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The Refugia Attract Arthropods in a Paddy Field in Malang, East Java, Indonesia

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KEYWORDS

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Abstract A study on the effect of refugia areas to attract on Arthropods has been done in a semi-organic paddy field in Malang, from March to June 2017. The arthropod was measured by abundance, diversity and composition variables. Arthropod observations were performed on 6 plots of 1 m^2 each, consisting of 3 plots on the side near the Refugia area (treatment) and 3 plots on the opposite side (control). The refugia areas consisted of plants as follows chili (*Capsicum frutescens*), the wild cosmos (*Cosmos caudatus*), the long beans (*Vigna unguiculata*), and Marigold (*Tagetes erecta*). The visual encounter surveys method was conducted for 15 minutes on each plot. There were 2249 individuals of Arthropod observed visually in the study sites. This study showed that of the abundance (mean ± SE) of Arthropod visitors was lower in plots adjacent to refugia areas (treatment) (33.7± 2.63), than that far from Refugia area (control) (38.33 ± 2.54); while the taxa richness and diversity was higher found in treatment plots. The species richness in the treatment plots (12.2 ± 0.70) was higher than that in control (9.70 ± 0.51). The diversity of Arthropod visitors in the treatment plots (2.10 ± 0.07) was also higher than that in control (1.71 ± 0.07). Proportion of predator in the treatment plots was almost twice higher (33.14) that in the control plots (17.65); while that of herbivore was vice versa. This meant the refugia areas have attracted more predators. The composition of Arthropod visitors was remarkable affected by treatment. The abundance of common predator families such as Coccinellidae, Coenagrionidae and Oxyopidae were higher in treatment plots.

Introduction

Rice (*Oryza sativa* L.) is one of the important cereal crops in Asia and nearly 90 per cent of the area, production and consumption of rice are confined to South East Asian countries (Parasappa, et al. 2017), including Indonesia. Pests are the main limiting factor in rice production, especially in vegetative and generative phases. The most common effort to control the pest is to apply pesticide. However, since chemical pesticide may affect the non-target organism and human health, the usage is limited. Therefore, most the research was focused on the use of more environmentally friendly method such as biological control and the use of refugia areas (Leksono, 2017).

The refugia are areas in farmland grown with local plants that provide shelter, feed sources, and other resources especially to natural enemies such as predators and parasitoids (Nentwig, 1998). Predators and parasitoids may suppress the pest population and create more balance community composition. Local wild plants also known as weeds and grasses can serve as an alternative habitat for the survival of certain organisms. Plant abundance enhances regulatory services by ensuring the survival of honeybees in the

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absence of oil seeds and pollination services (Bretagnolle and Gaba, 2015). Planting of wild plants in a narrow area on the edge of paddy field aims to increase the diversity and abundance of Arthropods especially predators, parasitoids and pollinators.

There are many studies on the performance and effectiveness of herbaceous plants both wild plant and crop species such as *Bidens pilosa*, *Capsicum frutesens*, *Commelina difussa*, *Ageratum conyzoides*, *Brachiaria mutica*, *Mimosa pudica*, *Vernonia cinera*, *Marsilea crenata*, *Pistia startiotes*, *Panicum repens*, *Vigna unguiculata* and *Zea mays* to attract natural enemies (Maisyaroh et al., 2010, Purwantiningsih et al. 2011, Leksono et al., 2011). However, in most studies the natural enemy is observed in both planted and naturally grown wild species, while this study looks at the impact of the planting on Arthropod composition on the rice plots. The purpose of this study was to analyze the effect of refugia area on the Arthropod abundance, diversity and composition has been done in a semi-organic paddy field in Malang.

