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Factors affecting the decomposition of leaf litters in a mini-forest

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ABSTRACT. The fallen leaves, small twigs, seeds, and other woody debris that accumulate on the ground are a natural part of the forests and make up the leaf litter. Leaf litter is an important factor in healthy soil. As it decomposes, it replenishes soil with nutrients such as nitrogen, phosphorus, and other inorganic compounds. This study aimed to identify the factors affecting the rate of the leaf litter decomposition process. The study was conducted in the mini-forest and observation was conducted from August to October 2017. Data was collected weekly by observing and counting insects, and invertebrates in the leaf litter set-up which was composed of varying decaying leaf colors placed inside a mesh; the setup was separated into three colors: green, orange and brown colors and initially weighed 200 g for each mesh bag and deployed in the forest floor. The weight changes were noted every week during the visit to the field setup. This leaf litter observation concludes that various factors are affecting the process of decomposition of the leaf litter. This includes the presence of invertebrates and decomposers, age of the leaves used in the setup, temperature, and the disturbances.

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INTRODUCTION

The fallen leaves, small twigs, seeds, and other woody debris that accumulate on the ground are a natural part of the forests and make up the leaf litter (Johnson and Catley, 2002; Tonkin, 2006). Leaf litter is an important composition for a healthy soil as it decomposes, it replenishes soil with nutrients such as nitrogen, phosphorus, and other inorganic compounds (Bish, 2015). According to Bothwell et al. (2014), decomposing leaf litter can also supply carbon to other soil microorganisms and a large source of carbon dioxide to the atmosphere when released through forest fire. Moreover, this dead organic material provides the perfect habitat for a variety of living organisms from the smallest bacteria to the largest macro-invertebrates (Lin, 2012; Bish, 2015).

Different factors influence the rate of decomposition of leaf litter. Every day, different organisms thrive and inhabit the leaf litter. Some of these animals such as earthworms, snails, millipedes, and termites feed on the litter, breaking it up into pieces. This makes it easier for other organisms like bacteria and fungi to decompose the tiny litter pieces converting them to soluble chemicals and minerals which will then be recycled and used again as food by trees and other plants growing in the forests (Johnson and Catley, 2002). About 80 to 90 % of the decomposition of dead plant and animal matter is accomplished by bacteria and fungi. On the other hand, according to Bothwell et al. (2014), temperature in the environment can affect leaf litter decomposition. Their study concluded that leaf litter decomposition rates increase with rising environmental temperatures. In addition, disturbances can accelerate decomposition by helping expose new surfaces, promoting aeration, and temporarily increasing soil moisture. While there are previous studies on leaf litter, there are few described or recorded in the Philippines (Perez and Barrio-Dupo, 2013; Macandog et al., 2017). This study aimed to identify and describe the factors affecting the process of leaf litter decomposition and to understand the cycle of nutrients in nature from living organisms to the soil and the atmosphere.

MATERIALS AND METHODS

Study area

The study was conducted in the mini-forest, which has an area of approximately 10 m x 30 m between the Science and Nursing buildings of Davao Oriental State College of Science and Technology (Figure 1). These are mainly made up of planted mahogany and paper tree, growing for more than 5 years in the area. The observation was done from August to October 2017.

Data collection

For the conduct of the experiment, nylon mesh bags were used for making leaf litter bags. Three different leaves of the same species (*Acacia mangium*) in various colors and decomposition stage: green, orange, and brown were selected and placed on separate mesh bags. Each mesh bag contained leaves that initially weighed to 200 g and served as the initial weight. There were five replicates for each leaf color and tied with a nylon wire. These mesh bags were deployed to five various locations with flags to be noticed in the forest floor area. The first station and fourth stations were the rarely disturbed areas whereas stations two and five were considered disturbed sites, then station three was considered as slightly disturbed. During each week, the set-ups were monitored and observed in terms of the arthropods present as well as the fresh weight of the litter bags. The observationwas done for eight weeks. After eight weeks, the mesh bags were dried, and the final weights were recorded using a platform balance. All data collected on invertebrates and decomposers found in each mesh bag were then analyzed and shown in graphs. The weekly change in biomass of the mesh bags of leaf litter were also shown in graphs.

