Research Article

Soil collembola on land affected by pyroclastic material of Kelud Volcano, Ngantang Malang

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Abstract: A study of Collembola on land affected by pyroclastic material of Kelud Volcano, Ngantang Malang was conducted to elucidate the abundance and diversity of soil Collembola in a volcanic environment at various elevations. The study area was divided into two habitats, affected and unaffected by pyroclastic materials at each altitude of 900 m above sea level (asl), 1000 m asl, and 1100 m asl. The research was carried out in June 2019 using a stratified purposive sampling method. Soil Collembola was collected on litter and soil layers using a square frame, length and width of 20 x 20 cm to a depth of 5 cm. Litter and soil layer samples were extracted using Modified Berlese Funnel. Collembola was identified based on morphospecies up to the genus level. Each genus was found only one species; therefore, the genus was considered as a species. Results of the study showed that soil Collembola on land affected by pyroclastic has 20 species and an abundance of 8790 individuals/m². In the pyroclastic unaffected areas, were found 33 species and an abundance of 3865 individuals/m². Entomobrya sp. was dominant in the litter and soil layers of all the study areas. This indicates that Entomobrya sp. is a species that is easy to adapt and has high habitat tolerance.

Keywords: abundance, diversity, Entomobrya sp., pyroclastic

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Introduction

Environmental changes due to volcanic eruptions can affect ecosystems above and below ground of the land. The eruption of Kelud Volcano in 2014 produced the deposition of pyroclastic material (Wardhana et al., 2014). The distribution of pyroclastic material is affected by the direction and speed of the wind, amount and size of the material, and height of the material erupted into the atmosphere (Swardana, 2018). In general, Kelud Volcano area is divided into pyroclastic affected and unaffected ecosystems. Pyroclastic flows cause vegetation burning, while pyroclastic falls cause accumulation of sand and ash materials on the soil. These conditions can increase temperature and decreases the humidity of the soil, can affect the diversity, composition, and species abundance in the ecosystem (Sholikha, 2013). Subagja (1996) reported that Collembola in pyroclastic fallout ecosystems would migrate to deeper soil layers as a form of self-defence.

Collembola or springtails are ubiquitous members of the soil fauna which found in almost all ecosystems and lives in various types of habitats such as vegetation, litter surfaces, tree canopies, caves, and in the soil profile (Widyastuti, 2005; Raschmanová et al., 2018). Collembola has a role in the ecosystem as organic materials decomposer, controller plant pest and disease caused by fungi, soil conditions indicator, toxic chemical decomposition and ecosystems counterweight.
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(Lartey et al., 1994; Broza et al., 2001; Kreuzer et al., 2004; Fountain and Hopkin 2001; Eisenhauer et al., 2011; Chang et al., 2017). Collembola also has a role as a first-rate consumer in the food chain (Brown, 1978). Research conducted by Daghighi et al. (2017), Santonja et al. (2018), and Turnbull and Lindo (2015) reported that climate, soil temperature, and soil moisture were dominant factors influencing the abundance and diversity of Collembola. Collembola is an indicator of good environmental quality if it is associated with environmental factors (Cassagne et al., 2003).

This study aimed to elucidate the abundance and diversity of soil Collembola in the volcanic environment at various elevations. The results obtained are the first report on soil collembola in the Kelud volcano area. This study is expected to provide an overview of the condition of the ecosystem after five years affected by pyroclastic material.

Materials and Methods
The study was conducted from 10 to 14 June 2019 in areas of Kelud Volcano, Ngantang Malang, East Java. The study area was divided into two habitats, i.e. affected and unaffected by pyroclastic materials at each altitude of 900 m above sea level (asl), 1000 m asl, and 1100 m asl (Table 1). The study was carried out using a stratified purposive sampling method with 5 sampling points taken of 10 m each point. Soil Collembola was collected from litter and soil layers using the square frame having length and width of 20 x 20 cm to a depth of 5 cm. Litter and soil layer samples were extracted using Modified Berlese Funnel (Suhardjono, 2012). The extracted soil was analyzed further to determine the soils physical and chemical properties. Collembola was identified based on morphospecies up to the genus level. Each genus was found only one species, therefore genus was considered as species based on Suhardjono (2012). The number of individuals abundance was calculated according to Meyer (1996) as follows:

\[ N = \frac{IS}{A} \]

where :
- \( N \) = Number of individuals /m²
- \( IS \) = Mean number of individuals per sample
- \( A \) = Square frame area (20 cm x 20 cm) = 400 cm² = 0.04 m²

The diversity index was calculated following the Shannon diversity index (Magurran, 2004) as follows:

\[ H' = -\sum\frac{n_i}{n} \ln \left(\frac{n_i}{n}\right) \]

where:
- \( H' \) = Shannon’s diversity index
- \( n_i \) = Number of individual species of Collembola
- \( n \) = The total of number individuals in the sample

\[ H' \text{ value ranges:} \]
- \(< 1.5 \text{ = low diversity} \]
- \(1.5-3.5 \text{ = medium diversity} \]
- \(>3.5 \text{ = high diversity} \]

Abundance analysis and Collembola diversity were performed using Analysis of Variance, followed by Duncan test at the level of 5%.