Material and methods

The study was carried out in a semi-organic paddy field in Pagelaran Malang Indonesia (8°12'S and 112° 35'E, 313 m in altitude) on March to June 2017. Rice field where the study was observed measuring 24 x 36 m2. On one side of the small dike is planted a refugia plant consisting of chili (*Capsicum frutescens*), Wild cosmos (*Cosmos caudatus*), Marigold (*Tagetes erecta*), the ridge gourd (*Luffa acutangula*), long beans (*Vigna unguiculata*) and tomato (*Solanum lycopersicum*). These species are chosen because they have flowers that attract the natural enemy insects. Arthropod observations were performed on 6 plots of 1 m2 each, consisting of 3 plots on the side near the refugia area and 3 plots on the opposite side.

The Arthropod observations were done by adopting visual encounter survey during 15 minutes period. When species identity was not determined at the time of observation, specimens were collected and taken to the laboratory for detail identification. The result of each observation unit was classified and identified into families based on standard identification. All of six plots were observed for 3 observation periods throughout the day, (08.00-09.30; 12.00-13.30; and 15.00-16.30). The sampling efforts were repeated three times in 25, 35, 42, 51, 65, 72, 79, 83, 88, 93 days after replanting (DAR). The DAR is started from first day of replanting paddy from seedling area to cultivation area. The differences in the abundance and diversity were analyzed by using general linear model analysis of variance (ANOVA) with treatment (Plot adjacent to refugia areas and plots far from refugia Areas), as main factors while phase and time periods (observation periods) as covariates. The data of abundance, taxa richness and Shannon-Wiener diversity was test 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 $p \geq 0.05$. Canonical correspondence analysis (CCA) was applied to analyze the relationship between the abundance of family and environmental variables (treatment, reproduction phase (phenology), temperature, humidity, and time periods) using the PAST ver. 2.17c (Hammer *et al*. 2001). All factors were coded as categorical variables. Only common families (less than 26 individuals) were included in the analysis. The families were clustered by k-means clustering.

Results and discussion

There were 2161 individuals of Arthropod observed visually in the study sites. Overall the samples showed that rice plants were visited by 61 families of Arthropods. The abundance and diversity of insect visitors varied between location, seasonal periodicity of flowering and

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observation time. This study showed that of the abundance (mean ± SE) of Arthropod visitors was lower in plots near to refugia (treatment) (33.7± 2.63), than that in plots far from refugia (control) (38.33 ± 2.54); while the taxa richness and diversity was higher found in treatment plots (Table 1). The species richness in the treatment plots (12.2 ± 0.70) was higher than that in control (9.70 ± 0.51). The diversity of Arthropod visitors in the treatment plots (2.10 ± 0.07) was also higher than that in control (1.71 ± 0.07). Overall, Formicidae, Alydidae, Acrididae and Coccinellidae were dominant in the observation composing about 46.7% individual (18% in treatment plots and 28.7% in controls) (Table 1).

Table 1. Mean (± SE) of dominant families, abundance, taxa richness and diversity of Arthropod visitors on Refugia area and grasses.

Group	Treatment plots	Control plots
Formicidae	1.46 ± 0.49	4.41 ± 0.66
Alydidae	0.60 ± 0.18	1.52 ± 0.34
Acrididae	1.01 ± 0.11	0.88 ± 0.14
Coccinellidae	0.81 ± 0.15	0.53 ± 0.15
Chlorophidae	0.80 ± 0.12	0.38 ± 0.12
Libellulidae	0.57 ± 0.11	0.58 ± 0.13
Coenagrionidae	0.87 ± 0.19	0.20 ± 0.06
Oxyopidae	0.71 ± 0.12	0.27 ± 0.09
Delphacidae	0.42 ± 0.11	0.53 ± 0.15
Staphylinidae	0.39 ± 0.10	0.21 ± 0.08
Abundance	12.21 ± 0.97	12.78 ± 1.12
Taxa richness	12.2 ± 0.70	9.70 ± 0.51
Diversity	2.10 ± 0.07	1.71 ± 0.07

