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1. **Manuscript Title**

**Diversity and Community Structure Of Arthropods On Rice Ecosystem’ In Aceh Province, Indonesia**

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**DIVERSITY AND COMMUNITY STRUCTURE OF ARTHROPODS ON RICE ECOSYSTEM IN ACEH PROVINCE, INDONESIA**

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**ABSTRACT**

Arthropods biodiversity in a rice ecosystem plays an important role in deciding the pest management methods. A research to investigate the diversity and community structure of arthropods in the rice ecosystem has been conducted in Aceh Province, Indonesia. Arthropods samplings were done using sweeping insect net on four rice plots locally grown. The samplings were done on 35 days after transplanting (DAT), 45 DAT, and 55 DAT representing vegetative, transition, and generative stages of rice growth consecutively. There were 25 morpho-species found on vegetative stage of rice plantation, which was higher than those found on transition and generative stages. They were categorized as phytophagous insects, spiders, predatory insects, parasitoid, and neutral insects. Each category of arthropods had higher abundance in vegetative stage of rice plantation, except for phytophagous insects which significantly had higher abundance in generative stage. The *Shannon-Weaver* H' index was significantly higher in vegetative stage of rice plantation than those of in later stages, while *Simpson Dominance* C and *Pielou evenness* J indices were not significantly different among the three stages observed. The results of this study have provided useful foundation and information for integrated pest management methods to be applied in the area.

**Keywords: biological control, food crop, natural enemies, parasitoid, predator**

**INTRODUCTION**

Rice (*Oryza sativa* L.) is a staple food for most people in Indonesia. Rice plantation is a rapid changing ecosystem due to the change of activities during cultivation. These activities affect not only the pest population, but also the abundance of their natural enemies in the rice field (Khaliq, et al., 2014, Tsutsui, et al., 2018) Some of the insect pests that are known to harm the rice plantation are *Leucopholis rorida* (Fabr.) (Coleoptera: Scarabaeidae), rice shoot fly *Atherigona oryzae* Malloch (Diptera: Muscidae), white stem borer *Scirpophaga (Tryporyza) innotata* (Walker) (Lepidoptera:Crambidae), rice bug *Leptocorisa oratorius* Thunberg (Hemiptera:Coreidae), and brown plant hopper *Nilaparvata lugens* (Stål) (Hemiptera:Delphacidae) (Ooi, 2015, Thorburn, 2015). Reduction of rice production caused by the pests can reach 40-55 % or even worse (Herianto, et al., 2015).

The increase of Indonesian population has also driven the higher need to increase the rice production, however many rice farmers are still very much dependent on chemical pesticides (Kalsum & Romza, 2014). The excessive use of chemical pesticides i.e. insecticides can lead to pest resistance, resurgence, the killing of non-target organisms (such as natural enemies), ground water contamination, change of soil microbial diversity, and risks to human health (Gill & Garg, 2015). Integrated pest management (IPM) strategies have been developed in order to control rice pests in the field. IPM is defined as a holistic strategy to decrease plant pests and diseases using all available and compatible methods, but minimizing the use of chemical pesticides (Stenberg, 2017; Matthews, 2017). Several methods of pest control which are more environmentally friendly such as biological and mechanical controls, and also botanical pesticides are employed in IPM (Borkhani, et al., 2010). Integrated Pest Management (IPM) has been adopted formally as the principle of plant protection in Indonesia through the government regulation number 12 in the year 1992. Years before that (the mid-1980s) Indonesia introduced integrated pest management (IPM) as a new crop management approach particularly for rice plantations and developed the Farmer Field School (FFS) model of empowering farmers to make their own decisions regarding management of their rice field. However, FFS was not no longer practiced since the late 1990s, and nowadays, rice farmers tend to use pesticides with many negative consequences occur in the field (Thorburn, 2015)

There have been many studies conducted to preserve beneficial organisms such as natural enemies which can be used as biological control agents (Sanda & Sunusi, 2014, Ovawanda et al., 2016). These natural enemies (predators and parasitoids) instinctively can also play an important role in regulating the pest population. Therefore, the maintenance of biodiversity, including predator and parasitoid, within the rice ecosystem is important to enhance their role in natural control or as biological control agents (Ueno, 2013). After rice establishment, arthropod species colonize and over time progressively increase in diversity. Their communities may vary with the environment, varieties, cropping patterns, and cultivation practices.

