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Soil mesofauna amount and diversity by returning fresh and compost of crops biomass waste in ultisols in-situ

JUNITA BARUS[1,♥], DIAN MEITHASARI[1], JAMALAM LUMBANRAJA[2], HAMIM SUDARSONO[3], KUSWANTA FUTAS HIDAYAT[4], DERMIYATI[2]

[1]Lampung Assessment Institute for Agricultural Technology. Jl. ZA. Pagar Alam No. 1A, Rajabasa, Bandar Lampung 35144, Lampung, Indonesia
Tel.: +62-721-701328, Fax.: +62-721-705273, ♥email: junitabarus65@gmail.com
[2]Department of Soil Science, Universitas Lampung. Jl. Sumantri Brojonegoro No. 1, Bandar Lampung 35145, Lampung, Indonesia
[3]Department of Plant Protection, Universitas Lampung. Jl. Sumantri Brojonegoro No. 1, Bandar Lampung 35145, Lampung, Indonesia
[4]Department of Agronomy and Horticulture, Universitas Lampung. Jl. Sumantri Brojonegoro No. 1, Bandar Lampung 35145, Lampung, Indonesia

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Abstract. *Barus J, Meithasari D, Lumbanraja J, Sudarsono H, Hidayat KF, Dermiyati. 2021. Soil mesofauna amount and diversity by returning fresh and compost of crops biomass waste in ultisols in-situ. Biodiversitas 21: 92-98.* Newly added organic matter to the soil often has no significant effect on the physical and chemical properties of the soil. However, the addition of organic matter greatly affects the abundance and diversity of living organisms in the soil, because the addition of organic matter is one of the sources of food. The aim of this research was to study the impact of returning crop biomass waste in fresh or compost forms on the abundance and diversity of soil mesofauna. Three types of crop biomass residues (i.e. maize stover, rice straw, and soybean stover) were used at doses of 0, 2.5, 5.0, 7.5, and 10 t ha^{-1}. Mesofauna observations were carried out three times, namely at two weeks after biomass waste application (before planting rice), at eight weeks (there were rice plants in the soil), and at fourteen weeks (after rice harvest). The soil sample for mesofauna observation was dry extracted using a Berlese funnel set up, and to calculate and identified using a binocular microscope. The result showed that the number and diversity of mesofauna in the addition of compost was higher than that of fresh biomass waste. Increasing the dose of biomass waste has an effect on increasing the number and diversity of soil mesofauna. The presence of rice plants in the soil at the time of observation also affected the abundance of soil mesofauna.

Keywords: Crops biomass, diversity, in-situ, mesofauna

INTRODUCTION

Intensive rice farming system that brings out all the residual plant biomass without any effort to return it, in a long time causes a decrease in soil fertility. Maintaining soil organic matter is one of the keys in preserving soil and environment, because C-organic as a source and absorbent (sink) of nutrients, as a substrate for soil microbes (Tornquist et al. 2009; Powers et al. 2009; Kara et al. 2014), and triggers the availability of nutrients for plants (Bot and Benites 2005).

The constraints related to the addition of organic material to agricultural land from outside such as manure or other organic fertilizer are its transportation and costs if it has to be purchased. Because organic material is voluminous, so it requires large amounts of organic fertilizer. Therefore, it is necessary to utilize the organic material available therein (in-situ), that is the part of the plant that remains after the economic part is harvested. The remaining biomass from food crops such as rice, corn, and soybeans is very potential because it occupies the top rank in harvested area in agricultural land in Indonesia. The remaining biomass is usually taken out from the farm or left on the field then burned.

The effect of adding organic matter on soil properties was often reported not have an impact in a short time, especially on chemical and physical properties. Eden et al. (2017) has done long-term field experiments (≥9 years) to investigate the effects of organic amendments on organic carbon and water availability in topsoils. However, biological properties such as abundance and diversity of macro, meso, and microfauna in the soil can occur in a short time. The challenge going forward is the importance of manipulating the soil-plant system as a growing environment favored by organisms and increasing soil carbon storage in various conditions of agricultural land (Gougoulias et al. 2014).

