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Leaf Litter Arthropods in the Gallery Forest of Jos Zoological Garden, Jos, Plateau State, North Central Nigeria

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ABSTRACT

Arthropods are an important and the most diverse component of terrestrial ecosystems and they occupy a wide variety of functional niches. Consequently, during the rainy season of September to October 2019, a study on the species composition of leaf litter arthropods in relation to some soil physicochemical parameters was conducted in the Gallery forest of the Jos Zoological Garden. Arthropods found in leaf litter were gathered using pitfall traps. Standard techniques were used to determine the physic-chemical characteristics of the soil. A total of 965 arthropods were collected, representing 4 Classes, 12 Orders, 30 Families, 36 Genera, and 39 Species. There was a significant difference (P<0.05) in the abundance of leaf litter arthropods in comparison to arthropod taxa, with Insecta accounting for 89.01% of the total, followed by Hymenoptera (48.08%), Formicidae (47.56%), and Camponotus pennsylvanicus (40.41%) as the most abundant taxa. The amount of organic matter, pH, temperature, and soil moisture all have an impact on the diversity and quantity of leaf litter arthropods. The quantity and variety of leaf litter arthropods depend on the availability of food, suitable microhabitats, and favorable soil conditions. Therefore, it is advised that the management of Jos Zoological Garden prohibit all anthropogenic activities.

INTRODUCTION

Arthropods are essential components of the marine, freshwater, terrestrial, and avian ecosystems (Rupert et al. 2004) and play key roles in food chains, population dynamics, and community structure (Latif et al. 2009). Arthropod species make up over 80 % of all known living animal species, with estimates ranging from 1,170,000 to 5 to 10 million (Odegaard, 2000). Cuticle, a non-cellular substance released by the epidermis, makes up the exoskeletons of arthropods (Rupert et al. 2004). The procuticle is the collective name for the exocuticle, which is made up of chitin and chemically hardened proteins, and the endocuticle, which is made up of chitin and unhardened proteins (Schmidt-Rhaesa et al. 1998). A flexible cuticle covers the joints between limb segments and between body segments (Rupert et al. 2004). A distinguishing characteristic of Ecdysozoa (arthropods, tardigrades, onychophorans, nematodes, and related taxa) is ecdysis or moulting, which characterizes the process of shedding the exterior integument, the cuticle (Schmidt-Rhaesa et al. 1998). Growth, progress toward an adult body plan, and body part regeneration are all facilitated by moulting (Drage, 2016). A few species of crustaceans and insects can reproduce by parthenogenesis, particularly when the conditions are right for a "population explosion." The majority of arthropods, however, reproduce sexually, and parthenogenetic species frequently switch to sexual reproduction when environmental conditions deteriorate (Smith, 2014). According to Rupert et al. (2004), most arthropods lay eggs. Most often, the small nauplius larvae that hatch from crustaceans have three segments and pairs of appendages (Rupert et al. 2004). Arthropods can act as infectious pathogen carriers or vectors. (Duvallet et al. 2018), yet other arthropod species are crucial to our survival, giving us access to things like food, clothing, medicine, and protection from hazardous critters as well as helping to maintain ecological equilibrium (Myers, 2001). Healthy soil contains leaf litter, dead leaves, twigs, and pieces of bark that have fallen to the ground. This dead organic matter offers a wide variety of creatures the ideal habitat (Lin, 2012). Invertebrates, with arthropods having the biggest abundance, make up the majority of the live organisms found in leaf litter. The need to gather data on the species composition of leaf litter Arthropods in conservation areas like the Gallery Forest of Jos Zoological Garden stems from the fact that sound information on leaf litter composition must be incorporated into management practices if ecosystems are to be managed properly by the next generation.

MATERIALS AND METHODS

Study Area

The investigation was carried out in the Gallery Forest of Jos Zoological Garden from September to October of 2019.

Techniques for Collection, Identification, and Quantification of Arthropods

Twenty pitfall traps were distributed throughout the Gallery Forest of the Jos Zoological Garden. The sampling method involved placing traps at intervals of 50 meters along a transect for a period of 72 hours. Giving all Arthropods an equal chance to be ensnared is the goal. After 72 hours, arthropods were harvested. Arthropods were collected and stored in 70% alcohol and glycerol after being freed of plant detritus. Arthropods were transported to the laboratory for sorting, identifying, and categorization. A colored atlas and identification keys from Castner (2000) and Shattuck (2000) were used to identify, organize, and classify each sample of arthropods into groups, orders, families, genus, and species.

Determination of Soil Physicochemical Parameters

The soil temperature was measured by excavating the ground (approximately 5 cm), inserting a thermometer, waiting 5 minutes, and then taking the measurement. Following weighing and the subsequent calculation, 20 g of soil samples were placed in an ovum at 100°C for 24 hours. The moisture content was then calculated as follows:

$$\% \text{ of soil moisture content} = \frac{W1-W2}{W1} \times 100$$

Where w_1-w_2 is loss in weight; w_1 is initial weight

In a 500 ml beaker, 20 g of processed soil samples were placed. 20ml of distilled water was added to it and stirred; then allowed to stand for 30min. It was occasionally stirred with a glass rod. A calibrated pH meter's electrode was put into the partially settled slurry, and the meter's screen displayed the pH. A modified version of Walkley and Black's (1934) approach was used to calculate the soil organic matter.

Statistical Analyses

R Console software was used to analyze the data (version 3.2.2). The relative abundance of leaf litter arthropods with respect to classes, orders, and families was compared using Pearson's Chi-square test. Statistics were judged to be significant for P-values under 0.05.