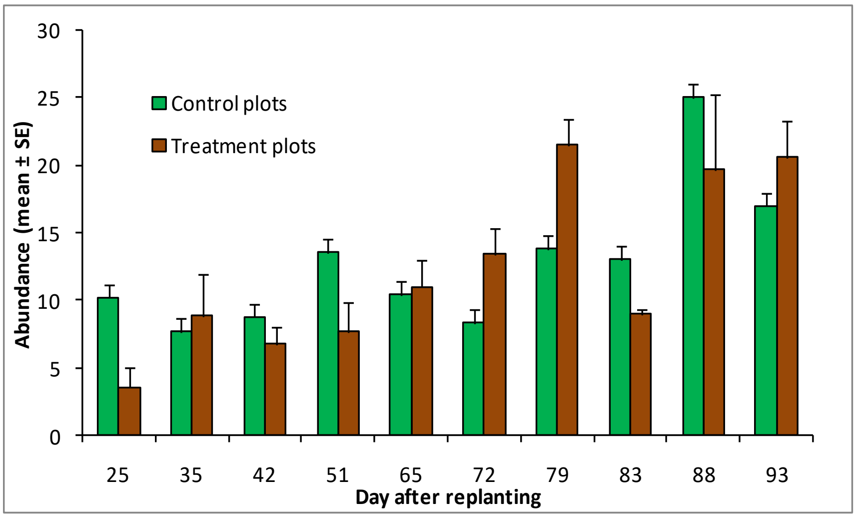

Figure 1. The temporal variation of abundance (mean ± SE) of Arthropod in paddy field adjacent to refugia area (treatment) and far from refugia area (control).

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The abundance of Arthropod in treatment plots fluctuated from the 25 DAR and peaked in 79 DAR then decreased in 83 DAR and increased again in 88 to 91 DAR. Those in controls were fluctuated slightly and peaked in 88 DAR (Figure 1).

Statistical analysis of variance showed that the taxa richness ($F = 5.9$; $P < 0.05$) and diversity ($F = 9.2$; $P < 0.01$) of Arthropod visitors were significantly higher in treatments; while there were no significant differences of the abundance between treatment and control. Treatment also had a significant effect to many groups. Coccinellidae, Chlorophidae, Coenagrionidae and Oxyiopidae were more abundant in treatment plots, while Formicidae and Alydidae were more abundant in control plots (Table 2). However, Acrididae and Libelullidae were not significantly different between treatment and control plots.

Reproduction phase had a significant effect to many groups. The abundances of most taxa were also significantly higher in the treatment plots. These included several dominant groups such as Alydidae, Acrididae, and Libellulidae. However, the abundance of Formicidae, Coccinellidae, Coenagrionidae and Oxyiopidae were not significantly different between vegetative and generative phase (Table 2).

Table 2. Summary of *F* values followed by degree of significance using General Linear Model Analysis of variance (ANOVA) of the abundance, taxa richness and diversity of several Arthropod visitor families.

Group	Treatment	Reproduction phase	Time
Formicidae	13.2***	2.5	0.3
Alydidae	6.1*	11.3**	0.2
Acrididae	0.3	4.5*	0.1
Coccinellidae	10.7**	2.3	1.2
Chlorophidae	6.4*	8.6**	1.3
Libellulidae	0	7.6**	8.7**
Coenagrionidae	10.7**	2.3	1.2
Oxyopidae	8.7**	0.1	0.9
Abundance	0.1	19.1***	1.4
Taxa richness	5.9*	24.7***	0.2
Diversity	9.3**	6.5*	0.2