The soil mesofauna is an important part of terrestrial ecosystems and a connecting link between microfauna and macrofauna which together form an essential part of soil decomposer community that transfers nutrients through the result of microbial activities (Xin et al. 2012). The several orders of soil mesofauna found on agricultural land were Collembola, Acarina, Hymenoptera, Diptera, Coleoptera, Orthoptera, Araneae, Spirobolida, Polyxenida, Scolopendromorpha, Hemiptera, Odonata, and Oligochaeta (Fitrahtunnisa and Ilhamdi 2013). Collembola and Acarina are the dominant order among others (Lavelle and Spain 2001; Haneda and Asti 2014; Odum and Barrett 2004). Their presence is an important reservoir of biodiversity and reflects the metabolism in ecosystems. They constitute important reservoirs of biodiversity and are reflectors of ecosystem metabolism. They are able to use the existing pore space in soil, cavities or channels, and regulate a major proportion of the organic matter transformations and nutrient fluxes in terrestrial ecosystems (Dervash et al. 2010), as previously reported that population and diversity of mesofauna are greatest at in soil with high porosity and organic matter (Andren and Lagerlof 1983). The reduced population of soil fauna often occurs due to disturbances in the soil such as fire, drought, tillage, application of pesticides, etc. However, the population increases rapidly when new organic matter was added, but fauna groups respond differently. Therefore, it is necessary to return remaining plant biomass to the soil as a food source for soil fauna.

MATERIALS AND METHODS

Study area

This research was conducted in Research station of Assessment Institute for Agricultural Technology, Natar District, South Lampung, Lampung, Indonesia (-5,322795^{O}, 105,174483^{O}) in March-July 2017. The type of soil at the study site was ultisols, the soil characteristics were pH 5.17; Organic-C 1.32 %; Total-N 0.11 %; P_2O_5 (Bray-1) 12,59 mg.kg^{-1}; and Potassium (K), Calcium (Ca), Magnesium (Mg), and exchangeable Al (cmol kg^{-1}) were 0.16, 3.23, 2.85, and 0.68, respectively (Barus et al. 2019a). Soil texture consists of sand 10%; silt 54%; and clay 36%.(Barus, 2016).

Procedures

The research comprised two sub-experiments: (i) The fresh form of biomass residues (as a mulch); and (ii) The compost form of biomass residues. The treatments applied in the two studies were A) Three types of crop biomass residues (i.e. maize stover, rice straw, and soybean stover), and B) Doses of crops biomass: 0, 2.5, 5.0, 7.5, and 10 Mg ha^{-1} (mega gram per hectare). The treatments were arranged in a randomized block design with three replications with a plot size of 5 x 8 m^2, and in each plot was planted rice after two weeks of application of plant biomass waste. The ratio C and N (C/N) of the fresh plant biomass waste (maize stover, rice straw, and soybean stover) were 43, 44, and 45 respectively. The C/N of compost forms were 34, 29, and 31 respectively. Crops biomass waste materials used in this study were available in the research area (in-situ). Fresh form of crops biomass waste is spread evenly on the ground as mulch. Meanwhile, the composted biomass waste was spread evenly and mixed with the soil at a depth of 10-20 cm.

Mesofauna observations were carried out three times, at two weeks after biomass waste application (before planting rice), at eight weeks (there were rice plants in the soil), and at fourteen weeks (after rice harvest). Soil sampling for observation of soil mesofauna was carried out using a sample ring (3.7 x 3.7 x 4 cm). The soil sample was dry extracted using a Berlese funnel set up (Parisi et al. 2005; Niswati et. al. 2010; Laksmi and Josep 2018; Gruss et al. 2019). The soil sample was irradiated with 25-watt lamp for 5 x 24 hours. Mesofauna that falls down were accommodated in the film tube that already contains 70% alcohol. Furthermore, the number of mesofauna in the tube calculated and identified using a binocular microscope which has a camera that is able to display images directly from a slide preparation and then saved it in softcopy. The number of mesofauna per ring sample was converted into total population in dm^{-3} with the equation:

$$x/(\pi r2\ t): X\ dm^{-3}$$

Where:
X : Total mesofauna dm^{-3}
x : Number of mesofauna/sample ring
r : radius of the sample ring (3.7 cm)
t : height of the sample ring (4.0 cm)
π : 3.14

Data analysis

Analysis of variance (F-test) and followed LSD post hoc test using SPSS 18 software. Correlations between mesofauna abundance and soil water content were determined using Pearson's rank correlation coefficient.

