding vegetation, except for parasitoid group. In the more diverse arthropod communities reduce the dominance of phytophagous groups such as planthoppers[16]. Solid bioinsecticide and the lowest synthetic insecticides keep the diversity of predatory arthropods (H') in rice plants at the highest level[17].

The results of the diversity index (Table 2) showed that the value of each index at each spatial distribution of the arthropod is the same therefore it belongs to the same category as well. The diversity index value is in moderate category, the evenness index and the richness index are in high category.

The data in Table 2 shows that the results of the diversity index (H ') at all observation points indicate moderate diversity category. The results of evenness index (e') and richness index (R) indicate high category. The dominance index (C) indicates no dominance at any observation point of arthropod spatial distribution. The higher value of evenness distribution shows uniformity of the population[18]. It means that that the community does not have the dominant population of particular organisms against other organisms.

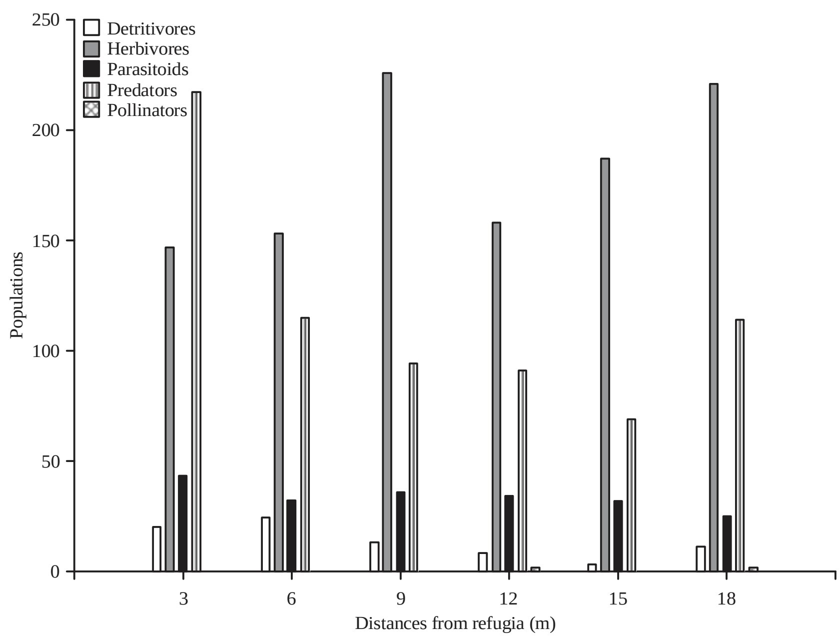

Fig. 4: Spatial distribution of arthropods based on role in agro-ecosystem

Temporal distribution of arthropods on rice fields: The observation data of temporal distribution obtains the number of arthropod as follows: (a) 318 heads in vegetative I, (b) 695 heads in vegetative II, (c) 528 heads in generative I and (d) 592 heads in generative II. The data is presented in Fig. 5.

The observation data of temporal distribution grouped in accordance with the role is presented in Fig. 6. Figure 6 showed that herbivores always dominate the population in all phases of plant growth. Herbivores on vegetative I, is still low and rise drastically in vegetative phase II. In entering generative phase I and generative phase II, the population continues to decline but it is still higher than arthropods that have other roles. Each phase of rice growth affects arthropods in terms of numbers, especially the number of herbivores and predators[19]. In vegetative and reproductive phases, the number of herbivores is higher than that of predators. It is due to the availability of host quality as a source of herbivorous feed.

