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Diversity Relation Between Soil Mesofauna and C-organic Content in Pepper Plantation Area, Petaling, Bangka Belitung Islands

Ratna Santi
Faculty of Agriculture, Fisheries and Biology
University of Bangka Belitung
Indonesia
ratnasanti_ubb@yahoo.com

Deni Pratama
Faculty of Agriculture, Fisheries and Biology
University of Bangka Belitung
Indonesia
deni.pratama16@gmail.com

Riwan Kusmiadi
Faculty of Agriculture, Fisheries and Biology
University of Bangka Belitung
Indonesia

Robiansyah
Faculty of Agriculture, Fisheries and Biology
University of Bangka Belitung
Indonesia

***Abstract*— Forest was source of biodiversity. Forest conversioninto plantation area causes disruption to existence of soil mesofauna such as Collembola and Acarina. Soil mesofauna have a role to decomposition of organic matters in soil. Purpose of this research is to know the diversity of soil mesofauna and relation between diversity of soil mesofauna and the C-organic content in pepper plantation area in Petaling Village, Bangka Regency, Bangka Belitung Islands. Experiment conducted at three pepper plantation area. Identification of soil mesofauna conducted in the Microbiology Laboratory, Faculty of Agriculture, Fisheries and Biology, University of Bangka Belitung in December 2016 to February 2017. Method used was descriptive correlational with survey technique. Sampling technique used purposive sampling technique and soil sample collected by using ring sample. Separation of soil mesofauna used Berlese-Tullgren funnel. Correlation analysis used was IBM SPSS Statistics Version 21.The results of experiment indicate that the value of soil mesofauna diversity was 1.114 and goes to criteria of medium diversity. Correlation coefficient value between soil mesofauna diversity and C-organic content was 0.335. The positive correlation value means that increased diversity followed by increased C-organic content in the soil.**

Keywords*—Bangka Belitung Islands, C-organic, Diversity, Soil Mesofauna, Pepper

I. INTRODUCTION

The existence of vast forests makes Indonesia as rich country in biodiversity. It is estimated about 27% of various species in the world are in Indonesia. Biodiversity of flora and fauna in Indonesia is about 245,000 species makes Indonesia referred as the state of Mega Biodiversity. Biodiversity among living organism belongs to species, between species, and ecosystems. Ten percent of natural ecosystems are nature reserves, wildlife sanctuaries, national parks, protected forests, and some are for the benefit of germplasm cultivation [14].

Forest is a natural habitat for the soil organism to sustain its life. Soil fauna have an important role in maintaining the balance of forest ecosystems. Land transformation from forests into plantation area is one of the disturbances factors that can affect the existence of soil fauna in ecosystem, because of that, existence of soil fauna such as mesofauna can be used as an indicator of soil environment changes [19]. Piper plantation (*Piper nigrum* L.) is a form of land transformation from forest into plantation land.

The existence of soil mesofauna is very dependent to availability of energy and food sources. Energy and food sources are organic materials which are related to flow of soil carbon cycle. Availability of energy and nutrients for the soil mesofauna can maintain the development and activity of mesofauna itself, and have positive impact to soil fertility [4].

Soil mesofauna plays a role as bio-indicator to environment or ecosystem quality. Soil system, soil mesofauna interaction is difficult to avoid, because it involve in soil food webs. Soil mesofauna serves as producer of soil organic compound in the soil ecosystem. In the pepper cultivation area, soil mesofauna obtains energy and food from fragmentation of organic material by soil macrofauna which then goes through the decomposition process by various soil microorganisms [20].

Mesofauna is part of a soil fauna that have body length about 100 μm - < 2 mm [5]. Types of mesofauna that have an important role in soil biological processes include Collembola (spring tail) and Acarina (mites). Collembola and Acarina generally live on the soil surface with humid conditions. Collembola feeds on bacteria, hyphae, and fungal spores and also decomposing organic matter, while Acarina have little contributes to chemical decomposition of plant residues and also some of Acarina related to the late stages of the decomposition process. The population and type of Collembola and Acarina in the soil depend on soil conditions. Plantation land as a form of forest conversion will determine the population and type of Collembola and Acarina due to changing soil conditions. On plantation land, population and biomass of Collembola and Acarina at cultivation layer (15 cm) are 4 x 10^5 and 2 kg / ha [2].