RESULTS AND DISCUSSION

Total-C, total-N, and Cation Exchange Capacity (CEC)

Based on recapitulation analysis of variance (F-test) of three types of biomass waste and doses on pH, total-C, total-N, and soil cation exchange capacity (CEC), after two weeks of application, both the type of fresh biomass and doses had no effect on soil pH, total-C, total-N, and CEC. The trend was the same for the application of compost biomass waste, except for the N-total. Increasing the dose of compost biomass waste increase the total N-soil content (Table 1). Soil chemical properties do not change easily with soil input because the soil is a buffer that neutralizes these changes. Usually, the research on the chemical properties of soil is carried out in long-term field experiments (Eden et al. 2017).

Number of soil mesofauna

Based on recapitulation analysis of variance (F-test) of three types of biomass waste and doses on number of mesofaunas, after two weeks of application of fresh biomass waste, both the type of biomass and the application dose had no effect on the number of soil mesofauna (Table 2).

Table 1. Total-N of soil after two weeks application of three types of compost plant biomass waste with multiple dosage levels

Doses	Compost biomass waste		
	Maize stover	Rice straw	Soybean stover
	Total-N (%)		
0.0 (control)	0.14 b	0.14 b	0.13 b
2.5 Mg ha^{-1}	0.16 ab	0.15 ab	0.14 ab
5.0 Mg ha^{-1}	0.16 ab	0.16 ab	0.15 ab
7.5 Mg ha^{-1}	0.14 b	0.17 a	0.15 ab
10.0 Mg ha^{-1}	0.17 a	0.17 a	0,16 a
LSD (5%): 0.02			

Note: Means followed by same letter in the same column are not significantly different (LSD, $P < 0.05$)

However, the addition of compost biomass waste, an increase in the application dose had the effect of increasing the number of soil mesofauna. In observations after eight and fourteen weeks, returning waste biomass at high doses significantly increases the amount of soil mesofauna in both fresh and compost waste biomass.

The amount of mesofauna observed varied in fresh or compost of biomass waste added (Table 3 and 4) both in two or eight weeks after application of biomass waste. Increasing the dose of biomass waste resulted in an increase in the number of soil mesofauna observed. This is because the added plant biomass waste increase food source for macro, meso, and microorganisms in the soil. Purwanto et al. (2017) reported that increasing the level of application of biomass waste affects the population of soil fauna, as same as reported by Barus (2019 b) that increases the number of earthworms. The research results of organic rice management were reported by Damarmoyo et al. (2018) that tends to increase abundance of earthworms, non-parasitic nematodes, and soil respiration.

The average number of mesofauna in the addition of compost biomass waste was more than the addition of fresh biomass waste. In observations 2 weeks after application, the average number of mesofauna in the addition of compost biomass waste was 88 with the highest number 127, while in the addition of fresh biomass waste the average number was 54 and the highest number was 65 (Table 3). This relates to the quality of biomass waste material. Organisms involved in weathering organic material will prefer higher quality materials, so that the speed of decomposition of plant residues under certain temperature and humidity conditions is a function of the chemical quality of plant material (Nourbakhsh, 2006; Zhang et al. 2008). The C/N ratio is commonly used as a guideline for predicting the relative decomposability potential of organic materials added to soil. Plant biomass waste materials that have been composted in this study have a C/N ratio of 29 to 34, while the fresh materials are between 43 to 45. In general, the higher the ratio of C and N in organic matter, the more difficult it is and requires a long time to decompose (Köchy and Wilson, 1997; Silveira, 2011). Soil organisms need carbon as an energy source and nitrogen is needed as a source of protein for their body.