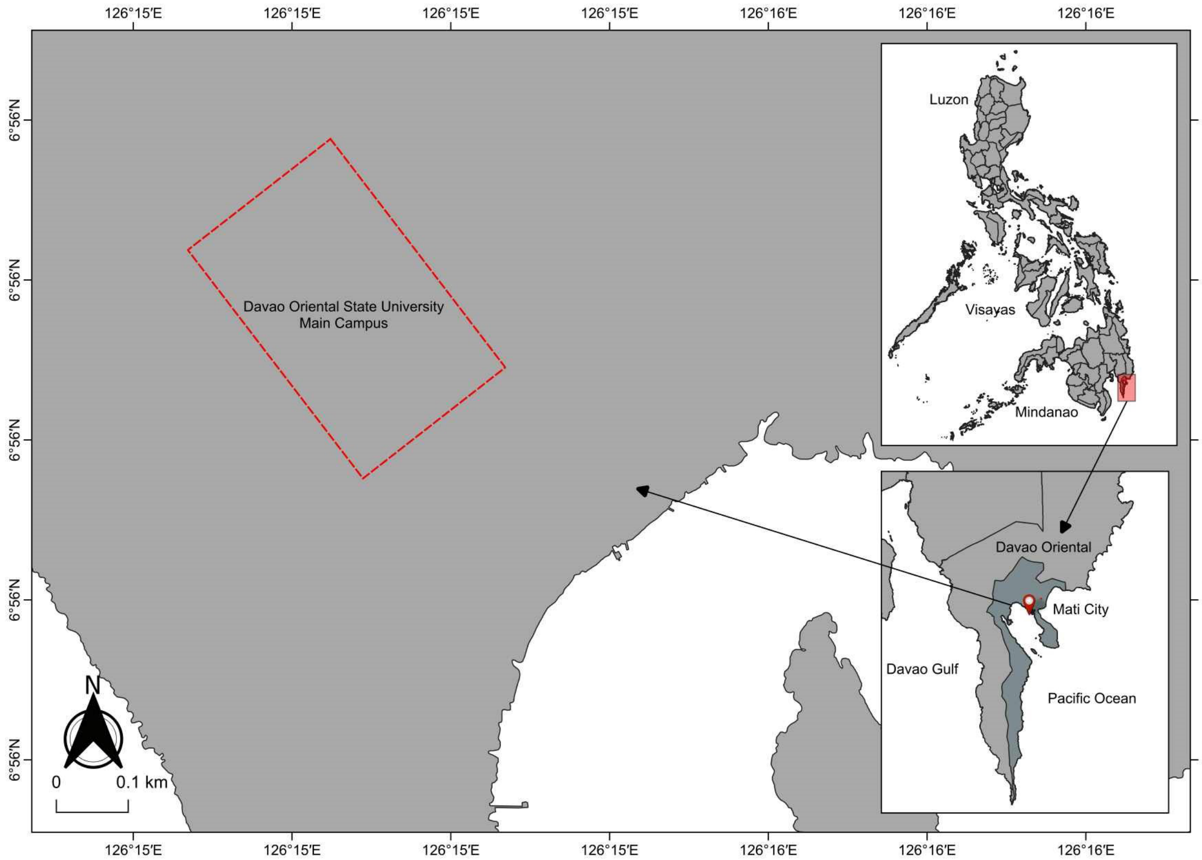

Figure 1. Location of the study area at the Davao Oriental State College of Science and Technology.

RESULTS

Different types of *Acacia mangium* leaf in varying stages of decomposition, green, orange, and brown leaves were monitored and observed for changes in biomass and collection of invertebrates. The data collected were analyzed and compared to the weight of each leaf litter per station. Moreover, the organisms found in the mesh bags were counted and shown in tables and graphs.

Changes in biomass

The change in the biomass of the three leaf types per week found in station 1, the green, orange, and brown leaves dropped in weight around week two (an average drop of 54 g for green, 0.26 g for orange and 11 g for brown leaf litter). This then suddenly increased in week four (an average increase of 78 g from the original 200 g for brown, about 58 g increase for brown from 200 g and for the green an average decrease of 50 g) due to rains, and then it declined in the following weeks. The green leaves have faster decomposition rates followed by the orange and then the brown leaves. The biomass of the green leaves declined to 75 g by the end of the observation period in the forest area.