Collembola as an indicator of soil conditions has been widely used. It because Collembola is able to occupy a large number of ecological niches in high diversity and sensitive to ecosystems changes such as changes of water content, humidity [2], or to certain chemical elements [11]. Collembola and Acarina also play an important role in the fragmentation of organic material. The result of fragmentation causes an increase of surface area which will further increase the activity of soil microbes so that organic matter in the soil remains available.

Knowledge of the soil mesofauna diversity is very important to estimate the soil fertility. Lack of information of soil mesofauna in pepper plantation areas makes this topic is important to study. This is the earlier step to find a specific bio-indicator of soil quality for pepper plantations, comparison between differences of soil mesofauna diversity in the pepper plantation area with availability of carbon in soil. The purpose of this research is to study the relationship between diversity of soil mesofauna with C-organic content in pepper cultivation area in Petaling Village, Bangka. Petaling village is one of central production of pepper in Bangka Belitung Island (Figure 1). The area of Petaling Village is 48.27 km^2 with a population of 6,302 people consisting of 1,474 households. In general, topography of Petaling Village is an area of productive plains, few hills and few wetlands. The majority of Petaling villagers are farmers. One of the leading commodities of the Petaling Village is pepper. Almost every family in Petaling Village has pepper plantation area. If that plantation area used optimally for growth and production of pepper, it will economically improve the fulfillment of the livelihoods of the people of Petaling Village [12].

II. MATERIAL AND METHODS

This research conducted in 3 different location of pepper plantation area in Petaling Village, Bangka. Identification of soil mesofauna conducted in Laboratory of Microbiology, Faculty of Agriculture, Fisheries, and Biology, University of Bangka Belitung. The method used in this study is descriptive correlational method with survey techniques. The sampling technique used was purposive sampling technique. Soil sample was taken by using ring sample. Separation of soil mesofauna was carried out by using Berlese-Tullgren funnel.

Morphological specimen identification under stereo zoom microscope conducted based on Arthropoda identification books [15], Soil Animal Ecology books [16], and Iowa State Entomology Index of Internet Resources [18]. Observed Parameters were abundance of population density [16], diversity of soil mesofauna using the Shannon-Wienner diversity index [9], species richness obtained using the Margalef richness index [9], evenness of soil mesofauna types calculated by the following equation [9], analysis of soil C-organic content using the Walkey and Black method [1]. Environmental observations include soil temperature and humidity (soil moisture), soil acidity (soil tester).

III. RESULT AND DISCUSSION

There were differences in the total of observed individuals and the number of species that found in each pepper plantation area. The highest soil mesofauna population was found in plantation area of Petaling 2 with the total individuals found were 57 soil mesofauna and the smallest population found in pepper plantation area of Petaling 3 with total individuals found were 6 soil mesofauna (Table 1).

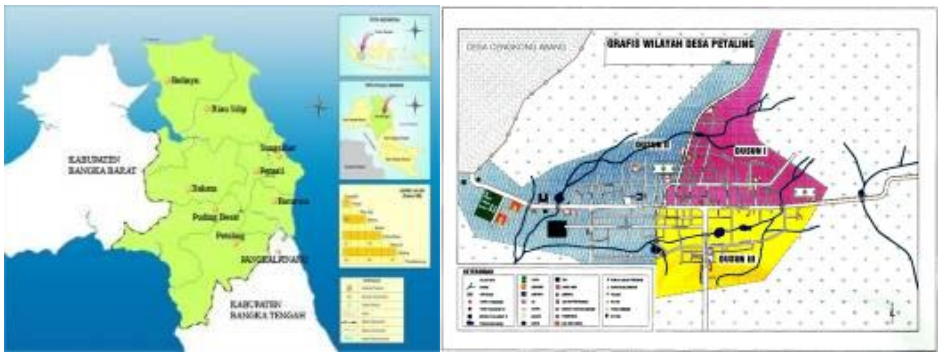

Figure 1. (a) Map of Bangka district area; (b) Map of Petaling village area [12]