Table 2. Recapitulation of the analysis of variance the effects of three types of fresh and compost plant biomass waste, application level, and their interaction on the total soil mesofauna in the two-week observation

Treatments	F-test Total of soil mesofauna		
	2 WAA	8 WAA	14 WAA
Fresh biomass			
Type of plant biomass	ns	ns	Ns
Dose of plant biomass	ns	**	**
Type X doses	ns	ns	Ns
Compost biomass	ns	ns	Ns
Type of plant biomass	ns	ns	Ns
Dose of plant biomass	**	**	**
Type X doses	ns	ns	Ns

Note: ** significant at α: 1 %; ns: not significant; WAA: Weeks after application

Table 3. Soil mesofauna population (number dm^{-3}) after application of three types of fresh and compost biomass waste with several doses at 2 weeks after application

Dosage ($Mg\ ha^{-1}$)	Fresh biomass waste after 2 weeks application			Compost biomass waste after 2 weeks application		
	Maize stover	Rice straw	Soybean stover	Maize stover	Rice straw	Soybean stover
	Total soil mesofauna (number dm^{-3})			Total soil mesofauna (number dm^{-3})		
0.0	42 a	49 a	60 a	55 c	55 c	46 c
2.5	55 a	49 a	49 a	55 c	78 b	78 b
5.0	55 a	60 a	42 a	96 ab	109 a	91 b
7.5	60 a	55 a	55 a	109 a	91 b	125 a
10.0	49 a	65 a	65 a	91 b	110 a	127 a
				LSD (5%): 15.97		

Note: Means followed by same letter in the same column are not significantly different (LSD, P < 0.05)

Table 4. Number of soil mesofauna population (tail dm^{-3}) after application of three types of fresh and compost biomass waste with several doses at 8 weeks after application

Dosage ($mg\ ha^{-1}$)	Fresh biomass waste after 8 weeks application			Compost biomass waste after 8 weeks application		
	Maize stover	Rice straw	Soybean stover	Maize stover	Rice straw	Soybean stover
	Total soil mesofauna (number dm^{-3})					
0.0	49 b	49 d	36 b	57 b	49 c	49 c
2.5	49 b	55 cd	49 b	73 b	60 c	60 c
5.0	60 b	67 c	67 a	93 a	93 b	87 b
7.5	91 a	85 b	73 a	107 a	127 a	107 ab
10.0	104 a	109 a	78 a	100 a	100 b	113 a
LSD (5%)	14.16			16.05		

Note: Means followed by same letter in the same column are not significantly different (LSD, P < 0.05)

The number of mesofauna in the 8-week observation was more than in the 2 and 14-week observation especially at doses > 2.5 Mg ha^{-1} (Figure 1). This is related to at that time there were paddy plants above ground, while in the 2-week observation the rice had not been planted and at 14 weeks the rice plants had been harvested (the soil was in a fallow condition). The presence of rice plants affects the soil moisture underneath. Abundance and diversity of soil fauna refer to the number and diversity of plant species in an ecosystem that affects soil organic matter content and other environmental factors such as soil moisture. Soil properties, especially physical properties (bulk density and soil moisture) greatly affect the growth of plant roots and the spread of soil fauna and microbes.

The results of the Pearson correlation show that numbers of mesofauna positively correlated with soil water content (%) both at 2 weeks and 8 weeks of observations after the addition of biomass waste (Table 5). Drought conditions and the humidity is the most important factor determining distribution, abundance, and survival of soil mesofauna in tropical forest (Wiwatwitaya & Takeda, 2005). George et al. (2017) reported that number of mesostigmata had significant positive relationships with bulk density, soil moisture, and pH, but had significant negative relationships with C:N ratio. The presence of macrofauna such as earthworms also has a positive correlation with soil water content (Barus et al. 2019 b).

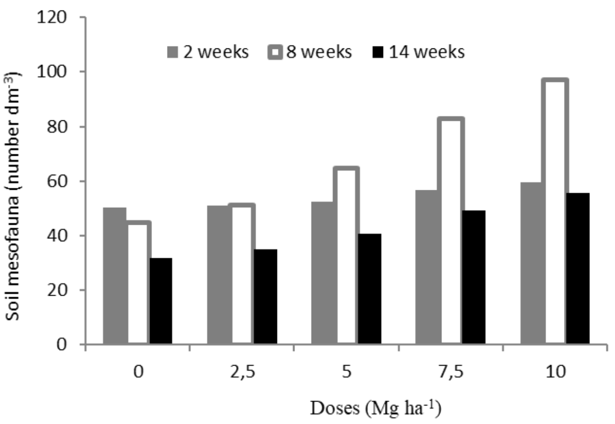

Figure 1. The average number of soil mesofauna (number dm^{-3}) after adding several doses of fresh biomass waste at 2, 8, and 14 weeks after application