The orange and brown leaves also declined in masses; the green leaves continued to decrease in mass while the orange and brown leaves whose weight also increased during week 4 took some time to lose the added weight. The notable decline was only recorded after eight weeks of observation e.g. decrease of 61 g from the original 200 g for the orange-colored leaf litter and about 38 g from the original 200 g for the dark brown colored leaf litter. Overall, it showed that the orange and dark brown leaf litter are taking some time for its biomass to decline.

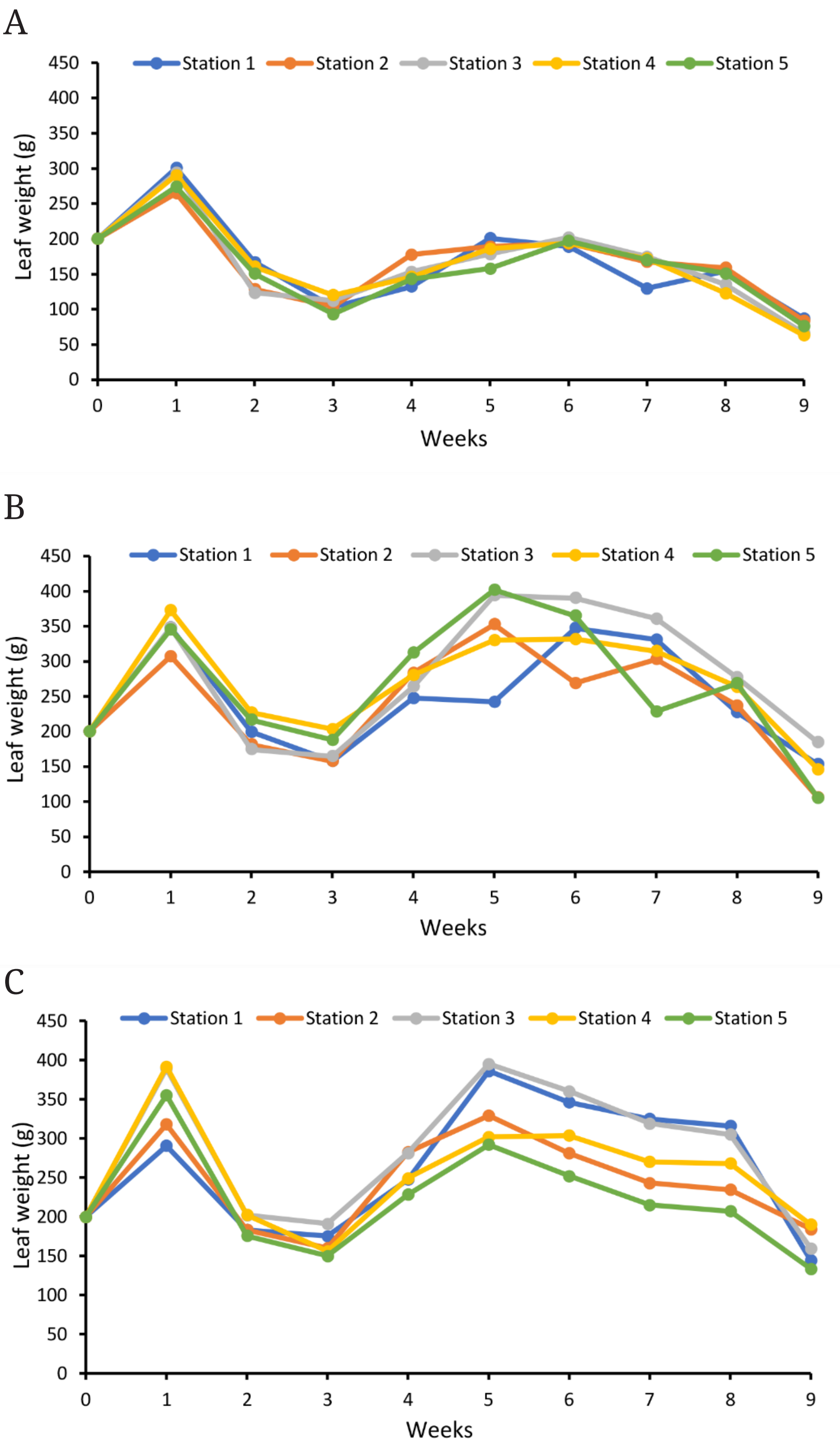

Figure 2. Change in biomass of green colored leaf litter (A), orange colored (B) and dark brown colored leaf litter (C) in the different stations found in the mini-forest.