Biodiversity refers to the species variety or number present in an area or ecosystem (Price et al., 2011). Rice fields often support high levels of biodiversity, which play an important role in the agricultural productivity of the systems. An important aspect of IPM is to enhance natural control in the rice plantation, therefore, the presence of various species of arthropods and their population ecology are important things to be considered when designing pest management methods. The arthropod community in rice fields is known have different ecological roles, they include pests, natural enemies (predators and parasitoids), saprophytes and aquatic arthropods. These different groups can perform a stability in rice field ecosystem (Luo, et al., 2014). Their communities’ structure may differ according to environment, rice varieties, and cultivation practices employed (O’Malley 1999). Many studies in Asia have shown that when the use of pesticides was reduced to conserve the predator communities, the destruction of rice plantation by the insect pests such as *N. lugens* is decreased (Thorburn, 2015).

One of the major limitations in promoting natural and biological controls as part of IPM strategies is that not many farmers realize the role of arthropod groups found in their rice fields. They cannot differentiate pests from beneficial organisms, and they often just apply pesticide when they see species of arthropods in the rice field. Aceh Besar Regency is one of the centres for rice production in Aceh Province. Based on our preliminary interview with the rice farmers in this area, most of them think that any insect or other arthropods found on the rice plantation are pests that damage the plants. The fact that some of the arthropod groups are beneficial in regulating pest populations is new information for them. This research was conducted to identify arthropod species and to investigate the diversity and community structure of arthropods, in the conventional rice ecosystem grown by local farmers. The results can be used in assessing conservation plan of natural enemies in the rice ecosystem in order to promote natural and biological controls as part of IPM approach.

**MATERIALS AND METHODS**

**Arthropod Samplings**

The study took place in Lembah Seulawah District, Aceh Besar Regency from February to August 2016. The study site is one of rice production area in Aceh Province, having an altitude of 360 m above sea level. The arthropod samples were taken using sweeping insect nets from four plots that belong to local farmers in two nearby villages. The plots size ranged from 1500 m2 up to 3400 m2) (Table 1.). All rice fields in this area were surrounded by secondary forest ecosystem consisting different species of plants. The same variety of rice (Inpari-36) was planted in each plot. There was no particular treatment applied to the plots. Rice cultivation was employed as commonly practiced by the farmers. In this area, pesticides application was quite high, ranged from two to four times during the rice plantation.

The research was conducted from February to August 2016. The samplings were done between 07.00 – 10.00 am using a sweeping insect net on at least 10 % of plot size consisting five sub-areas in each plot. The five sub-areas were selected in a diagonal way, four on the side and one in the middle of each plot. The samples were collected at least one meter from the edge of each plot in order to reduce edge effects. The arthropod samples taken were mainly the ones flying above and near the surface of the rice plantation. The arthropods were sampled three times in each plot, namely 35 days after transplanting (DAT), 45 DAT, and 55 DAT. Each represented vegetative stage, transition stage, and generative stage of rice growth consecutively. All sampled arthropods were kept in plastic bottles containing liquid of 70% ethanol and were brought to the Biological Control Laboratory Agriculture Faculty, Syiah Kuala University for further identification. The collected arthropods were then classified into 5 groups: phytophagous insects (pests), spiders, predatory insects, parasitoid, and neutral insects. Individual number of each Arthropod category was calculated to define its population. The diversity indices (the Shannon-Weaver diversity index H', the Pielou-eveness index J, and the Simpson dominance index C.) were used to represent the species diversity in each phase of rice plantation.