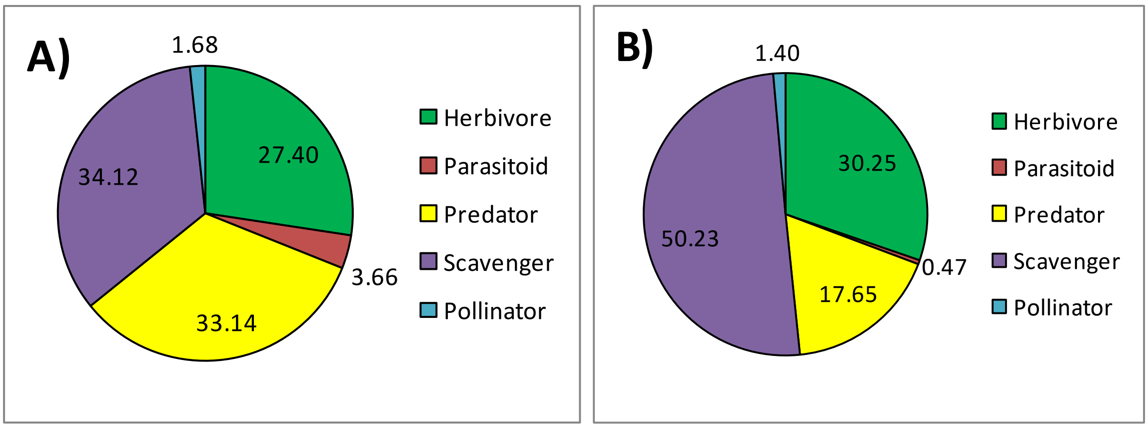

Figure 2. Arthropod functional group proportions (%) based on the abundance in treatment (A) and control (B) areas.

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The composition of functional group was dominated by scavenger both in the treatment and control plots. Proportion of predator in the treatment plots was higher (33.14) that in the control plots (17.65); while that of herbivore was vice versa. Herbivores were higher in control (30.25%) than in the control plots (27.40%). A small portion of Pollinators and Parasitoid was occurred in the study sites, both are higher in treatment that in the control (Figure 2). This result showed that predator was more abundant in treatment plot. The predators prefer to inhabit the treatment than in the control plots.

Canonical Correspondence Analysis (CCA) revealed that environmental variables were significant for explanation of the variance in species abundance pattern. The sum of the first two canonical eigenvalues was 0.26. The first axis, explained 57% of the family-environment relations, while the second explained 35.8 % of the family-environment relations. Treatment ($P <$ 0.01) and reproduction phase ($P < 0.01$) were significant factors in explaining variation in community composition, while temperature and humidity had no significance effect ($P < 0.05$).

The score of the CCA for families were plotted in Figure 2. This figure showed the classification of the families into three groups. Group I was more abundant in treatment plots and occurred in the morning. This group included Coccinellidae, Coenagrionidae, Muscidae, Tettigoniidae and Apidae. Pompilidae. Group II was highly abundant in control plots and occurred in the morning. This group included Formicidae, Alydidae, Libellulidae, Staphylinidae, Tephritidae, Pieridae, Ceratopogonidae and Pompilidae. Group III was more abundant in treatment plots and occurred in the afternoon. This group included Acrididae, Chloropidae, Oxyiopidae, Delphacidae, Miridae, Sarcophagidae, Tabanidae and miscellanies (Figure 3).

