INTRODUCTION

Sugar can be produced from a variety of plants. Sugarcane (Saccharum officinarum L.) is the main crop to produce sugar, animal feed, sugarcane syrup, among other products (Cheavegatti-Gianotto et al., 2011). This is because sugarcane has advantages such as high sugar content and can be made into sugar in large quantities. Sugarcane quality is very important to produce good quality sugar, so it must be improved to increase sugar production (Abd Elateef, Abbas, Gaber, Saif, & El-Geddawy, 2016).

Soil health or soil quality is the ability of the soil to sustainably support plant growth in a stable environment quality (Magdoff, 2001). Based on this statement, high soil health will improve the quality of sugarcane produced so that sugar production will also increase. Soil can maintain its own health naturally. This happens if the soil has enough time to recover and only gets minimal disturbance (such as the use of synthetic fertilizers, pesticides, and herbicides). Organic matter and soil fauna biodiversity are some of the many supporting factors of the soil health recovery process (Magdoff, 2001).

The basic management to improve soil health is to reduce plant stress, increase soil resistance to various plant pests and toxic substances and combine methods is needed that affect three aspect: biology, physics and chemistry (Reeve et al., 2016). One treatment that can affect all three aspects is adding organic matter to the soil.

In Kebonagung Sugar Factory, the leaves of sugarcane plants are pruned regularly by farmers so that the plants do not collapse easily when hit by strong wind. The pruned leaves then become leaf litters. Usually the leaf litters are collected then burned after the sugarcane is harvested. This is not efficient because the burning treatment is not useful and causes air pollution and degradation of the micro environment.

The burning treatment affects the presence of nutrients and soil fauna because it causes degradation of the microenvironment, including a decrease in soil fauna populations (Bot & Benites, 2005). Decreasing soil fauna population will cause...
damage to soil structure by rain, wind and sunlight. And then water hits the damaged soil and erode the topsoil layer which will cause leaching of the soil nutrients. If this is allowed continuously, the population and biodiversity of soil fauna will decline dramatically, and the cycle will continue until the soil cannot be used for farming.

Instead of burning, leaf litters should be used to increase soil organic matter, both in the form of litter and compost. Leaf litter contains organic material and if it returned to the soil it can help to increase or restore soil fertility. The communities plant matter presents an increased surface area to process of mineralization, convert its organic nutrients into simpler, inorganic compounds available to plants (Culliney, 2013).

Bot & Benites (2005) explained that soil microfauna uses soil organic matter as food. So, increasing soil organic matter will also increase the biodiversity of soil microfauna. In addition, the decomposition process which is carried out by soil microfauna will release nutrients to the soil in a form that can be utilized by plants.

Protozoa, nematodes, Collembolan and mites are soil microfauna which are also a soil bioindicator, organisms that can provide information regarding soil health (Coleman & Wall, 2015). From those three organisms, Collembola is the most easily found organism in various ecosystems (Santeshwari, Raghuraman, & Singh, 2015), making it easier to assess the soil health status.

It is hypothesized that giving sugarcane leaf litter to the ground will have a positive impact on the diversity of soil microfauna, especially Collembola. The increase in diversity will benefit farmers because it will improve the soil health. Therefore, it is necessary to do more research related to the impact of sugarcane leaf litter on Collembolan’s diversity. This research aimed to study the effect of sugarcane leaf litter on the diversity of Collembolan.

MATERIALS AND METHODS

This study was conducted in Kebonagung Sugar Factory in Bululawang, Malang District from March to June 2018. The identification was done in Pest Laboratory, Department Plant Pest and Disease, Faculty of Agriculture, Brawijaya University from March to October 2018. The chemical content of soil and leaf litter were analysed at Soil Chemistry Laboratory, Faculty of Agriculture, Brawijaya University. The analysis was done to get the data about nutrients and organic matter level.

Research Preparation and Collembolan Collection

This research was divided in two plots based on the treatment. Control plot was free of sugarcane leaf litter and treated area had sugarcane leaf litter buried into its soil. Interview with farmer was conducted to obtain information about the history of the land, cultivation methods, crop varieties, and methods for managing pests. Transect method was used to determine sampling spots (Fig. 1). This study had three randomized repetition for each treatment. Each research area was approximately 3 x 10 m.

Fig. 1. Design of the research plot

Research Implementation

Applying Sugarcane Leaf Litter

Sugarcane leaf litter were collected from removing dead leaves from sugarcane and applied approximately 5-10 cm under the soil surface.