Table 5. Correlation of soil water content (%) and numbers of mesofauna after 2 weeks and 8 weeks added of biomass waste

Numbers of mesofauna after 2 weeks		
Soil water content (%)	Pearson Correlation	.324*
	Sig. (2-tailed)	.029
	N	45
Numbers of mesofauna after 8 weeks		
Soil water content (%)	Pearson Correlation	.454**
	Sig. (2-tailed)	.002
	N	45

Note: *. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed)

Diversity of soil mesofauna

In general, there were seven soil mesofauna orders found in this study (Acarina, Coleoptera, Collembola, Diplura, Diptera, Anoplura, and Symphyla), six of them are shown in Figure 2. Most of them are found in groups, but for the photo one clearly is chosen (Figure 2).

The number and types of soil mesofauna at various doses after two weeks added fresh and compost of plant biomass waste showed in Table 6 and 7. Increasing in doses of fresh and compost of biomass waste increases the total population and diversity of soil mesofauna. In control and low doses (2.5 Mg ha^{-1}), the dominant types of mesofauna were Acarina and Anoplura, while at doses of 5 Mg ha^{-1} or more, the dominant type was Collembola. The study results showed that Acarina and Collembola are the most important group of decomposer organisms that play an active role in the initial process of breaking down organic material (Sugiyarto 2000; Haneda and Asti 2014). Rizalli et al. (2019) reported that soil organic matter in the soybean field supports arthropod abundance and their covariation, especially for collembolan and ants (Culliney 2013) reported that approximate abundance (number m^{-2}) of mesofauna in tropical savanna is microarthropoda 2000 and symphyla 2000.

The results of this study also showed that the composition and amount of each soil mesofauna group were different in fresh biomass and compost waste. The amount of mesofauna is higher in compost biomass waste (average number: 88) than in fresh biomass waste (average number: 53). In fresh biomass waste, it was found that the dominant number of Acarina groups, whereas in compost biomass, a dominant Collembola group was found. Gatiboni et al. (2011) report a change in the soil fauna groups in the different decomposition stages, principally due to the increase of Collembola in later stages of straw decomposition.

The type and number of mesofauna found were also different in each observation (2 weeks, 8 weeks, and 14 weeks). In the application of fresh biomass waste (Figure 3A), at the observation of 2 weeks, there were five types of mesofauna found which were dominated by group of Acarina, Collembola, and Diptera. After 8 weeks of application of plant biomass, six types of mesofauna were found, and were dominated by Collembola, Diplura, and Coleoptera. Observation after harvest (14 weeks), four types of mesofauna were found which were dominated by Acarina, Coleoptera, and Anoplura.

Observation in compost biomass waste (Figure 3B), after 2 weeks application, there were seven types of mesofauna found which were dominated by group of Collembola, Acarina, and Coleoptera. After 8 weeks of application of biomass waste, seven types of mesofauna were found, and were dominated by Collembola, Symphyla, Diplura, and Acarina. Observation after harvest (14 weeks), four types of mesofauna were found which were dominated by Acarina, Coleoptera, and Anoplura. The type of mesofauna that was observed also varied in compost biomass waste applications. The observation of 2 weeks, there were seven types of mesofauna which were dominated by the order of Collembola and Acarina. At eight weeks of observation, seven types were found too, and were dominated by Collembola and Diplura. Furthermore, after harvest observation, six types of mesofauna were found which were dominated by Acarina, Anoplura, Coleoptera, and Collembola.