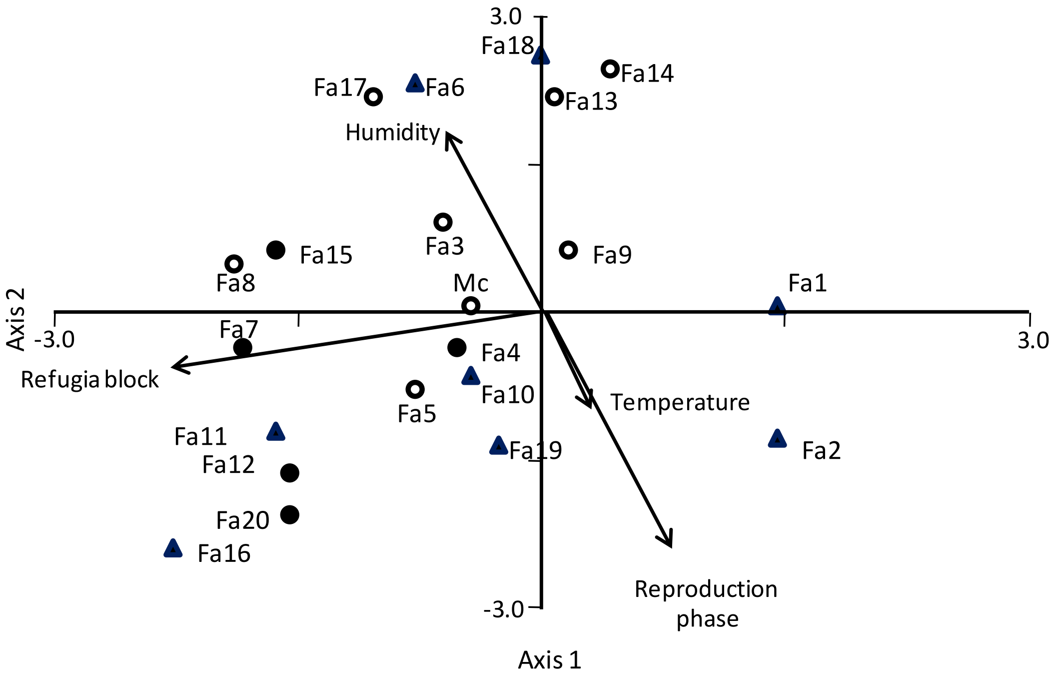

Figure 3. Ordination of family compositions responding to environment factors: arrows represent degree of environmental variable. The code of families enclosed was grouped by k-means clustering. Numbers in family score are as follows: Fa1. Formicidae, Fa2. Alydidae, Fa3. Acrididae, Fa4. Coccinellidae, Fa5. Chlorophidae, Fa6. Libellulidae, Fa7. Coenagrionidae, Fa8. Oxyopidae, Fa9. Delphacidae, Fa10. Staphylinidae, Fa11. Tephritidae, Fa12. Muscidae Fa13. Miridae, Fa15. Sarchophagidae, Fa16. Tettigoniidae, Fa17 Pieridae, Fa16. Tabanidae, Fa18. Ceratopgonidae, Fa19. Pompiilidae and Fa20. Apidae.

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Refugia area supported a change in Arthropod composition that affects the decrease in the proportion of herbivore. This is due to the existence of predators which favorable from the existence of refugia plants. The predators are able to suppress the herbivore population. Several studies in agricultural ecosystem suggest that an increase in the diversity of insect predators and parasitoids can have effects on prey consumption rates (Letourneau and Bothwell, 2008). Furthermore, refugia area also provides an alternative habitat for parasitoids, thus allowing parasitic processes that suppress pest populations. Thus, the presence of refugia areas is able to maintain the balance of Arthropod composition and ultimately maintain the balance of the ecosystem. The taxa richness and diversity were greater in plot adjacent to refugia areas than those in plot far from refugia areas (control). Refugia areas support the Arthropod by provide shelter, feed sources, and other resources. Interestingly, the abundance showed different situation. This may because the appearance of predator and parasitoid lead to herbivore population decrease. The presence of modified habitat by planting Refugia plants increased the habitat complexity. This may increase the natural enemy population that enable to control pest population in complex habitats compared to simple habitats. Pest repellents that are driven by complex landscapes can cause lower plant injuries. Enhanced natural enemy activity was associated with herbaceous habitats in 80% of the cases (e.g. fallows, field margins) (Bianchi et al. 2006).

In this study, a high composition of scavenger was observed. Scavenger acts as a waste feeder such as fallen fruit, animal waste and decaying fallen leaves. The possible explanation of the highest abundant was that the paddy field was rich in resources for scavengers, such as compost fertilizer, animal waste and decaying plants. The decrease in the proportion of scavenger in the area treatment indicates a balance between functional groups. This balance is important because it can maintain healthy ecosystem sustainability. One of the common scavenger groups is Formicidae. This study showed the huge number of ants (Formicidae) observed both in treatment and control. Formicidae are predominantly dominant in a variety of habitats e. g in olive cultivation fields, konjack, grassland, farmland (Leksono *et al*., 2011; Onyeka and Ugwumba, 2013; Zayadi *et al*., 2013; Azmi et al., 2014). Formicidae occupies several functional roles in the ecosystem including as nectar feeder, predator, scavenger and seed feeder (Widyastuti, 2002). A study conducted in rice fields in the Philippines shower that 14 species of Formicidae were identified as potential predators of which the very aggressive. Those included *Solenopsis geminata* and *Tapinoma* sp. Other ant species act as soil engineer, for example, the nest mounds constructed by ants can improve nutrient enrichment for the plant (Wilby et al. 2001).

