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ASSESSMENT AND DISTRIBUTION OF SOIL ENTOMOFAUNAL COMMUNITY OF ENTOGNATHOUS HEXAPODS IN FOREST AND GRASSLAND

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Abstract

The abundance of entognathous hexapods in the soil ecosystem discloses the fact that degradation of its resources is not imminent. This entomofauna group of soil fauna is very related to the fertility status and sensitive to soil pollution and accumulation of toxic substances. Results of this study show the abundance of entognathous hexapods, as well as other soil arthropods in the forest and grassland soil of the Central Luzon State University, Philippines. In accordance with other similar researches, forest ecosystem has greater number of enthognathous population as compared to grassland, however, diversity indices revealed high diversity of entognathous populations in grassland.

There are four families of Collembola identified that were present in both soil ecosystems, one of the two families of Diplura was present also in both ecosystem and the lone family of Protura species was found only in the forest ecosystem. Dominance of entognathous species was observed in the forest area while evenness of entognathous hexapods distribution was extracted in grassland soil samples.

Keywords: Entognathous, Collembola, Diplura, Protura.

1. Introduction

The living organisms in the soil is responsible in most of the complex natural processes and cycles that maintain ecological sustainability (Brady and Weil, 1996). The exploration of their presence and abundance in a given ecosystem provides a glimpse on the present environmental condition, as well as the fertility status of the soil. Study on soil fauna, particularly of entognathous hexapods, is primitive in its discovery. As early as Devonian geologic time, soil hexapoda marked its way to further knowledge on the significance of entomofauna (Nel, 2015). Nevertheless, despite the necessity to unravel the importance of identifying the soil inhabitants, the science of taxonomy and soil zoological systematists remains the least among the researches' thrusts.

The rhizosphere, being the most productive layer of the soil due to the central site of chemical reactions, as well as biological activities, is the focus of most soil related researches that discloses significant information about the phenomenon of natural cycles and processes occurring in the environment that basically support the biosphere (Walker et al., 2003). Soil, being the product of weathering of rocks and decayed organic materials, is the habitat of millions of micro and macro soil-fauna (Brady and Weil, 1996; Chapin III, et al., 2002). Their abundance signifies life of the soil that carries decomposition process which involves the geochemical cycle and other symbiotic relationships and their metabolisms that uphold ecological stability.

The importance of studying the abundance of soil entomofauna, particularly the community of entognathous micro arthropod, is its linkage in the soil organic matter status. Nevertheless, soil microarthropods are not just aiding the decomposition and degradation process of organic materials in the soil (Chapin et al., 2002), but being one of the primary decomposer of soil litters (Chahartaghi et al., 2005). Researches show that the presence of soil microarthropods particularly for the Collembola in woodland ecosystem has a positive effect in plant litters decomposition process particularly in leaf litters (Gonzalez and Seastedt, 2001; Sayer et al., 2006; Yang et al., 2012) wherein nutrient mineralization and accumulation of soil organic matter are facilitated within the system (Heneghan et al., 1999, Palacios-Vargas et al., 2007).

The vastness of soil faunal population, the group of entomofauna, particularly the entognathous hexapoda or the soil microarthropods, is the concentration of this study. The three orders belonging to the group of hexapods, namely; Collembola, Diplura and Protura were assessed and identified. The determination of their abundance in forest and grassland soil, is the main objective of this study. The baseline information gathered by this study through establishing entognathans' abundance in forest and grassland of Central Luzon State University can contribute to further studies in soil productivity, nutrient recycling and management and mitigation of soil toxicity. The objective of this research is to determine the abundance and distribution of entognathous hexapoda in the soil. It specifically aims to compare the population and diversity of the aforementioned group of soil fauna in forest and grassland soils.

2. Methodology

The assessment of the abundance and distribution of entognathous hexapods in the forested as well as the grassland soils of Central Luzon State University was done through soil sampling. The extraction of entognatous hexapod was facilitated using a Berlese funnel technique and identified following the key to families of order collembolla, protura and diplura.

Establishment of Sampling Site and Characterization

Using satellite imagery, the Central Luzon State University has patches of forested area and grassland. These were preserved and maintained for about a century since its establishment. The sampling sites were selected using aerial photo (Figure 1) from Google Earth application to determine which among the areas within the university has the highest density of trees, as well as locating undisturbed and significantly large area of grassland. After locating the specific sites for the assessment of entognathous hexapods abundance, actual and ground evaluation was also done to determine if there were any major disturbance present within the area.