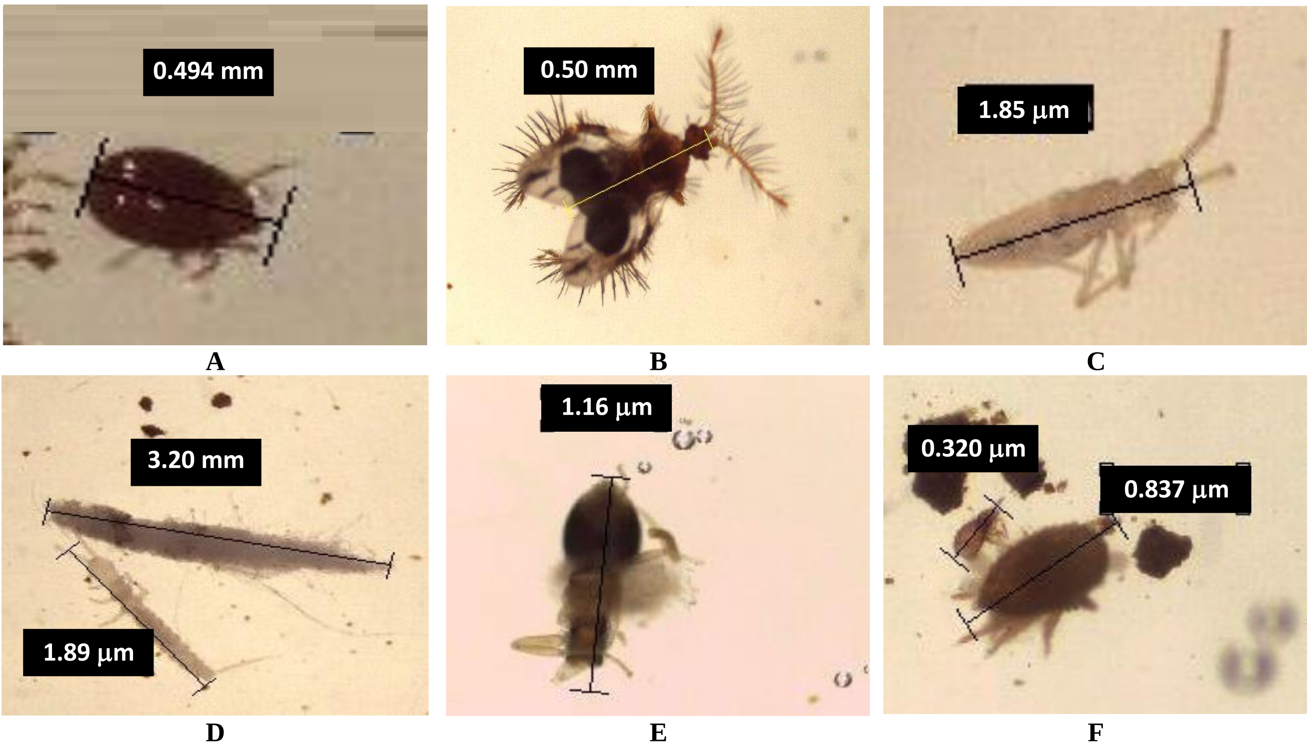

Figure 2. Types of soil mesofauna after application of compost biomass waste of maize, rice, and soybean. A. Acarina, B. Coleoptera, C. Collembola, D. Diplura, E. Diptera, and F. Anoplura. Identified and photographed using a binocular microscope

Table 6. The number and types of soil mesofauna at various doses of fresh biomass waste were observed 2 weeks after application

Type of Mesofauna	Doses of fresh biomass (mg ha^{-1})					Average
	0	**2.5**	**5.0**	**7.5**	**10.0**	
	Number of soil mesofauna					
Anoplura	10	10	8	8	6	8
Diplura	0	6	0	8	8	4
Acarina	23	17	12	10	10	14
Collembola	7	6	12	14	16	11
Diptera	0	0	6	0	6	2
Coleoptera	10	8	8	10	6	9
Symphyla	0	4	6	6	7	5
Total	50	51	52	56	59	53

Table 7. The number and types of soil mesofauna at various doses of compost biomass waste were observed 2 weeks after application

Type of Mesofauna	Doses of compost biomass (mg ha^{-1})					Avarage
	0	**2.5**	**5.0**	**7.5**	**10.0**	
	Number of soil mesofauna					
Anoplura	8	8	16	8	6	9
Diplura	0	6	12	20	22	12
Acarina	20	24	18	16	12	18
Collembola	8	10	23	33	36	22
Diptera	10	12	12	10	6	10
Coleoptera	8	6	14	14	17	12
Symphyla	0	4	3	6	10	5
Total	54	70	98	107	104	88