Refugia area may support multiple predators such as Coccinellidae, Coenagrionidae and Oxyopidae. Meanwhile, the effect of refugia area is not significant against Libellulidae. Libellulidae or Dragonflies is known as an active predator that easily seeks broader habitat, while the first group is a less active group of Arthropods.Libellulidae and Coenagrionidae are belong to Odonata. The families are all predatory Arthropods inhabit habitat close to the water resource. In East Java, a paddy field is one of the suitable habitats for this group (Leksono *et al*., 2017). In this study dragonflies were seen preying on grasshoppers and Aleyrodidae. Dragonflies for example species *O. sabina* was reported to prey on Acrididae and Hesperidae such as *Pelopidas conjunctus*. Other groups also devoured by dragonflies are Crambidae, Alydidae, Aleyrodidae, Pentatomidae Culicidae, Muscidae, Chironomidae, Tephritidae, Acrididae, Gryllidae, Tetrigidae (Dalia and Leksono, 2014). The abundance of those families in treatment

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plots may relate with the behavior to select open area. The Coccinellidae, a family belong to Coleoptera group is among a common predator in paddy field habitat (Sunariah *et al*., 2016). In general, Coccinellidae prey small insects such as Aphididae and Aleyrodidae. In addition to the two groups, Oxyopidae (Lynx spider) which are a group of spiders were also quite dominant. In this study the Oxyopidae was observed to inhabit their web at the middle of paddy foliage. The importance of spiders in the conservation biological control is being increasingly realized due to their abundance. A study in India showed that species Oxyopidae can be effective in regulating the population of the gregariously occurring lepidopteran larvae, hence contributing to biological control of insect pests such as *Spodoptera litura* (Shivakumar and Kumar, 2010). A study in Sri Lanka showed that Paddy field is also commonly inhabited by three spider groups. The first group made a nest in the top leaves of rice plant from where they prey upon the rice pests and other insects. The second group made the web at the base of rice plant. The third group is cursorial hunting spider which is ambush prey while hiding among the foliages.

This study showed that Arthropod compositions in treatment and control plots differ remarkable. This result meant that refugia areas attracted more Arthropod group and raise the taxa richness and diversity. The increase in the diversity may lead the ecosystem stability and sustainability. Several plants are known to attract insects, including chili (Leksono *et al*., 2012). Group of Arthropod visitors include *Phygadeuon* sp., *Spathius* sp., Coccinellidae and Apidae. A previous study in the apple orchard showed the structure of the community of pollinator insects attracted to wild plant are Apidae, Specidae, Formicidae and Syrphidae (Abidin *et al*., 2013).

In general, Arthropods were active in the morning, but there were also active in the noon or afternoon. The tendency of Arthropod grouping in nearby habitats with the refugia area as well as activity at different times indicates a foraging pattern influenced by the availability of prey. In each group there was also a balanced composition between herbivore and predator. This means that each group was populated by both functional groups. This shows a positive situation because in all habitats predators were able to demonstrate their performance to control herbivore population.

Conclusion

This study showed that the species richness and diversity of Arthropod visitors was affected by Refugia area. The species richness in the treatment plots (12.2 ± 0.70) was higher than that in control (9.70 ± 0.51). The diversity of Arthropod visitors in the treatment plots (2.10 ± 0.07) was also higher than that in control (1.71 ± 0.07). Overall, Formicidae, Alydidae, Acrididae and Coccinellidae were dominant in the observation composing about 46.7% individual (18% in treatment plots, and 28.7% in controls). Refugia area supported a change in Arthropod composition that affects in the decrease in the proportion of herbivore and creating a functional group composition balance.

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