The selected forest area as sampling site is an environmental awareness project not just for the students, but also for the faculty and staff of the university. The joint project functions as a park known as "Lingap Kalikasan" (better known as Little Baguio) is used for several student activities. The area covers a total area of about 10 hectares including the residential area within the park. From the total forested area, the inner 4 hectares of the forest was only included in the randomization for the transect line used in the assessment of entognatous hexapods abundance. The topography of the area is flat, having a slope ranging from 0 to 3 percent. The area is covered by different tree species, but the area wherein the assessment was done has a distinctive dominance of mango, mahogany and agoho trees. The soil was covered by thick, partially to fully decomposed organic material from the leaves that shed-off from the trees.

The grassland area used for the experiment is just adjacent (eastside) of the forest area. A total of approximately 2 hectares was used in the assessment of the abundance of entognatous hexapods. The area was covered with diverse species of grasses but dominated by Talahib (*Saccharum spontaneum*). Similar to the topography of the selected forest site for sampling, the grassland area is also flat with 0 to 3 percent slope. Both the forest and grassland area are within the northern peripheral part of the university's domain.

Figure 1. Aerial photo of Central Luzon State University locating the forest and grassland sampling site

Quadrat Sampling and Soil Collection

Soil samples were collected separately from both sampling sites. Following the quadrat sampling technique, the selection of specific sites was randomly assigned. The size of the quadrat used was 1x1 meter. Three quadrat samplings for each ecosystem, forest and grassland, were used in the experiment. For grassland sampling, the reference point used to start sampling was the service road of the university. Through the generation of random numbers using calculator, twelve (12) meters westward from the service road was the first quadrat sampled. The following quadrats were assigned also through the generation of random numbers wherein the first quadrat was then used as reference. Using a ninety (90) degree angle from the reference quadrat, twenty-five (25) meters southwest and eighteen (18) meters southeast was measured and assigned as the second and third quadrat, respectively. This procedure of randomly designating quadrats within the sampling area is a modified wandering-quarter method. For designating quadrats within the forest area, modified line transect method was used. The same with the procedure in designating the first quadrat in grassland area, for the forest area, the service road of the university was again used as the starting reference. Eight (8) meters southward from the road was the location of the first quadrat. The line transect was paralleled to the lagoon within the forest area. Fifty-three (53) meters away from the first quadrat was the location of the second quadrat and seventy-eight (78) meters from the second quadrat was the third quadrat.

Each of the quadrats of both grassland and forested area were soil sampled by scraping the upper most layer of the soil at about 2 to 5cm depth. In grassland area, soil sampling was done by scraping the soil using a hand trowel after uprooting the vegetation within the quadrat The soil attached to the roots were also collected and placed in a plastic bag. On the other hand, soil from the forest area were collected by scraping the soil together with the partially and decayed organic materials accumulated at the surface of the soil. All the collected soil samples were contained separately in a plastic bag and labeled in accordance to their respective sampling sites. The collected soil samples were brought to the laboratory at the Department of Entomology, College of Agriculture, Central Luzon State University for the extraction and identification of entognatous hexapods.

Extraction of Entognathous Hexapods

There were six (6) soil samples collected from the two sampling areas, representing three from each site. From the soil samples collected, a uniform weight of one (1) kilogram of soil sample including the collected organic materials from the forest area was used and placed in the Berlese funnel to extract the entognathous hexapods. The extraction was done simultaneously for all of the six samples, since there were six Berlese funnels, which is also available, in every Berlese chamber. Figure 4 shows the Berlese funnels within the chamber.

Below each Berlese funnel has a collector glass container with 100ml of 70% ethyl alcohol. The glass container serves as a catcher of the entognathous hexapods and other soil animals that passed from the screen mesh at the bottom of each Berlese funnel. The samples were incubated for about 48 hours in the Berlese funnel and all the collected and extracted soil animals were counted and identified through the microscope.

Figure 4. Berlese funnels used in extracting entognathous hexapods

Taxonomic Identification

The collected and extracted entognathous hexapods from the soil samples were counted and identified up to the family level of the order collembola, protura and diplura. The taxonomic identification was based on the key references of the three entognathous orders. Other hexapods were just counted and identified into its classes or orders.