Pitfall Trap Installation

The pitfall traps were installed twenty-four hours before soil sampling procedure. Pitfall traps were installed at each spot. Soil fauna was collected from pitfall traps was categorized in soil surface fauna.

Soil Sampling

Soil sampling was carried out using the Neuman method in each sampling spot. For treated soil, soil sampling was carried out on the 28th day after the sugarcane leaf litter applied. Sampling spots was marked with bamboo stake without disturbing the soil fauna. Shovel and intact-soil-frames were used to extract soil at a depth of 0-20 cm. Ground drill was used to extract soil at a depth of 0-40 cm. The total volume of soil samples collected was ± 10 litres. The soil samples then turned into a composite
and put into a cloth bag and then labelled according to the spot it was extracted from. After that, the bag was inserted into the storage box. Soil and pitfall trap samples were immediately taken to the laboratory to minimize the death of the organism.

**Soil Fauna Separation Process**

Each soil sample was poured into a different Berlese - Tullgren funnel. Then a cup of glass, containing alcohol and dish soap solution, was placed below the funnel. The funnel light was turned on for 48 hours to separate the soil fauna from the soil sample. Soil fauna was poured into a container, labelled with date and sample number and mixed with formalin solution. The soil fauna obtained from the Berlese-Tullgren funnel are categorized as an underground fauna while the soil fauna obtained from the pitfall traps are categorized as a soil surface fauna.

**Identification of Soil Fauna**

The soil fauna were observed using a stereoscopic microscope (8-56 x magnification) and separated into categories according to its morphology. The soil fauna were separated into three categories, which were Collembolan, Acarina, and other insects. Specimens in other insect categories were collected and its population were calculated for additional population data. Colembolan species were identified using the identification key of Collembola Ekorpegas (Suhardjono, Deharveng, & Bedos, 2012) and www.collembola.org (Bellinger, Christiansen, & Janssens, 2019).

**Data Analysis**

The data were analysed by using Shannon Wiener diversity index (H), Species Evenness index (E) and Simpson’s dominance index (1-D) (Magurran, 2004), which uses the following formula.

Shannon-Wiener’s biodiversity index:

$$H' = -\sum_{i=1}^{n} \left( \frac{ni}{N} \right) \ln \left( \frac{ni}{N} \right)$$

Remarks: $H'$ : Biodiversity index; $ni$ : Population of "i" species; $N$ : Total population; $\ln$ : Natural logarithm

Piellou’s evenness index:

$$E = \frac{H'}{\ln s}$$

Remarks: $e'$ : Evenness index; $s$ : Total amount of species; $H'$ : Biodiversity inde; $\ln$ : Natural logarithm

$$1 - D = 1 - \sum_{i=1}^{n} \left( \frac{ni}{N} \right)^2$$

Remarks: $D$ : Domination index; $n$ : The amount of species; $I$ : Designated species; $ni$ : Population of "i" species; $N$ : Total population

Higher value of domination index means there are some species which dominate the community, which means bad population equilibrium between species. Domination index highest value is 1.

**RESULTS AND DISCUSSION**

**Population and Diversity of Collembola**

The Collembola population are divided into two categories; they are population found on pitfall trap and population found on Berlese-Tullgren funnel (Table 1). The results showed that Brachystomella sp. had the highest population (3.942) on the surface of control soil. Brachystomella sp. mandibles were jagged, a characteristic of an effective leaf litter decomposer. The jagged mandibles are suspected to make it able to easily crush the leaf litter into smaller pieces (Weiner & Najt, 2001).

The population of Collembola was lower on the treated soil than the control soil. This was allegedly due to the increase in population of natural enemies such as ants, Coleopteran larvae, mites and spiders. This population increase behaviour was supported by other insect population data which was collected by researcher. Their population and biodiversity, especially mites, were higher on the treated soil than the control soil. It was recorded that the treated soil had more mites than the control soil. Ferreira, Bellini, & Vasconcellos (2013) stated that the existence of Collembola is influenced by the existence of natural enemies such as predators and parasitoids which acts as population control agent. Ferguson & Joly (2002) stated that mites’ population are the main factor that influences Collembola population because predation Collembola by mites. Lawrence & Wise (2000) stated that the decrease of spider’s population can increase Collembola’s population.