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Presence of decomposers

Different numbers of organisms that thrive in the leaf litter mesh bags were observed each week. For eight weeks, a total of ten species of decomposers were found, and identified; the most represented invertebrates are pillbugs, and black ants. In Figure 2 below, this also shows that the decomposers slowly declined in numbers up to week 8.

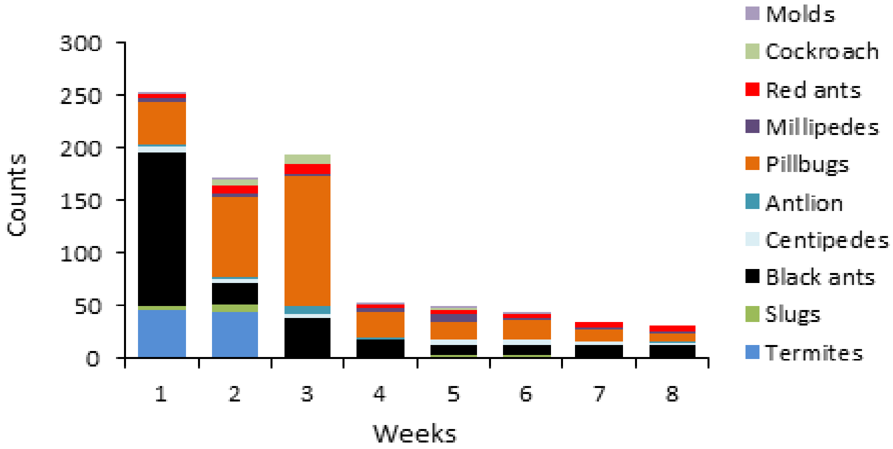

Figure 3. Invertebrates and decomposers found in the green-colored leaf litter in all stations.

For the decomposers in Figure 3, there was sudden abundance of decomposers in week 2 and then it began to decline until it was reduced in number by week 8. There were 11 species found in the leaf litter. The most common ones were still the black ants and the pillbugs. Millipedes were also one of the most dominant invertebrates represented. This activity also showed how the invertebrates and decomposers changed through time.

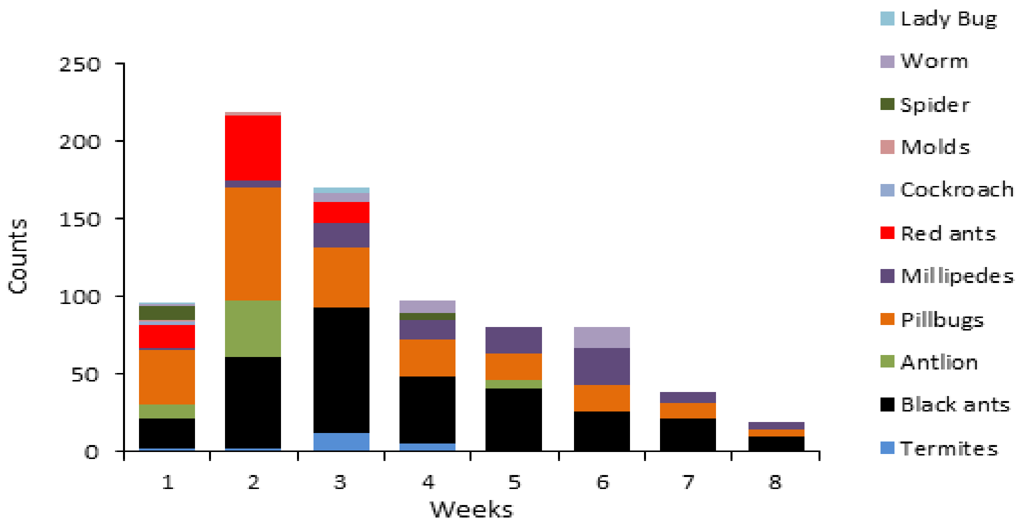

Figure 4. Invertebrates and decomposers found in the orange-colored leaf litter in all stations.

The brown leaves found in all the stations in Figure 4 were still dominated by the black ants and the pillbugs followed by the millipedes. The same pattern was shown in the graph showing the same result as those found in the orange leaf litter, that there was a sudden increase in the number of decomposers by week two and then it continued to decline until week 8. The number of invertebrates and decomposers found in each leaf color per station was shown in Table 1.