3.1 Results

Soil Cover of Transect Quadrats in Forest and Grassland

The three quadrats obtained from transect procedure in forest and grassland study areas has a dominant species that covers the soil sampled. The location of the first quadrant from the transect made in forest area is dominated by mango trees (*Mangifera indica)* while the remaining two quadrats from the same transect were obtained from mahogany area (*Sweitenia macrophylla)* and fine trees (*Casuarina equisetifolia)*, respectively. Dominated species in grassland area were also observed during the sampling period. Species of *Pennisetum* sp. (napier grass), *Saccharum* sp., locally known as *talahib*, and *Digitaria* sp. (crab or summer grass) found dominant in the first, second and the third quadrat, respectively.

Extracted Soil Entognatous Hexapods in Forest and Grassland

There were 220 soil species of hexapods extracted from all samples collected from both forest and grassland areas. Only 67 species belong to entognathous hexapods, representing about 30% of the total population extracted from the soil samples. From the total entognathous species extracted, 55% was obtained from forest ecosystem with a total of 37 species, representing all of the three orders with 7 families (4 from Collembola, 2 from Diplura and 1 from Protura) and only 30 species of entognathans were extracted from grassland ecosystem representing orders Collembola and Diplura (4 families from Collembola and 1 family from Diplura). Among the three orders of entognathous hexapods, order Collembola has the highest population of 61 out of 67 species with 4 families, followed by 5 species of Diplura belonging to 2 families and a lone family and species of Protura (Figure 3).

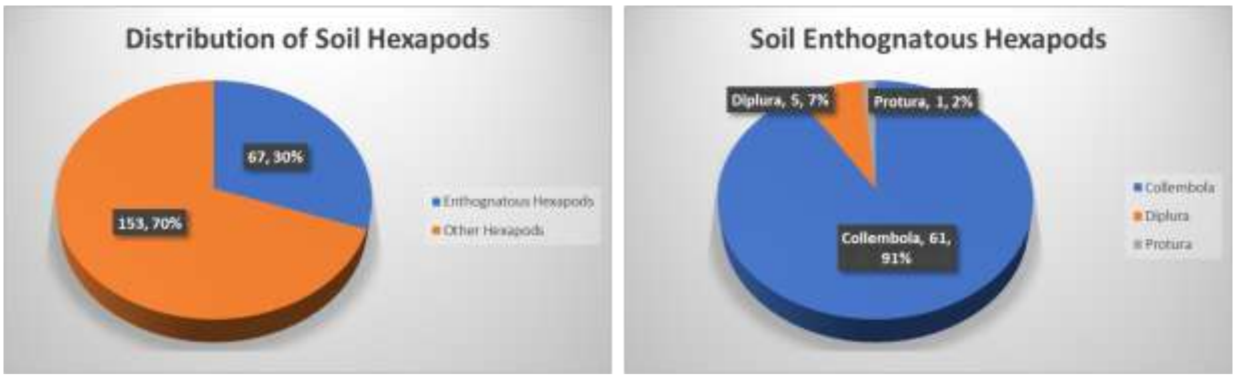

Figure 3. Distribution of Enthognatous Hexapods in Collected Soil Samples

In addition, from the three designated quadrats in both forest and grassland area, the first quadrat (Q1) had the highest number of entognathous species in both forest (19), dominated by mango trees and grassland (14), dominated by *Pennisetum*. In contrast, the lowest number of entognathous species in forest was extracted from Q3 (7) dominated by *Casuarina equisetifolia,* and Q2 (5) for grassland, which was dominated by *Saccharum* sp. The tabulated result of all the extracted hexapods in forest and in grassland area in each quadrat is summarized in Table 1. The abundance of entognathans and other hexapods in forest ecosystem is higher as compared to grassland ecosystem.

Other hexapods such as ants, which was the highest population extracted (86), followed by spiders (49), clambid beetles (8), rove beetles (6), chironomid flies (2) and ceratopogonid flies (2) which were also extracted from the soil samples. There were 88 species and 65 species extracted from forest and grassland, respectively. Among the quadrats designated for both sampling areas, the highest number of other hexapods species was observed from quadrats having the lowest population of entognathous hexapods both in the forest and grassland areas.