TABLE 1. TOTAL OF SOIL MESOFAUNA DAN RELATIVE DENSITY OF SOIL MESOFAUNA THAT FOUND IN PEPPER PLANTATION AREA

Class	Order	Family	Total of Individual			Rd (%)		
			Pt 1	Pt 2	Pt 3	Pt 1	Pt 2	Pt 3
Arachnida	Acarina	Oppidae	4	7	0	50	12,28	0
Collembola	Entomobryomorpha	Cyphoderidae	1	0	0	12,5	0	0
	Entomobryomorpha	Paronellidae	1	7	3	12,5	12,28	50
	Poduromorpha	Neanuridae	2	10	0	25	17,54	0
	Entomobryomorpha	Entomobrydae	0	26	0	0	45,61	0
	Entomobryomorpha	Isotomidae	0	7	3	0	12,28	50
Total	3	6	8	57	6			

Notes: Rd (Relative density); Pt 1 (Petaling 1); Pt 2 (Petaling 2); Pt 3 Petaling 3

Figure 2. Soil mesofauna that found in pepper plantation area: (1) Acarina (Family Oppidae); (2) Collembola (Family Cyphoderidae); (3) Collembola (Family Paronellidae); (4) Collembola (Family Neanuridae); (5) Collembola (Family Entomobrydae); (6) Collembola (Family Isotomidae).

Pepper plantation area of Petaling 1 has 4 individual of Acarina, with 50% relative density. Pepper plantation area of Petaling 2 was dominated by Collembola Family Entomobrydae with 26 Collembola individuals and 45,61% relative density. Pepper plantation area of Petaling 3 was dominated with Collembola population consist of Paronellidae and Isotomidae families with total of 3 Collembola individuals and 50% relative density respectively (Table 1).

Based on analysis result, the highest population density (0,039) and diversity (1,436) were found in Petaling 2 plantation areas. The lowest population density (0,005) and diversity (0,693) were found in Petaling 3 plantation area. Average population density of soil mesofauna is 0,016 and the average value of mesofauna diversity index is 1,114.

The highest species richness index was found in Petaling 1 plantation area (1,442) and the lowest species richness index was found in the Petaling 3 plantation area. Average value of species richness index Margalef is 0,996. Petaling 3 plantation area has the highest Index of evenness of soil mesofauna that is 1, and the lowest index value is 0.875 in Petaling 1 plantation area (Table 2).

The highest soil pH value was found in Petaling 1 plantation area (5,68). The lowest soil pH value was found in the Petaling 2 plantation area (5,10). The highest soil temperature was obtained in the Petaling 2 pepper plantation area (29,96 ^{0}C) and the lowest soil temperature was found in Petaling 3 plantation area (25,04 ^{0}C). The highest percentage of soil moisture was found in the Petaling 3 plantation area (76 %). The lowest humidity percentage is found in Petaling 1 plantation area (43,58 %) (Table 3).

TABLE 2. POPULATION DENSITY, SPECIES DIVERSITY INDEX, SPECIES RICHNESS INDEX, AND INDEX OF EVENNESS OF SOIL MESOFAUNA

Plantation Area	K	H'	DMg	E
Petaling 1	0,006	1,213	1,442	0,875
Petaling 2	0,039	1,436	0,989	0,892
Petaling 3	0,005	0,693	0,558	1
Means	0,016	1,114	0,996	0,922

Notes: K (Population density); H' (species diversity index Shannon-Wienner); DMg (species richness index Margalef); E (index of evenness)

TABLE 3. CONDITION OF SOIL PH, SOIL TEMPERATURE, SOIL HUMIDITY AND C-ORGANIC CONTENT IN PEPPER PLANTATION AREA

Plantation Area	pH	Soil temperature (^{0}C)	Soil humidity (%)	C-organic (%)
Petaling 1	5,68	28,88	43,58	2,59
Petaling 2	5,10	29,96	54,16	2,52
Petaling 3	5,32	25,04	76,00	2,51

TABLE 4. COEFFICIENT CORRELATION VALUE BETWEEN SOIL PH, SOIL TEMPERATURE, SOIL MOISTURE AND DIVERSITY INDEX OF SOIL MESOFAUNA.