The number of predators occupy the second level (carnivores). The number of predators follows a pattern of herbivores abundance which is the main prey for predators. The predator abundance in the vegetative phase I is the lowest because of the low prey population in the early phase

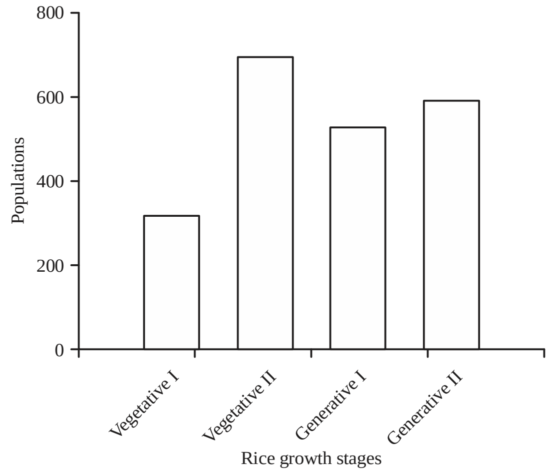

Fig. 5: Population of arthropods on rice growth stages

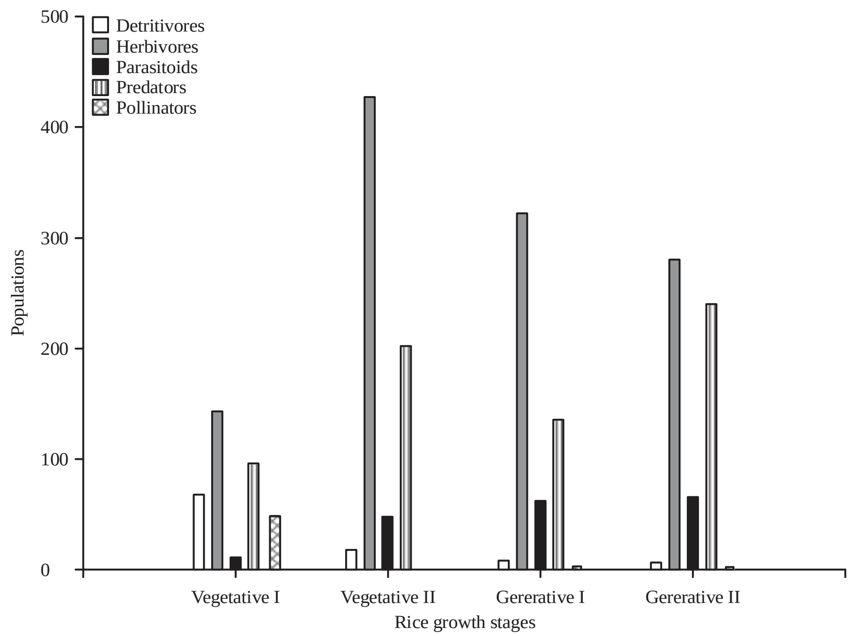

Fig. 6: Temporal distribution of arthropod based on role in agro-ecosystem

Table 2: Arthropod diversity index based on spatial distribution

	Observation point (m)											
Index	3	G	6	G	9	G	12	G	15	G	18	G
H'	2.686	M	2.874	m	2.518	m	2.720	M	2.488	M	2.504	m
e'	0.701	H	0.755	h	0.703	h	0.742	H	0.731	H	0.688	H
C	0.124	Nd	0.090	nd	0.131	nd	0.112	Nd	0.126	H	0.134	nd
R	7.430	H	7.611	h	5.921	h	6.694	H	5.047	H	6.251	h

H’: Diversity index, e’: Evenness index, C: Dominance index, R: Richness index, G: Category, m: Moderate, h: High, nd: Not dominant

Table 3: Arthropod diversity index based on temporal distribution

	Rice growth stages							
Index	V-I	G	V-II	G	G-I	G	G-II	G
H'	2.325	m	2.546	m	2.518	m	2.426	m
e'	0.691	h	0.665	h	0.658	h	0.641	h
C	0.180	nd	0.139	nd	0.144	nd	0.151	nd
R	4.859	h	6.877	h	7.178	h	6.736	h

V-I: Vegetative I, V-II: Vegetative II, G-I: Generative I, G-II: Generative II, H': Diversity index, e': Evenness index, C: Dominance index, R: Richness index, G: Category, m: Moderate), h: High, nd: Not dominant

of growth and the highest abundance is in the generative phase II when the prey population has been abundant.