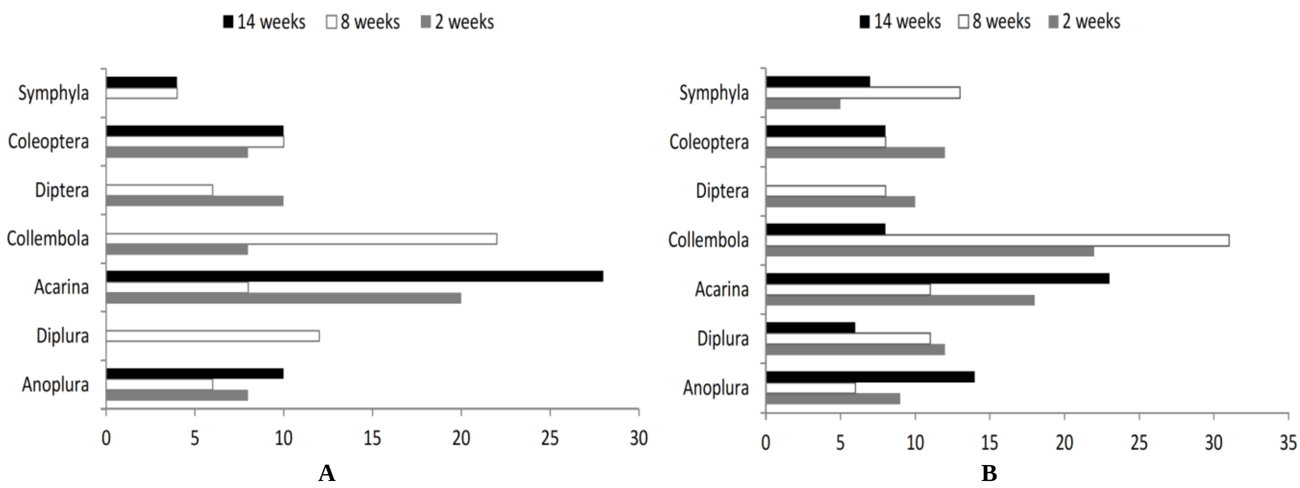

Figure 3. Types and amounts of mesofauna (number dm-3) after application of fresh biomass waste (A) and compost (B) at observations 2, 8, and 14 weeks after application of biomass waste

In general, the number of mesofaunas was higher and the species varied more at 8 weeks of observation compared to 2 weeks and 14 weeks. Observation at 14 weeks (after harvest) showed the number of mesofaunas had decreased considerably compared to that at 8 weeks of observation. This relates to soil moisture, where at eight weeks of observation the rainfall was still high and above there were rice plants so that it affected the soil moisture in the root layer which was the preferred place for mesofauna. While, observations after rice harvest, the land is fallow (without plants) and rainfall at that time (July) was relatively low, so that it affects the low of soil moisture. Pratiknyo et al. (2018) also report that maximum rainfall, canopy closure, and manure application affect the abundance of Families Rhinotermitidae and Termitidae in plain Mount Slamet, Central Java. In observations after rice harvesting, the dominant type of soil mesofauna is the type of lice and mites (Acarina) and Anoplura (sucking lice), this is due to the fact that this species is more resistant to dryness than other types such as Collembola or Diplura.

The results of this study indicate that the addition or return of organic matter to the soil periodically is very important, because new organic matter, whether fresh or composted, is a source of food and energy for soil fauna which affects the abundance and diversity in the soil rapidly.

In conclusion, there was a difference in the abundance and diversity of soil mesofauna with the addition of fresh or composted waste biomass. The type of biomass waste (rice straw, corn stover, or soybean stover) has no effect on the number and diversity of soil mesofauna species. However, increasing the dose of biomass waste has the effect of increasing the number and diversity of soil mesofauna. The presence of plants in the soil at the time of observation also affected the abundance of soil mesofauna, this is related to the soil moisture was higher below it compared to the fallow soil.

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