**Data Analysis**.

The differences among the number of individual arthropods based on different functional groups were analyzed using analysis of variance (ANOVA of logarithmic data). Means were separated with the Tukey-test when ANOVA analysis shows any significant difference (P<0.05). The same analysis was done for each of diversity indices of the arthropod in the three stages of rice growth. All analysis were done using R Statistical Software version 3.3.1 (2016-06-21). Results were shown as means ± SE throughout the text.

**RESULTS AND DISCUSSION**

**Species richness and abundance.**

In total there were 2454 individuals arthropods collected during the three phases of rice plantation. They all belonged to two classes, nine orders, 20 families and 25 morphospecies. The morphospecies and corresponding taxa of the specimens collected are shown in Table 1. Number of species found on vegetative stage of rice plantation (25 species) were higher than those on transition and generative stages of the plantation (16 species each) (Table 2). The species richness of arthropods in the rice plantation depends on the location of study, cultivation technique, and sampling methods (Zhang et al. 2013). In South Kalimantan, earlier study has shown that number of species and their abundance are higher in the rice field that were received an IPM system of cultivation than those in the non-IPM system. Number of Arthropods species found was more than 50 species in IPM system of rice field. However, the arthropods samples in the study were caught using four kinds of trap: insect nets, yellow sticky traps, light trap and pitfall trap (Samharinto et al. 2012). Here in our study site, pesticides were used 2-4 times during the rice growth in each plot of the study. Besides, the arthropods samples were taken using one method only (sweeping insect nets). It means the arthropods caught in this study were only the ones flew over the rice plantation or the ones found on the surface of rice plantation. The arthropods that were deep in the plantation or staying in the ground might have been missed. These two factors might contribute to less species richness in the area compared to those found in earlier study. Pesticides have been known as one of major factors affecting biological diversity with serious negative impacts on pollinators, other invertebrates, amphibians and birds. In a short term, pesticide may have toxic effects to directly exposed organisms, or in a long term they may cause changes in habitat and food chains (Chagnon et al., 2015).

Three species of predators were always caught from each plot, namely *Tetragnatha maxillosa* (Araneae:Tetragnathidae) *Agriocnemis femina* (Odonata:Coenagrionidae), dan *Verania lineata* (Coleoptera: Cocinelidae). These three species are known as general predators. The availability of their prey in all stages of rice growth probably had maintained their population in the field. Spiders have been known as important natural enemies of pests and also as indicators of biodiversity in rice field ecosystems (Betz & Tscharntke, 2017; Tanaka, 2016). *Tetragnatha maxillosa* is a spider species that is very active during the night and preys upon brown plant hopper (*N. lugens*), leaf hopper (*Nephotetteix* spp.) and some other insect pest species (Betz & Tscharntke, 2017). Spider diversity is significantly dependent on vegetation structure (Landsman & Bowman, 2017). The abundance and species richness of spiders are higher in the abandoned fields in which more plant species grown than in rice fields (Baba et al., 2019). More species of spiders and/or more numbers might have occurred in the lower levels of the rice vegetation or at the base of the tillers. They might be missed by insect net that was used in this study. *Agriocnemis femina* is a small damselfly that consumes other small insects while *V. lineata* is a predator species that mostly consumes brown plant hopper and leaf hopper (Herianto, et al. 2015),

Mean number of individual arthropods collected per plot based on different functional categories are presented in Table 3. Number of species across each category varied greatly and almost all categories had higher number of individuals in vegetative stage of rice growth, except for phytophagous insect. All phytophagous insects found were known as pests in rice plantation. This study showed that the abundance these phytophagous insects was higher significantly (F= 8.31, P= 0.009) in generative stage of rice growth than those of transition and generative stages. The high frequency of pesticide application in the study site might decrease the other arthropods abundance in later stages of rice plantation (Kartohardjono 2011; Ueno 2013). The number of spiders collected in vegetative stage of rice growth was significantly higher (F= 9.74, P=0.005) than those in transition and generative stages. However, in the three stages of rice growth, the difference among the numbers of predatory insects was not significant (F= 1.65, P=0.24).