The parasitoid population for spatial distribution shows an increase from observation in vegetative I to generative II. Arthropods as detritivore, observed from temporal distribution are declining in the population, while as the pollinators are only found in generative I and generative II.

In vegetative I, all arthropods are very low in population compared to other phases. In the vegetative I, all arthropods still adapt to the environment. During planting paddy, herbivores will come because the host is a paddy plant. Herbivores in the field can invite both predators which are looking for prey and parasitoids that need herbivores as host. An increase number of herbivores in vegetative II makes the number of predators also increase because predator needs herbivores as food sources. Natural enemies are effective population regulators because they are density-dependent. If there is an escalation in insect pest populations[2,20,21], it will be followed by an escalation in natural enemy population and also followed by increased feeding power from natural enemies.

The data presented in Fig. 5 are also supported by the data of arthropod diversity index based on their temporal distribution (Table 3). The diversity index (H'), evenness index (e'), dominance index (C) and richness index (R) are measured.

The results of the diversity index (H ') at all observation points indicate in moderate category. The evenness index (E') and richness index (R) indicate in high category. The dominance index (C) indicates no dominance at any observation point of arthropod spatial distribution. Ecosystems with high biotic diversity generally have longer and more complex food chains, so there is greater opportunity for interactions such as predation, parasitism, competition, commensalism and mutualism[20,21]. The existence of negative feedback which control these interactions can absorb the shocks that occur. Therefore, the ecosystem is stable.

CONCLUSION

Several conclusions can be drawn as follows:

- Spatial distribution of arthropods in rice fields at three meters observation point from refugia has the highest number of arthropods. The lowest number of arthropods found at 15 m observation point from refugia. Results of diversity index (H') at all observation points are categorized in moderate. Evenness index (E') and richness index (R) are categorized in high. The dominance index (C) indicates no dominance
- Temporal distribution of arthropods in soil shows that the highest numbers is in vegetative II and the lowest is in vegetative I. The results of diversity index (H') at all observation points are categorized in moderate. Evenness index (E') and richness index (R) are categorized in high. The dominance index (C) indicates no dominance

SIGNIFICANCE STATEMENT

This study provided information related to the spatial and temporal distributions of arthropods on rice fields including the natural enemies and herbivores completely.

ACKNOWLEDGMENT

Authors thank to Department of Plant Pest and Disease, Faculty of Agriculture, University of Brawijaya for in kind support during research.

REFERENCES

1. Badan Pusat Statistik, 2015. Produksi padi menurut provinsi (ton), 1993-2015. https://www.bps.go.id/dynamictable/2015/09/09/865/produksi-padi-menurut-provinsi-ton-1993-2015.html
2. Ghahari, H., R. Hayat, M. Tabari, H. Ostovan and S. Imani, 2008. A contribution to the predator and parasitoid fauna of rice pests in Iran and a discussion on the biodiversity and IPM in rice fields. Linzer Biol. Beitr., 40: 735-764.