Table 1. Abundance of Entognathous and other hexapods in forest and grassland

	Hexapods	Forest				Grassland				Total
		Q1	Q2	Q3	*Total*	Q1	Q2	Q3	*Total*	
Collembola	Isotomid	5	9	6	*20*	5	2	5	*12*	32
	Podurid	2	1	0	*3*	5	0	0	*5*	8
	Sminthurid	1	0	0	*1*	2	4	1	*7*	8
	Entomobryid	7	1	0	*8*	1	0	4	*5*	13
	Total	*15*	*11*	*6*	*32*	*13*	*6*	*10*	*29*	61
Diplura	Sp. 1	1	0	0	*1*	0	0	0	*0*	1
	Anajapygid	3	0	0	*3*	1	0	0	*1*	4
	Total	*4*	*0*	*0*	*4*	*1*	*0*	*0*	*1*	5
Protura	Acerentomid	0	0	1	*1*	0	0	0	*0*	1
	Total	*0*	*0*	*1*	*1*	*0*	*0*	*0*	*0*	1
Entognathous Hexapods		*19*	*11*	*7*	*37*	*14*	*6*	*10*	*30*	67
Others	Ants	0	3	24	*27*	3	53	3	*59*	86
	Spiders	0	0	48	*48*	0	1	0	*1*	49
	Rove beetles	0	0	3	*3*	0	2	1	*3*	6
	Clambid beetles	0	0	8	*8*	0	0	0	*0*	8
	Chironomid flies	0	0	1	*1*	0	0	1	*1*	2
	Ceratopogonid flies	0	0	1	*1*	1	0	0	*1*	2
	Total	*0*	*3*	*85*	*88*	*4*	*56*	*5*	*65*	153
	TOTAL	19	14	92	125	18	62	15	95	220

Diversity Indices

In terms of the diversity indices of entognathous hexapods, using Shannon and Simpson's index, grassland is more diverse, having 0.96 and 0.58, respectively, as compared to forest soil having 0.87 and 0.36, respectively. This result is due to averaging the diversity indices of the three quadrats within the sampling area. The individual diversity indices of each quadrat show high diversity of entognathous hexapods in the first quadrat, dominated by mango trees in forest ecosystem, followed by the first quadrat, dominated by *Pennisetum* of grassland. However, the less diverse quadrat was observed in the third quadrat, dominated by *Casuarina equisetifolia* of forest ecosystem. The result of the diversity indices (Shannon and Simpson) is presented in Table 2. In addition, the dominance and evenness of species extracted from forest and grassland were also compared. Forest ecosystem has higher dominance value of 0.56 as compared to grassland, 042. Thus, evenness of species distribution in grassland is much higher (0.87) as compared to forest area (0.69). The result of the dominance, evenness and diversity indices is presented in Table 2.

3.2 Discussion

Results show the abundance of entognathous hexapods in forest ecosystem as compared to grassland. Bellinger (2011) cited the abundance of Collembola in forest soils. He further stated that the dense population of Collembola in forest soil is due to the presence of high organic materials particularly leaf litters. Bellinger (2011) also emphasized that Collembola inhabits soil rich in leaf litters, thus its abundance in forest soil is well noted. In grassland, the presence of Collembola is also observed. Though the number of entognathous species in forest is much higher compared to the species extracted from grassland soils, all of the 4 families of Collembola extracted in forest soil are also present in grassland soil samples. It was also observed from the tabulated result (Table 3) of the presence and absence of identified species (family level) in each quadrat in both forest and grassland, that among all the identified families, sp.1 of the two families identified under order Diplura and the lone family species of order Protura (Acerentomid), were the species of entognathous hexapods that were not present in grassland. However, statistics show using t-test analysis in Table 4 that there is no such significant difference between the abundance of entognathous hexapods in forest compared to grassland. Through this analysis, the population of entognathous hexapods in forest and in grassland is the same.

The abundance of Collembola as compared to Diplura and Protura in both sampling areas was also very obvious. This observation was also stated by Meyer (2010) and cited by Luan et al. (2005), emphasizing that among the three orders of entognathous hexapods, Collembola are the most abundant of all soil-dwellers arthropods. He further stated that Collembola have high survival adaptability, thriving in a variety of habitats and feeding in wide ranges of composted substrate materials. Protura and Diplura are very rare, only 4 and 7 families worldwide, respectively. Aside from their rarity, they are very selective in their habitat as well as feeding preferences. Protura are usually found in temperate deciduous forest and diplura prefer to be predacious on other Diplura and on fungal mycelia (Meyer, 2010).