*Culex* sp. (Diptera : Colicidae) was categorized as a neutral insect species (Widiarta, *et al*. 2006). The abundance of this species was very high in vegetative stage of rice growth and none of them was found in later stages. The watery rice field in earlier stage of plantation was a suitable site for larval development of *Culex.* This mosquito species develops inside standing fresh water, such as puddles, pools, ditches, tin cans, and water storage tanks. The neutral insect species may have an important role in rice field ecosystem, they could serve as an alternative prey when the main ones are not available for natural enemies to consume (Pradhana, *et al*. 2014).

**Species diversity and dominance.**

Table 4 shows diversity indices calculated from four plots in each stage of rice growth. the *Shannon-Weaver* H', the *Simpson Dominance* C, and the *Pielou evenness* J were calculated for each stage of rice growth. The *Shannon-Weaver* H' index was significantly higher in vegetative stage of rice growth (F=4.66, P=0.04) than those in transition and generative stages. Both *Simpson Dominance* C (F=3.91, P=0.06), and the Pielou evenness J (F=2.45, P=0.14) indices were not significantly different among the three stages of rice growth. According to Zhang *et al*. (2013) diversity of arthropod community varies greatly in different seasons and in rice growth stages. The results in the present study showed that the three indices varied across different stages of rice growth, even though only the *Shannon-Weaver* H' index that was significantly different. The *Shannon-Weaver* H' index less 0.60 means that the community structure is not stabil, while the index that lies between 0.61-1.20 means that the the ecosystem less stabil (Krebs 1989).

The composition of species based on each functional category showed a different trend in the three stages of rice growth. With respect to species abundance, 63 % of total individual numbers of arthropods was collected in vegetative stage of rice growth compare to 21 % in transition stage and only 16% in generatif stage. However, the distribution of each fungsional category in vegetative stage was quite homogen compared to the distribution in transition and generative stages (Figure 1). İn transition stage, arthropods community was dominated by predatory insects (64%) while in generative stage, it was dominated by phytohagous insects (63%). The availability of neutral insect is the highest (30%) compare to other functional category in vegetative stage of rice growth. The presence of this neutral insect in earlier stage of rice growth may caused higher composition of predatory insects in transition stage. The neutral species has been known to play an important role in the community food web in rice fields (Zhang *et al*. 2013).

The predatory insect found in transition stage of rice growth was dominated by the species *Verania lineata* (Coeloptera: Coccinellidae), while the majority of phytophagous insects collected in generative stage was the species *Leptocorisa oratorius* (Hemiptera:Coreidae). The high density of the species *L. oratorius* was corresponded to the stage of rice growth. The samplings for generative stage of rice were done on 55 DAT, the stage where the rice plantation just formed panicles and their content were still soft. This stage of rice growth was very much attracted to the species *L. oratorius* which feeds on the sap of the panicles rice. The rice bug *L. oratorius* is a common and conspicuous insect that emits a strong odour. *L. oratorius* is the dominant species associated with lowland rice in Indonesia (As’ad et al., 2018). In this study we have shown that despite the use of pesticide by local farmers in their field rice, natural enemies especially predators still exist. Their presence in rice fields can be used to enhance natural control and to reduce the pesticide application. The results of this study can be used as basic information for the farmers to get to know more about pests and beneficial organisms in their own rice fileds. Furthermore the results of this study have provided useful foundation in designing suitable IPM methods in their rice fields.

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**CONCLUSIONS AND SUGGESTION**

This study has shown the arthropod community structures and the dynamics of phytophagous insects, spiders, predatory insects, neutral and parasitoid groups in local rice ecosystem in Lembah Seulawah District, Aceh Besar regency, Aceh Province. The species richness found quite varied, however there were several common species found in each plot sampled, namely *Tetragnatha maxillosa* (Araneae:Tetragnathidae) *Agriocnemisfemina* (Odonata:Coenagrionidae), and *Verania lineata* (Coleoptera: Cocinelidae). The presence of these general predators may have played an important role in limiting the pest population in the rice field observed. The study has provided useful foundation and information for designing integrated pest management strategies.