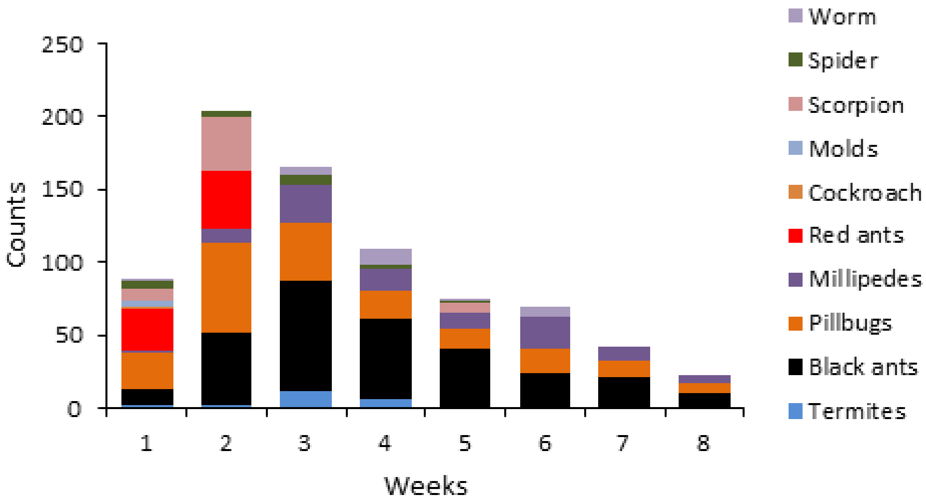

Figure 5. Invertebrates and decomposers found in the dark brown leaf litter in all stations.

The station with the highest number of invertebrates and decomposers in all the leaf litter setups was station 4 followed by station 5 while the station with the lowest number of invertebrates and decomposers was station 2 followed by station 3. On the other hand, station 2 was a disturbed area, while station 3 and 5 were slightly disturbed areas, and station 4 was an undisturbed area.

Table 1. Total number of invertebrates and decomposers in each leaf litter color per station.

Leaf litter	Station1	Station 2	Station 3	Station 4	Station 5
Green	161	126	124	270	142
Orange	118	71	78	119	87
Brown	129	147	153	172	204
Total	**408**	**344**	**355**	**561**	**433**

DISCUSSION

Leaves are organic matter that can be easily decomposed by various organisms. There are however leaf components that can be difficult to break down. Leaves contain higher concentrations of larger carbon molecules such as lignin, cellulose, and hemicellulose that are more difficult to break down since microbes must use specialized enzymes to process them (Larsen, 2006). Cellulose is a structural carbohydrate and is considered a complex sugar that is the major component of the tough cell wall of the leaves which surround plant cells, and make the plant stems, leaves, and branches strong. These cells decompose rapidly. Lignin, on the other hand, is found in the cell walls and between the cells of all vascular plants. They are responsible for the transport of liquids throughout the plant and for the reinforcement of the cell walls that keep them from collapsing to grow upright. Lignin is highly resistant to decomposition; thus, it is much more difficult to break down. In this experiment, the rates of decomposition of the same leaves with three different ages vary because of the different factors that need to be considered that could affect the process. In this study, we identified three different factors that could affect the result of the decomposition rate of the leaf litter for example presence of decomposers, age of leaves, and disturbance. We then discussed these three factors separately below.

Presence of decomposers

The most prominent factor that causes the decomposition of the leaf litter

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is the presence of insects and arthropods that function as decomposers. Different species of invertebrates and decomposers were found in the leaf litter which included termites, slugs, black ants, centipedes, antlions, pillbugs, millipedes, red ants, cockroaches, molds, scorpions, spiders, hank, worms, beetles and ladybug. The total number found in the green leaf litter in all the stations changed dynamically. The increased number of organisms in weeks 1 and 2, shows that the green leaves attracted more invertebrates because some made it their food source due to the presence of carbohydrates (Perez and Barrion-Dupo 2013). There was a gradual decline in the number of decomposers each week since the carbohydrates in the green leaves were depleted. The orange and brown leaves have a similar pattern in the changes as shown in the graphs. The only difference is that the increase in number of arthropods was higher in the orange than the brown leaves. This was again because the orange leaf litter still contained a tiny amount of carbohydrates that can be the source of food for other organisms while the brown leaves offer a tiny amount of carbohydrates left for fungal decomposers.