Coefficient correlation	**pH**	**Soil temperature**	**Soil humidity**	**H'**
Ph		-0,072	-0,448	-0,150
Soil temperature	-0,072		-0,860	0,997
Soil humidity	-0,448	-0,860		-0,817
H'	-0,150	0,997	-0,817	

TABLE 5. COEFFICIENT CORRELATION VALUE BETWEEN POPULATION DENSITY, SPECIES DIVERSITY INDEX, SPECIES RICHNESS INDEX, INDEX OF EVENNESS OF SOIL MESOFAUNA AND C-ORGANIC CONTENT.

Coefficient correlation	**K**	**H'**	**DMg**	**E**	**C-Organic**
K		0,749	0,011	-0,411	-0,374
H'	0,749		0,671	-0,912	0,335
DMg	0,011	0,671		-0,916	0,923
E	-0,411	-0,912	-0,916		-0,692
C-Organic	-0,374	0,335	0,923	-0,692	

Notes: K (Population density); H' (species diversity index Shannon-Wienner); DMg (species richness index Margalef); E (index of evenness).

Petaling 1 plantation area has higher C-organic content (2,59 %) than Petaling 2 (2,52 %) and Petaling 3 plantation area (2,51 %) (Table 3). Results of correlation analysis showed that the correlation coefficient between soil characteristic (soil pH, soil temperature, and soil moisture) with diversity index of soil mesofauna (H ') ranged from -0,817 to 0,997. By using Pearson correlation coefficient value, there are positive and negative values. Positive and negative values indicate the direction of the relationship between the two variables (Table 4).

Based on observations, 71 soil mesofauna obtained and divided into 2 classes, Collembola and Arachnida. Collembola class includes order of Entomobryomorpha (family of Cyphoderidae, Paronellidae, Entomobrydae, and Isotomidae), and order of Poduromorpha (family Neanuridae). Arachnida class includes order of Acarina (family Oppidae).

Based on the results of the identification, Acarina (Family Oppidae) has a body characteristics that not insulate between head, thorax, and abdomen, reddish brown in color, and has hair on legs. This is also explained by [16] that the body of the Acarina from head, thorax, and abdomen is converges.

Characteristics of Collembola from Cyphoderidae family had white body, eyeless, and the main characteristic is in furkula, that is the dens part has large scales. Characteristics of the Paronellidae family is has same color in every body parts and stained body color, an antenna length that is 0.5-3 times of the body, it has clear and pigmented eyes, and straight dens shape. Neanuridae family has flattened, fat and uneven body, its body color is white and red and did not having furkula. Characteristics of Entomobrydae family is an antenna with a clear segment, clear eyes, varied colors, a Paronellidae-like body shape, did not have post-antenna organ, antenna length is usually longer than width of head, and curved dorsal dens to the top. Characteristics of Isotomidae family has color of white to dark gray, size of 1 – 4 mm, without scale, long antenna, and clear eyes. Characteristic of the Isotomidae family is the same length of I – IV abdomen. The main characteristics of each Collembola family are in accordance with the classification book [15], [18]. Collembola usually lives on soil surface, inside soil, and also under plant litter [15].

Total of Collembola found in experiment location more than total of Acarina. Collembola found are 60 Collembola individuals with a total relative density 84,5 %. Total of Acarina found were 11 individuals with a total relative density 15,5 % (Table 1). Higher total of Collembola because Collembola is able to survive on various types of soil conditions and Collembola is divided into many species. The results of this study found Collembola individuals higher than Acarina in apple plantation area [6]. Collembola population is diverse and abundant to various types of soil because Collembola has many different species [15].

Activity of soil mesofauna (Collembola and Acarina) cannot separated from environmental influences, especially soil environmental factors. This is proved by relation between soil chemical properties and soil mesofauna diversity index (Table 4). Generaly, activity of soil organisms influenced by several factors, such as soil pH, humidity, temperature, and nutrients [15] and vegetation consist of forests, grassland, shrubs, etc [16].

Results of the analysis showed that the highest population density (0,039) and diversity index (1,436) were found in the Petaling 2 plantation area. Average population density of soil mesofauna (Collembola and Acarina) was 0.016 and the average diversity index was 1,114 (Table 3). Correlation value between population density of soil mesofauna and C-organic content is negative means that in abundant state of soil mesofauna, there was decrease in soil C-organic content. This is presumably because C-organic is not only utilized by Collembola and Acarina, but also utilized by other soil fauna as growth nutrient. There is a process of nutrient reform in soil by various soil fauna and the cycle of producer-consumer-decomposer-producer follow the flow of energy and nutrient utilization by organisms with soil as a cycle medium [2].