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Table 1. Rice plantation plots that were used as the sampling sites in Lembah Seulawah District, Aceh Besar Regency

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Village** | **Plot Number** | **Plot Size** | **Location Coordinates** | |
|  |  |  | **East** | **North** |
| Lon Baroeh | Plot 1 | 3.400 m² | 95⁰66'109'' | 5⁰35'952'' |
|  | Plot 2 | 3.000 m² | 95⁰66'280'' | 5⁰36'194'' |
| Lon Asan | Plot 3 | 1.700 m² | 95⁰66'493'' | 5⁰35'829'' |
|  | Plot 4 | 1.500 m² | 95⁰66'73'' | 5⁰35'762'' |

Table 2. The morpho-species and corresponding taxa of arthropods communities collected in Lembah Seulawah District, Aceh Besar Regency, Aceh Province (Morpho-species data from four plots were combined altogether and the same species that were sampled in more than one plot were counted once).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Rice field stage | Order | Family | Morpho-species | Category |
| Vegetative | Araneae | Tetragnathidae | *Tetragnatha maxillosa* | Spider |
|  |  | Araneidae | *Araneus inustus* | Spider |
|  |  | Linypidae | *Atypena formosana* | Spider |
|  |  | Oxyopidae | *Oxypes javanus* | Spider |
|  | Coleoptera | Coccinellidae | *Verania lineata* | Predatory insect |
|  |  |  | *Micraspis crocea* | Predatory insect |
|  |  | Carabidae | *Ophionea nigrofasciata* | Predatory insect |
|  | Odonata | Coenagrionidae | *Agriocnemis femina* | Predatory insect |
|  |  |  | *Agriocnemis pygmea* | Predatory insect |
|  |  | Libellulidae | *Diplocodes trivialis* | Predatory insect |
|  | Orthoptera | Tettigonidae | *Conocephalus longipennis* | Predatory insect |
|  |  | Gryllidae | *Metioche vittaticollis* | Predatory insect |
|  |  | Acrididae | *Oxya chinensis* | Phyto insect\* |
|  |  |  | *Valanga nigricornis* | Phyto insect\* |
|  | Hemiptera | Coreidae | *Leptocorisa oratorius* | Phyto insect\* |
|  | Homoptera | Cicadellidae | *Nephotettix virescens* | Phyto insect \* |
|  | Lepidoptera | Pyralidae | *Cnaphalocrosis medinalis* | Phyto insect\* |
|  |  |  | *Scirphophaga innotata* | Phyto insect\* |
|  | Hymenoptera | Braconidae | *Apanteles sp.* | Parasitoid |
|  |  |  | *Macrocentrus philippinensis* | Parasitoid |
|  |  | Ichneumonidae | *Tryphon sp.* | Parasitoid |
|  |  |  | *Xanthopimpla flavolineata* | Parasitoid |
|  | Diptera | Tachinidae | *Gonia picea* | Parasitoid |
|  |  | Pipunculidae | *Pipunculus mutillatus* | Parasitoid |
|  |  | Colicidae | *Culex sp.* | Neutral insect |
| Transition | Araneae | Araneidae | *Araneus inustus* | Spider |
|  |  | Tetragnathidae | *Tetragnatha maxillosa* | Spider |
|  |  | Linypidae | *Atypena formosana* | Spider |
|  | Coleoptera | Coccinelidae | *Verania lineata* | Predatory insect |
|  |  | Carabidae | *Ophionea nigrofasciata* | Predatory insect |
|  | Odonata | Coenagriocnidae | *Agriocnemis femina* | Predatory insect |
|  |  |  | *Agriocnemis pygmea* | Predatory insect |
|  | Orthoptera | Tettigonidae | *Conocephalus longipennis* | Predatory insect |
|  |  | Gryllidae | *Metioche vittaticollis* | Predatory insect |
|  | Hemiptera | Coreidae | *Leptocorisa oratorius* | Phyto insect\* |
|  | Homoptera | Cicadellidae | *Nephotettix virescens* | Phyto insect\* |
|  | Lepidoptera | Pyralidae | *Cnaphalocrocis medinalis* | Phyto insect \* |
|  | Hymenoptera | Braconidae | *Macrocentrus philippinensis* | Parasitoid |
|  | Diptera | Tachnidae | *Gonia picea* | parasitoid |
|  |  | Pipunculidae | *Pipunculus mutillatus* | parasitoid |
|  |  |  |  |  |
| Generative | Araneae | Tetragnathidae | *Tetragnatha maxillosa* | Spider |
|  |  | Coenagriocnidae | *Araneus inustus* | Spider |
|  | Odonata | Coenagriocnidae | *Agriocnemis femina* | Predatory insect |
|  |  | Coenagriocnidae | *Agriocnemis pygmea* | Predatory insect |
|  | Coleoptera | Coccinelidae | *Verania lineata* | Predatory insect |
|  |  | Carabidae | *Ophionea nigrofasciata* | Predatory insect |
|  | Hymenoptera | Braconidae | *Apanteles sp.* | Parasitoid |
|  | Diptera | Tachnidae | *Gonia picea* | Parasitoid |
|  | Orthoptera | Carabidae | *Conocephalus longipennis* | Predatory insect |
|  |  | Gryllidae | *Metioche vittaticollis* | Predatory insect |
|  |  | Acrididae | *Oxya chinensis* | Phyto insect\* |
|  |  |  | *Valanga nigricornis* | Phyto insect\* |
|  | Hemiptera | Coreidae | *Leptocorisa oratorius* | Phyto insect\* |
|  |  | Pantatomidae | *Nezara viridula* | Phyto insect\* |
|  | Homoptera | Cicadellidae | *Nephotettix virescen* | Phyto insect\* |
|  | Lepidoptera | Pyralidae | *Scirphopaga innotata* | Phyto insect\* |
|  |  |  |  |  |