There were more Collembola species on the surface of control soil than treated soil (Fig. 2 and Fig. 3). At the same time, there were more Collembola species under the surface of treated soil than control soil. This is suspected to be caused by the lack of organic matter under the control soil which forced the Collembola to go to the soil surface whereas the abundance organic matter inside the treated soil caused the Collembola to stay underground.
Table 1. Collembola population were collected using pitfall trap and Berlese-Tullgren funnel

| Species        | Control soil | Treated soil |
|----------------|--------------|--------------|
|                | Pitfall trap | Berlese-Tullgren funnel | Pitfall trap | Berlese-Tullgren funnel |
| Brachystomella sp. | 3,942        | 41           | 279          | 244          |
| Species B      | 383          | 3            | 40           | 71           |
| Folsomides sp. | 184          | 1            | 15           | 32           |
| Mesaphorura sp. | 28           | 0            | 0            | 16           |
| Species C3     | 2            | 0            | 0            | 2            |
| Alloscopus sp. | 63           | 3            | 83           | 57           |
| Species D2     | 10           | 0            | 21           | 2            |
| Dicranocentrus sp | 5           | 0            | 1            | 7            |
| **Total**      | **4,617**    | **48**       | **439**      | **431**      |

Remarks: A = *Brachystomella* sp.; B = Species B; C3 = Species C3; C1 = *Folsomides* sp.; C2 = *Mesaphorura* sp.; D1 = *Alloscopus* sp.; D2 = Species D2; D3 = *Dicranocentrus* sp.

**Fig. 2.** Venn diagram for Collembola species found using pitfall trap

Remarks: A = *Brachystomella* sp.; B = Species B; C3 = Species C3; C1 = *Folsomides* sp.; C2 = *Mesaphorura* sp.; D1 = *Alloscopus* sp.; D2 = Species D2; D3 = *Dicranocentrus* sp.

**Fig. 3.** Venn diagram for Collembola species found using Berlese-Tullgren funnel
Collembola in the nature, especially those that live in the soil, found in soil, leaf litter, and above ground vegetation (Verma & Paliwal, 2010). Collembola were then linked to pH, nutrient content or organic matter, soil chemical parameters (Cassagne, Gers, & Gauquelin, 2003).

In the pitfall trap, treated soil has higher average biodiversity index (0.53) and higher average evenness index (0.42) than the control soil (Table 2). Both of them were categorized as in low diversity. Tarno, Septia, & Aini (2016) stated that the value of diversity index less than 1 is categorized as in low level of diversity and low level of individual distribution for each species. Similar result was found on the Berlese-Tullgren funnel, whereas treated soil also had higher average biodiversity index (0.76) and higher average evenness index (0.14) than the control soil. Both of them were categorized as in low diversity (Tarno, Septia, & Aini, 2016). The leaf litter may lead to an increase of abundance and species richness of decomposer and detritivor community (Muscardi, Schoereder, & Sperber, 2014; Yang et al., 2018). High biodiversity index and evenness index indicate a healthy ecosystem (Garbach, Milder, Montenegro, Karp, & DeClerck, 2014). Soil microfauna and macrofauna community can support a well-developed ecosystem (Hattenschwiler & Gasser, 2005). Sayad, Hosseini, Hosseini, & Salehe-Shooshtari (2012) stated that microfauna and macrofauna richness is regulated by leaf litter mass and soil organic carbon. Treated soil has lower average domination index than the control soil (Table 2). On the pitfall trap, it was 0.33 lower, and on the Berlese-Tullgren funnel, it was 0.34 lower. The control soil had average domination index value of 0.76 and 0.73 (value is close to 1) which showed that there was an imbalance between the population of each species and some species dominated another. From ecological point of view, it proved that the current management of plant and soil by Kebonagung farmers were not beneficial for a sustainable agriculture. On the contrary, the treated soil had average domination index value of 0.43 and 0.39 (value was close to 0.5) which showed that there was population equilibrium between species. From ecological point of view, it proved that by adding sugarcane leaf litter into the soil was beneficial and supports sustainable agriculture.