Correlation analysis between soil pH and soil mesofauna diversity was negative, that was -0,150 (Table 4). This shows that the population and diversity of soil mesofauna remain abundant in acidic soil (5,36) (Table 3). Soil mesofauna probably adapted and have been tolerant to acidic pH. Acidic pH conditions support soil mesofauna to accelerate plant litter decomposition because process of decomposition of plant litter there was release of organic acids into the soil. Collembola and Acarina have adapted to various pH condition to survive [16]. Kinds of Collembola and Acarina types which adapted in pH <6,5 (acid) was called acidophilic groups. In tropical environments where soil conditions have been acidic for long periods of time, soil fauna has evolved and become tolerance to acidic pH [13].

Coefficient correlation between soil temperature and soil mesofauna diversity is linear positive (0,997) (Table 4). This means that the increase in soil temperature followed by an increase in the soil mesofauna diversity. Pepper plantation area as transformation land with only pepper commodity in it has increased of soil temperature. Soil mesofauna which gets shelter under pepper canopy probably easier to adapted to increasing of soil temperatures because they were protected by pepper canopy and has enough food sources from pepper litter. This study obtained criteria of moderate diversity (Table 2) at temperatures from 25,04 ^{0}C – 29,96 ^{0}C (Table 3). This situation obtained from moderate diversity values at soil temperature 29,4 ^{0}C [8] also at temperature 29,5 ^{0}C in oil palm plantation area [3].

Correlation between soil moisture and soil mesofauna diversity was negative which indicated that increased soil moisture caused decreased in soil mesofauna diversity. This is presumably because level of soil moisture is too high resulting in disruption of the life of soil mesofauna, especially in decomposition process of plant litter. Generally, Collembola and Acarina will move to places with suitable soil moisture level so they can support their lives. Appropriate soil moisture's conditions for soil

mesofauna were not too wet and not too dry [8]. High humidity is condition in soil with water content above 50% and low humidity with water content below 40%. Several mesofauna species are sensitive to changes of soil moisture [7].

Average value of index of evenness in the pepper plantation area was 0,922 (E > 0,6) (Table 2) and categorized in criteria of high evenness. This probably due the availability of adequate food sources and suitable environmental conditions for each type of mesofauna. Index of evenness value which was close to one, the habitat conditions in all plantation areas were heterogeneous, means that the existence of natural resources that supporting the life of soil mesofauna was evenly distributed in all habitats [10]. This condition cause the coefficient correlation between species index of evenness with the C-organic content is negative, (-0,692) (Table 5). Each type of soil mesofauna in the pepper plantation area is supported by C-organic content. Decrease of C-organic content in the soil caused by utilization of organic material by mesofauna as food source. The presence of soil mesofauna depends on condition of environment and the food source. One factor that determined the amount of organic matter in the soil was the existence of soil mesofauna.

There was a correlation between the Shannon-Wienner diversity index and species richness index with C-organic content, that were linear positive correlation 0.335 and 0.923. This shows that the higher diversity and richness of soil mesofauna means higher C-organic content in soil. In contrast, lower diversity and species richness of the soil mesofauna means lower C-organic content in soil. The relation of these two variables means that mesofauna population has influences to the amount of C-organic content in soil. Total of mesofauna play an important role in accelerating of decomposition process. High diversity index and high species richness of mesofauna were obtained in areas that contained high organic material for soil mesofauna as food sources [17].

IV. CONCLUSION

1. Diversity of soil mesofauna (Collembola and Acarina) in the pepper plantation area (*Piper nigrum* L.) in Petaling Village, Bangka was categorized in moderate diversity criteria with H' = 1,114 (H' = 1 – 3).
2. There was positive correlation between the diversity of soil mesofauna (Collembola and Acarina) with C-organic (0.335) content in the pepper plantation area in Petaling Village, Bangka. Increasing diversity of soil mesofauna followed by an increasing C-organic content in the soil.

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