3. Fritz, L.L., E.A. Heinrichs, V. Machado, T.F. Andreis and M. Pandolfo *et al*., 2011. Diversity and abundance of arthropods in subtropical rice growing areas in the Brazilian south. Biodivers. Conserv., 20: 2211-2224.
4. Allen, K.C. and R.G. Luttrell, 2009. Spatial and temporal distribution of heliothines and tarnished plant bugs across the landscape of an Arkansas farm. Crop Prot., 28: 722-727.
5. Tsutsui, M.H., K. Kobayashi and T. Miyashita, 2018. Temporal trends in arthropod abundances after the transition to organic farming in paddy fields. PloS One, Vol. 13. 10.1371/journal.pone.0190946.
6. Trematerra, P., M.C.Z. Paula, A. Sciarretta and S.M.N. Lazzari, 2004. Spatio-temporal analysis of insect pests infesting a paddy rice storage facility. Neotrop. Entomol., 33: 469-479.
7. Gunawan, 2005. UJI preferensi scaeva pyrastri (Diptera: Syrphidae) terhadap tanaman mimosaceae dan papilionaceae berdasarkan ketertarikannya terhadap bau. Bioscientiae, 2: 37-42.
8. Wesener, T., M.J. Raupach and P. Decker, 2011. Mountain refugia play a role in soil arthropod speciation on Madagascar: A case study of the endemic giant fire-millipede genus *Aphistogoniulus*. PLoS One, Vol. 6. 10.1371/journal.pone.0028035.
9. Allifah, A.N.A., B. Yanuwiadi, Z.P. Gama and A.S. Leksono, 2013. Refugia sebagai microhabitat untuk meningkatkan peran musuh alami di lahan pertanian. Prosidings of the FMIPA Universitas Pattimura, (FMIPAUP'13), Indonesia, pp: 113-116.
10. Wulan, H., S. Weni, Y. Pujiastuti and A. Umayah, 2016. [Refugia effects toward arthropods attacking rice (Oryza sativa) in tidal swamp]. Prosiding of the Seminar Nasional Lahan Suboptimal, October 20-21, 2016, Palembang, pp: 638-647.
11. Herlinda, S., A. Rauf, S. Sosromarsono, U. Kartosuwondo, Siswadi and P. Hidayat, 2004. Artropoda predator penghuni ekosistem persawahan di daerah cianjur, jawa barat. J. Entomol. Indones., 1: 9-15.
12. Barrion, A.T. and J.A. Litsinger, 1994. Taxonomy of Rice Insect Pests and Their Arthropod Parasites and Predators. In: Biology and Management of Rice Insects, Heinrichs, E.A. (Ed.). Wiley Eastern Ltd., New Delhi, India, pp: 792.
13. Tarno, H., E.D. Septia and L.Q. Aini, 2016. Microbial community associated with ambrosia beetle, *Euplatypus parallelus* on sonokembang, *Pterocarpus indicus* in Malang. Agrivita J. Agric. Sci., 38: 312-320.
14. Henuhili, V. and T. Aminatun, 2013. [Natural enemies conservation as natural control of pests by management of agroecosystem]. J. Penelit. Saintek, 18: 29-40.
15. Wilby, A., L.P. Lan, K.L. Heong, N.P.D. Huyen, N.H. Quang, N.V. Minh and M.B. Thomas, 2006. Arthropod diversity and community structure in relation to land use in the Mekong Delta, Vietnam. Ecosystems, 9: 538-549.
16. Yuan, F., J. Zhang, K. An, K. Shen and R. Zhang, 2013. Arthropod biodiversity and community structure in dongxiang wild rice (*Oryza rufipogon* Griff.) fields. J. Agric. Urban Entomol., 29: 55-67.
17. Khodijah, 2013. Keanekaragaman komunitas artropoda predator tanaman padi yang aplikasi boinsektisida berbasis jamur entomopatogen daerah rawa lebak sumatera selatan. J. Lahan Suboptimal, 2: 43-49.
18. Krebs, C.J., 2014. Ecological Data for Field Studies. In: Ecological Methodology, Krebs, C.J. (Ed.). University of British Columbia, USA., pp: 1-19.
19. Gallagher, K.D., P.A.C. Ooi, T.W. Mew, E. Borromeo and P.E. Kenmore, 2002. Integrated pest management in rice. Int. Rice Comm. Newsl, 51: 9-24.
20. Matteson, P.C., 2000. Insect pest management in tropical Asian irrigated rice. Annu. Rev. Entomol., 45: 549-574.
21. Woodmansee, R.G. and S.R. Woodmansee, 2015. The rise of ecosystem ecology and its applications to environmental challenges. Web Ecol., 15: 43-44.