Age of the leaves

Leaves undergo abscission, the removal of the whole leaf to the trunk of the body of the tree and fall off to the ground. Leaves have different ages and can fall to the ground at the same time, either due to wind, humidity or rainfall (Quimpang et al., 2018). There are those chlorophyllous leaves that contain the chlorophyll pigment responsible for its green coloration, that fall to the ground due to many disturbances (Hendry et al., 1987). Other leaves which contain no chlorophyll, but other pigments such as carotenoid responsible for its yellowish-orange coloration, fell into the ground due to either disturbances or natural phenomena (Shamina et al., 2008). Most leaves fall naturally when they reach the dying stage where there are no cells alive. Since cells are already dead and no pigment found, brown leaves undergo abscission and fall off to the ground (Karban, 2007). In this experiment, the green leaves on the ground decomposed faster than the other leaves. This is because the presence of carbohydrates from living cells in those leaves attracts more organisms, as mentioned earlier, that will enable them to decompose at a faster rate. On the other hand, the orange leaves contain a small amount of carbohydrates from the living cells present and still attract other organisms that also decompose not as fast as the green leaves. Lastly, the brown leaves decompose slowly since they no longer attract more organisms due to the absence of carbohydrates, and based on the result, these were the leaves that had a lower rate of decomposition.

Disturbance

One factor observed in the experiment is the area where the mesh bags with leaf litter were placed. In stations one, three, and four, the areas were rarely disturbed whereas stations two and five were the disturbed areas since it is near the pathway of the students. Based on the results, the disturbed areas, stations two and five, have a greater loss in biomass and, therefore, have a high decomposition rate. On the other hand, stations one, three, and four, have a lower loss in biomass than stations two and five. This indicates that disturbances can increase the rate of decomposition than undisturbed and naturally decomposing leaf litter (Neher et al., 2003). However, there is a source of bias in this area, and that is the disturbance caused by the students who trampled the mesh bags.

Leaf litter biomass

Normally, in the monitoring of a leaf litter setup, there should be a decrease in the leaf litter weight every week. However, this study showed that during the first and the fourth, fifth and sixth weeks, there were sudden increases in weight of the setup in almost all mesh bags because during those weeks, rains have occurred in the area which probably affected its weight during the data recording. The green leaves have declined more rapidly than the other leaf litter setup and this can be explained by factors that affect it such as the attraction of numerous organisms that could facilitate in the decomposition process of the leaves. The orange and dark brown leaf litter setup obtained similar biomass changes by the end of the experiment (average of 139 g and 160g compared to 75 g for the green leaf litter).

In general, the station with the greatest mass reduction was observed in station 4 for the green leaf litter setup (63 g) but in station 5 for the orange (105 g) and dark brown leaf litter (134 g). Station 3 was a slightly disturbed area since it is near to the garbage-throwing area and most likely, some students disturbed it. Additionally, some pests such as rats can also cause the decline of the biomass of the green leaves by creating holes in the mesh bags. On the other hand, setups in station 5 were also observed to have a high mass reduction. Station 5 was also a slightly disturbed area since it was near pathways.

But despite this, it registered the second highest number of decomposers with 433 individuals of all species so it was expected that it will have a higher decrease in leaf weight. Many studies mentioned that areas that were disturbed can sometimes have high rates of decomposition because these can introduce more species, however, some students can also trample the mesh bags such as those found in station 2 which could be a source of a bias in this simple experiment.

Station 4, was an undisturbed area, and registered the highest number of decomposers in the area with 561 total counts and it will likely have the highest decrease in leaf weight. In fact, the setup showed this pattern for the green leaf litter where the biomass decrease was highest compared to other stations e.g. final weight of the green leaf litter setup in station 1 (87 g) vs station 4 (63 g). This could be due to the lack of disturbances occurring in this station. Another reason could be because of the weighing scale that was used. Some of the weighing scales were defective and can have inaccurate results. This was an additional source of bias during the conduct of the monitoring of the leaf litter in the different stations.

CONCLUSION

In this simple field experiment we conclude that different factors can affect the decomposition process of the leaf litter. This includes the presence of invertebrates and decomposers in the environment, the age of the leaves, temperature, source of moisture, and other disturbances. Decomposers facilitate the return of nutrients to the soil, thus helping in the nourishment of the other plants thriving in the environment.

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