Table 2. Dominance, evenness and diversity indices (Shannon and Simpson) of each quadrat in both forest and grassland ecosystem

Quadrat	Family	Freq	Dominance	Evenness	Shannon	Simpson
	Forest		0.56	0.69	0.87	0.36
Q1	Isotomid	5	0.25	0.70	1.56	0.75
	Podurid	2				
	Sminthurid	1				
	Entomobryid	7				
	Sp. 1	1				
	Anajapygid	3				
Q2	Isotomid	9	0.69	0.61	0.60	0.31
	Podurid	1				
	Entomobryid	1				
Q3	Isotomid	6	0.75	0.75	0.41	0.24
	Acerentomid	1				
	Grassland		0.42	0.87	0.96	0.58
Q1	Isotomid	5	0.29	0.80	1.31	0.71
	Podurid	5				
	Sminthurid	2				
	Entomobryid	1				
	Anajapygid	1				
Q2	Isotomid	2	0.56	0.94	0.64	0.44
	Sminthurid	4				
Q3	Isotomid	5	0.42	0.86	0.94	0.58
	Sminthurid	1				
	Entomobryid	4				

Table 3. Presence and absence of identified families of entognathous hexapods in forest and grassland

Hexapoda			Forest			Grassland		
			Q1	Q2	Q3	Q1	Q2	Q3
Entognathous	Collembola	Isotomid	x	x	x	x	x	x
		Podurid	x	x		x		
		Sminthurid	x			x	x	x
		Entomobryid	x	x		x		x
	Diplura	Sp. 1	x					
		Anajapygid	x			x		
	Protura	Acerentomid			x			
Other Hexapods	Ants			x	x	x	x	x
	Spiders				x		x	
	Rove beetles				x		x	x
	Clambid beetles				x			
	Chironomid flies				x			x
	Ceratopogonid flies				x	x		

Table 4. T-test on the abundance of entognathous hexapods in forest and grassland.

Site	# of Observed Species	Mean	tc	t-tab
Forest	37	1.76	0.46	2.02
Grassland	30	1.43		

In terms of diversity, though forest ecosystem is abundant in entognathous hexapods, since it has higher dominance and lower evenness values, thus, making its ecosystem less diverse as compared to grassland. On the other hand, though entognathous species extracted from grassland is much lesser as compared to forest, it represents a more diverse population due to lower dominance and higher evenness values. Thus, Shannon and Simpson's indices used in determining the diversity of entognathous hexapods shows higher diversity indices in grassland as compared to forest. The presence of dominant species in a particular sampling area lowers its diversity index.

As a result, even though both sampling sites extracted the same number of entognathous families, if there is a dominant family present in it, then the diversity index would be low. Similarly, in the case of entognathous hexapods extracted from Q3 of forest area and Q2 of grassland, both sampling sites collected 2 families of entognathous species, but they have different diversity index (Table 3). In Q3 of forest area, there were 6 species of family Isotomidae and 1 species of family Acerentomidae that had been extracted resulting to lower diversity index. However, in Q2 of grassland, 2 of Isotomids and 4 of Sminthurids were extracted, having merely even distribution of species and higher diversity index.

Conclusion

Among the three orders of entognathous hexapods, Collembola species revealed the most from the soil samples, followed by Diplura and Protura; the latter being the least represented species from the soil samples collected. Out of the four (4) families extracted and identified under order Collembola, Isotomid dominated the population of entognathous hexapods in both forest and grassland soils. It was also found out that soil covered by mango leaf litters has much higher population of entognathous hexapods as compared to soil covered with mahogany and *Casuarina equisetifolia* leaf litters. Also, grassland dominated by *Pennisetum sp.* shows entognathous hexapods' abundance as compared to grassland dominated by *Saccharum sp.* and *Digitaria sp.*

The abundance of entognathous hexapods in the soil is dependent on its organic matter content. These soil insects inhabit soil with high humus or leaf litters with relatively high moisture. These characteristics of the soil are prevalent in forest condition, wherein the accumulation of leaf litter is relatively high. The soil moisture content is also preserved within the uppermost layer of the soil since evaporation rate is low due to close canopy effect, preventing sunlight to pass through. This soil condition is also present in grassland, however, there is little accumulation of organic material due to vegetational differences. Thus, the abundance of entognathous hexapods in grassland is not that much as compared to forest soil. However, through statistical analysis, the abundance of entognathous hexapods population in both forest and grassland areas is not significantly different, showing no difference in their abundance

Diversity is a measure of how many different kinds of species as well as its evenness in distribution. In averaging the diversity indices of all the extracted entognathous in each quadrat, soil samples from grassland has higher diversity index as compared to forest soils. This occurrence is due to the presence of dominant species in the forest, making its diversity index relatively low as compared to the even distribution of entognathous species in grassland area.

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