### Chemical Content Analysis of Soil and Sugarcane Leaf Litter

The soil sample and sugarcane leaf litter sample were taken to laboratory to analyze the pH level, water content percentage, organic carbon (C) percentage, nitrogen (N) percentage, C/N ratio, organic matter percentage, phosphorus (P) percentage, and potassium (K) percentage (Table 3). Sugarcane leaf litter had a high C/N ratio and low N, P, K level. 28 days after it was applied into the soil, it increased the organic carbon percentage by 0.44%, organic matter percentage by 0.74% and C/N ratio by 5. It was also decreased the nitrogen percentage by 0.01%, phosphorus percentage by 1.73% and potassium percentage by 0.44%.

| Sample            | Parameter | pH  | Water content (%) | Organic carbon (%) | N total (%) | C/N ratio | Organic matter (%) | P (%) | K (%) |
|-------------------|-----------|-----|-------------------|--------------------|-------------|-----------|-------------------|-------|-------|
| PS 864 leaf litter| pH        | 5.9 | 6                 | 32.29              | 0.81        | 40        | 55.85             | 0.10  | 0.52  |
| BL leaf litter    |            | 6.8 | 4                 | 28.27              | 0.84        | 34        | 48.90             | 0.12  | 0.88  |
| Control soil      |            |     |                   | 0.85               | 0.11        | 8         | 1.48              | 79.23 | 0.97  |
| Treated soil      |            |     |                   | 1.29               | 0.10        | 13        | 2.22              | 77.50 | 0.53  |

| Table 2. Shannon-Wiener’s biodiversity index (H’), Dominance Index (1-D) and Piellou’s evenness index (E) |
|-------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Index Value                                    | Pitfall trap    | Berlese-Tullgren funnel |
|                                                | Control | Treated | Control | Treated | Control | Treated | Control | Treated |
| H’                                              | 0.53    | 1.11    | 0.51    | 1.27    | 0.51    | 1.27    | 0.51    | 1.27    |
| 1-D                                             | 0.76    | 0.43    | 0.73    | 0.39    | 0.73    | 0.39    | 0.73    | 0.39    |
| E                                               | 0.27    | 0.69    | 0.41    | 0.67    | 0.41    | 0.67    | 0.41    | 0.67    |

| Table 3. Chemical analysis of sugarcane leaf litter and soil sample |
|------------------------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Sample                     | Parameter | pH  | Water content (%) | Organic carbon (%) | N total (%) | C/N ratio | Organic matter (%) | P (%) | K (%) |
|---------------------------|-----------|-----|-------------------|--------------------|-------------|-----------|-------------------|-------|-------|
| PS 864 leaf litter        | pH        | 5.9 | 6                 | 32.29              | 0.81        | 40        | 55.85             | 0.10  | 0.52  |
| BL leaf litter            |            | 6.8 | 4                 | 28.27              | 0.84        | 34        | 48.90             | 0.12  | 0.88  |
| Control soil              |            |     |                   | 0.85               | 0.11        | 8         | 1.48              | 79.23 | 0.97  |
| Treated soil              |            |     |                   | 1.29               | 0.10        | 13        | 2.22              | 77.50 | 0.53  |
The increase of organic carbon percentage will provide more food for Collembolan. This statement is proved by the increase of Collembola population after sugarcane leaf litter applied into the soil. Ferguson & Joly (2002) stated that organic carbon content and the microclimate were substantial factors that determined the diversity and vertical distribution of Collembola. Paolleti et al. (2007) stated that Collembola is an organism that lives in the soil and has an important role of being an organic matter detritivore.

Jiang, Schuchardt, Li, Guo, & Zhao (2011) stated that the increase of C/N ratio can decrease nitrogen percentage and lower C/N ratio caused higher NH₃ and CH₄ emissions. The high C/N ratio in sugarcane leaf litter will lower the decomposition speed and causes nitrogen immobilization in the soil. But it is also useful for maintaining soil organic matter percentage for a long period of time if it is applied into the soil correctly. Other than that, the slow decomposition process makes sugarcane leaf litter an ideal habitat for soil organisms. More soil organism means more food webs and more food webs means a more stable environment.

CONCLUSION

Based on the research, there were 5,535 Collembola individual identified. Those Collembola consists of 8 species, 6 families and 3 orders. The order with the highest population was Poduromorpha with a total of 4,554 individual. The order with the highest biodiversity was Entomobryomorpha with 4 species of Collembola. The identified Collembola were Brachystomellidae sp., Folsomides sp., Mesaphorura sp., Alloscopus sp., and Dicranocentrus sp. The application of sugarcane leaf litter into the soil had a positive effect on the biodiversity of Collembola by increasing the biodiversity index on the soil surface from 0.53 to 1.11 and lowering the domination index on the soil surface from 0.76 to 0.43. Farmers should avoid burning sugarcane leaf litter and start to use it as an organic matter source. An exploration research on the microbes that also act as detritivores is needed to verify and support this research.

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