Table 1. General description of sampling location.

| Location               | General description                                      |
|------------------------|---------------------------------------------------------|
| **Pyroclastic affected** | **Ecosystem**                                           |
| 900 m asl              | The dominant vegetation of *Eupatorium inulifolium*, with an average height of ± 2 m, litter thickness <1 cm. |
| 1000 m asl             | The dominant vegetation of *Eupatorium inulifolium*, with an average height of ± >3 m, litter thickness <1 cm. |
| 1100 m asl             | The dominant vegetation of *Eupatorium inulifolium*, with an average height of ± >3 m, litter thickness <1 cm. |
| **Pyroclastic unaffected** | **Ecosystem**                                           |
| 900 m asl              | Mahagony production forest (*Swietenia mahagoni*) ± 20 years old, litter thickness of 1-2 cm. |
| 1000 m asl             | Natural forest area, high vegetation heterogeneity, litter thickness > 2 cm. |
| 1100 m asl             | Natural forest area, high vegetation heterogeneity, litter thickness > 2 cm. |

Results and Discussion

Pyroclastic layers
The observation showed that the pyroclastic materials in the affected area have a thickness of 28-30 cm (Table 2) composed of ash, sand, and gravel.
Collembola. The soil moisture in this ecosystem is both the litter and soil layers. Humidity is a factor in the population of 110 individuals/m² of Collembola species in the litter layer with a population of 85 individuals/m² of Collembola species were found in the soil layer. This can affect the functioning of the ecosystem. *Eupatorium inulifolium* is a plant that can utilize available nutrients, so its presence can dominate at various heights at the observation site (Table 1). The higher location of the study showed that the growth of *Eupatorium inulifolium* was more fertile, this was supported by the highest soil organic-C content that was found at an altitude of 1100 m asl (Table 2). The high soil organic-C content is directly proportional to the soil moisture content. This affects the microclimate, which is the favourite of the soil Collembola species present.

### Table 2. Chemical–physical analysis of soil and pyroclastic layers.

| Location                        | Organic-C (%) | Total-N (mg/kg) | C/N ratio | pH  | Soil Moisture (%) | Pyroclastic (cm) | Soil texture (%) |
|---------------------------------|---------------|-----------------|-----------|-----|-------------------|------------------|------------------|
| **Pyroclastic Affected Ecosystem** |               |                 |           |     |                   |                  |                  |
| 900 m asl                       | 0.71          | 0.12            | 5.91      | 5.71| 0.63              | 30               | 81.6             |
| 1000 m asl                      | 2.75          | 0.19            | 14.4      | 6.51| 2.11              | 28               | 80.4             |
| 1100 m asl                      | 3.01          | 0.24            | 12.54     | 6.10| 5.02              | 28               | 74.2             |
| **Pyroclastic Unaffected Ecosystem** |               |                 |           |     |                   |                  |                  |
| 900 m asl                       | 5.56          | 0.39            | 14.25     | 6.57| 7.12              | -                | 63.8             |
| 1000 m asl                      | 7.67          | 0.61            | 12.57     | 6.26| 8.22              | -                | 70.6             |
| 1100 m asl                      | 6.90          | 0.51            | 13.52     | 6.16| 4.61              | -                | 72.5             |

**The abundance and diversity in pyroclastic affected ecosystem**

The results show varied diversity both in litter and soil layer. The highest diversity of soil Collembola was found at an altitude of 1000 m asl in the litter layer and 1100 m asl in the soil layer, while the lowest diversity was found in the soil layer in the pyroclastic affected ecosystem at an altitude of 900 m asl level (Table 3). The pyroclastic material of Kelud Volcanos in 2014 changed the diversity, composition, and abundance of species in the ecosystem. The heat from the pyroclastic flow and fall caused the burning of vegetation around the Kelud Volcano area and decreased soil moisture. Habitat changes, via different plant composition, can affect some functional groups, having, in turn, affect the functional diversity of the community (D’Annibale et al., 2017). Species that are present in the pyroclastic affected ecosystem have fluctuating abundance and diversity values at every height because each height has different environmental characteristics (Table 1). The sampling point at an altitude of 900 m asl was open land which bordering with agriculture land. Five Collembola species were found in the soil layer with a population of 85 individuals/m² and six Collembola species in the litter layer with a population of 110 individuals/m² (Table 3). *Entomobrya* sp. was the most dominant species in both the litter and soil layers. Humidity is a factor that influences the abundance and diversity of Collembola. The soil moisture in this ecosystem is 0.63% and have sand particles of 81.6% (Table 2). Sand textured soil has a smaller surface area, making it difficult to hold water and nutrient (Hardjowigeno, 1987). Based on a statistical test at an altitude of 1100 m asl in the pyroclastic affected ecosystem, the highest number of the population reached 6.335 individuals/m² in the soil layer. *Sphaeridia* sp. has a higher population compared to other species. This raises the allegation of aggregation behaviour in *Sphaeridia* sp. According to Suhardjono (2012), the principle of aggregation in Collembola is caused by three factors, i.e. a response to differences in local habitat, a response to daily or seasonal weather, and the result of the reproduction process. The results showed that *Sphaeridia* sp. aggregation was thought to be caused by two factors, season and vegetation cover. Data obtained at the locations showed that the pyroclastic affected ecosystem was dominated by *Eupatorium inulifolium* which covered almost all of the land surface. The height of vegetation up to ±3 m causes the low intensity of sunlight to reach the ground surface. In addition, many necromasses are found from plant stems which are not completely burned when the eruption occurred. Additional organic material derived from the remains of fallen plant stems is utilized by insoluble carbon spear microorganisms that convert the cellulose and lignin component into solider structures (Utomo, 2016). The presence of Collembola affects the food chain cycle in the soil, in another case Collembola able to feed predators. The pyroclastic affected ecosystem at an
The abundance and diversity in pyroclastic unaffected ecosystem