Table 3. Mean number of individual arthropods caught ((Mean ± SE) per plot based on different functional groups from three different stages of rice growth in Lembah Seulawah District, Aceh Besar Regency, Aceh Province

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Stage of Rice Growth | Phytophagous insects | Spiders | Predatory insects | Neutral insects | Parasitoid insects |
| Vegetative | 28 ± 5.13 a\* | 80 ± 19.58 a\* | 62 ± 13.93 a\* | 189 ±157 | 25 ± 13.86 |
| Transition | 17 ± 7.33 a | 18 ± 5.94 b | 65 ± 10.55 a | 0 ± 0.00 | 3 ± 2.5 |
| Generative | 80 ± 11.66 b | 7.0 ± 4.57 b | 39 ± 8.32 a | 0 ± 0.00 | 1 ± 0.50 |

Remarks: \*Mean values within a column followed by the same letters are not significantly different at p < 0.05 according to the Tukey-test

Table 4. Diversity indices of arthropods community collected (Mean ± SE) calculated from four plots in different stages of rice growth in Lembah Seulawah District, Aceh Besar Regency, Aceh Province

|  |  |  |  |
| --- | --- | --- | --- |
| Stages of rice growth | Diversity index | | |
| Shannon-Weaver, H´ | Simpson Dominance, C | Pielou Evenness, J |
| Vegetative | 0.88 ± 0.11 a | 0.51 ± 0.06 a | 0.31 ± 0.03 a |
| Transition | 0.47 ± 0.11 b | 0.72 ± 0.08 a | 0.21 ± 0.05 a |
| Generative | 0.67 ± 0.01 b | 0.54 ± 0.01 a | 0.31 ± 0.01 a |

Remarks: \*Mean values within a column followed by the same letters are not significantly different at p < 0.05 according to the Tukey-test



Figure 1. Composition of each fungsional category of Arthropods sampledd from four plots in different stages of rice growth in Lembah Seulawah District, Aceh Besar Regency, Aceh Province