The pyroclastic unaffected ecosystem at an altitude of 900 m asl is a mahogany production forest (Swietenia mahagoni) ±20 years old with a litter thickness of 1-2 cm (Table 1). In the soil layer, 11 species of Collembola were obtained with a population of 215 individuals/m², while in the litter layers, 16 species were found with a population of 820 individuals/m². *Entomobrya* sp. is the most dominant species both in the litter and soil layers. Dense of land cover and thick of litter affect the soil organic-C content, a value of 5.51 is obtained which is classified as very high carbon (Table 3). This causes the ecosystem in the mahogany production forest can provide a comfortable habitat for Collembola.
At an altitude of 1000 m asl and 1100 m asl is a natural forest which has a heterogeneity of vegetation and litter with a thickness of >2 cm (Table 1). At an altitude of 1000 m asl, 16 species of Collembola with a population of 615 individuals/m² were found in the soil layer, and 18 species with a population of 840 individuals/m² were found in the litter layer. At an altitude of 1100 m asl 18 species with a population of 415 individuals/m² were found in the soil layer and 17 species with a population 960 individuals/m² were found in the litter layer (Table 2). Collembola species found in these two regions have higher diversity value if compared to the mahogany production forest ecosystem. The availability of feed abundant from thick litter layers and the suitability of local microclimate attract Collembola to occupy the ecosystem. According to Windrializa (2016), the availability of abundant feed from thick litter is the main attraction of Collembola to live in forest habitat.

In general, Collembola diversity in the areas that are unaffected by pyroclastic material is directly proportional to the altitude of the area. The highest abundance of Collembola is found at an altitude of 1000 m asl with a total litter and soil layer population of 1455 individuals/m².

This observation concludes that 4 species have the highest abundance and are found in almost the study areas. Acrocyrtus sp., Ascocyrtus sp., Entomobrya sp., dan Salina sp. are members of the Order Entomobryomorpha. Entomobryomorpha is the most dominant group which has high abundance and diversity. This shows that Entomobryomorpha is a group that has a high ability of adaptation and tolerance of habitat. Amir (2008) states that the abundance and diversity of Collembola species are closely related to the ability of individuals to adapt to changes in the environment and food availability. Sphaeridia sp. is a group of Order Symphypleona which also has a tolerance of environmental disturbance.

**Relation of pyroclastic layer, vegetation, and Collembola**

Biological degradation of pyroclastic material continues, this is indicated by the development of plant roots that can penetrate the pyroclastic layer. In the process, there is a beneficial relationship between plant and soil organisms. Root activity affects the chemical properties of the soil. Organic acid exudate produced by roots can influence the microbial life in the rhizosphere. Microbes are also sources of organic material in the soil that will be consumed by other soil organisms (Utomo, 2016). Nutrients that are available from weathering of pyroclastic material and decomposition of soil organic matter are used by the plant for growth.

Produce of organic materials invite soil organisms to approach their main food sources, one of them is Collembola. The role of Collembola in decomposing organic matter is shown by the presence of soil organic matter fractions in the form of mycelium, spores, animal carcass parts, faeces, and other materials that have been fermented in the digestive tract (Suhardjono, 2012). Collembola directly plays an important role in the nutrient cycle.

**Conclusion**

Biotic and abiotic factors influence the abundance and diversity of soil Collembola. Pyroclastic layer affects the type of vegetation that can grow; it is closely related to the ecosystem that is formed and the type of Collembola that occupy the habitat. Entomobryomorpha is an Order that has a high ability to adapt and tolerate habitat, it was found in all research sites both in litter and soil layer. Abundance and diversity of soil Collembola in the pyroclastic affected ecosystem show varying patterns at each height. The higher an altitude of the location and the dense vegetation associated with the organic-C content of soil and pyroclastic layer able to affect the abundance and diversity of Collembola that is present in the areas, while in the pyroclastic unaffected ecosystem has a diversity that is directly proportional to the altitude of the place but not with its abundance.

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