RESULTS

In total, 965 arthropods were collected and identified, representing 4 Classes, 12 Orders, 30 Families, 36 Genera, and 39 Species. (Table 1). The most prominent species of identified arthropods were *Camponotus pennsylvanicus*, *Tipula* spp.., and Alphitobius spp (Table 1). As shown in Table 1, the species with the lowest species richness were *Brachycybe* spp., *Gromphadorhina portentosa*, *Blatella lituricollis*, *Clivina impressefrons*, *Galerita* spp., *Podabrus pruinosis*, *Episyrphus* spp., *Triatoma protracta*, *Triatoma sanguisuga* and *Dipogon subintermedius*. When compared to class, the number of leaf litter arthropods varied significantly ($\chi2= 2134.3$, df = 3, P 0.0001) as shown in Figure 1. As illustrated in Figure 1, the results showed that the class Insecta was the most numerous, with 859 (89.01%). According to Figure 2, the Order Hymenoptera had the most individuals with 464 (48.08%), followed by the Order Coleoptera with 154 (15.95%), and the Order Plasmidesmida with just 1 (0.10%). As a result, there was a significant variation in the number of leaf litter arthropods according to Orders ($\chi2= 2705.5$, df = 12, P 0.0001). As indicated in Figure 3, the Formicidae family had the highest population density with 459 (47.56%) individuals, while the Andrognalidae, Alaberidae, Blatellidae, Cantharidae, Pompilila, Syriphidae, Tenthredinoidea, and Tetrigidae families had the lowest density with 1 (0.10%) each. As a result, there were significant differences in the abundance of leaf litter arthropods according to family ($\chi2= 6633.6$, df = 29, P 0.0001).

Table 1: Species Checklist of Leaf Litter Arthropods from Gallery Forest of Jos Zoological Garden

Class	Order	Family	Common Name	Species	Total	Percent (%)
Arachnida	Aranea	Lycosidae	Wolf spider	*Lycosidae* spp	15	1.55
		Pholcidae	Daddy long legs	*Pholcus phalangioides*	4	0.41
		Sicariidae	Brown recluse spider	*Loxosceles reclusa*	80	8.30
Crustacea	Isopoda	Platyarthridae	Pill bug	*Armadilllidium vulgare*	4	0.41
Diplopoda	Plasmidesmida	Andrognalidae	Feather millipede	*Brachycybe* spp	1	0.10
	Spirostreptida	Spirostreptidae	Giant African millipede	*Archispirostreptus gigas*	2	0.21
Insecta	Blateria	Blaberidae	Madagascar hissing cockroach	*Gromphadorhina portentosa*	1	0.10
		Blatellidae	Blatellid cockroach	*Blatella lituricollis*	1	0.10
	Coleoptera	Carabidae	Ground beetle	*Stenolophus ochropezus*	9	0.93
			Vivid metallic ground beetle	*Chlaenius scapularis*	7	0.73
			Red ground beetle	*Clivina impressefrons*	1	0.10
			False bombardia beetle	*Galerita* spp	1	0.10
		Cantharidae	Soldier beetle	*Podabrus pruinosis*	1	0.10
		Staphylinidae	Devil’s coach horse beetle	*Staphylinus olens*	30	3.11
			Rove beetle	*Staphylinus aethiops*	2	0.21
		Tenebrionidae	Darkling beetle	*Alphitobius* spp	103	10.67
	Dermaptera	Anisolabididae	Ring legged earwig	*Euborelia annulipes*	48	4.97
	Diptera	Calliphoridae	Oriental latrine fly	*Chrysomya megacephala*	4	0.41
		Drosophilidae	Vinegar fly	*Drosophila melanogaster*	6	0.62
		Fannidae	Latrine fly	*Fannia scalaris*	12	1.24
		Muscidae	House fly	*Musca domestica*	2	0.21
			Muscid shoot fly	*Antherigona reversura*	2	0.21
			Unidentified	Unidentified	8	0.83
		Syriphidae	Hover fly	*Episyrphus* spp	1	0.10
		Tipulidae	Crane fly	*Tipula* spp	108	11.20
	Hemiptera	Cydnidae	Burrower bug	*Pangaeus bilineatus*	2	0.21
		Nabidae	Damsel bug	*Nabis roseipennis*	2	0.21
		Reduviidae	Western bloodsucking conenose bug	*Triatoma protracta*	1	0.10
			Eastern bloodsucking conenose bug	*Triatoma sanguisuga*	1	0.10
	Hymenoptera	Formicidae	Carpenter ant	*Camponotus pennsylvanicus*	390	40.41
			Sugar ant	*Camponotus consobrinus*	42	4.40
			Slender twig ant	*Tetrasponera allaborans*	2	0.21
			Fire ant	*Solenopsis geminate*	23	2.38
			Mystrium ant	*Mystrium rogeri*	2	0.21
		Pompilila	Spider wasp	*Dipogon subintermedius*	1	0.10
		Tenthredinoidea	Saw fly	*Tenthredo mesomela*	1	0.10
		Vespidae	Paper wasp	*Polistes* spp	3	0.31
	Lepidoptera	Erebidae	Oak moth	*Phoberia atomaris*	4	0.41
	Orthoptera	Gryllidae	Field cricket	*Gryllus campestris*	25	2.60
		Tetrigidae	Black sided pygmy grasshopper	*Tettigidea lateralis*	1	0.10
	Unidentified				12	1.24
				Total	965	
				Percent (%)		100

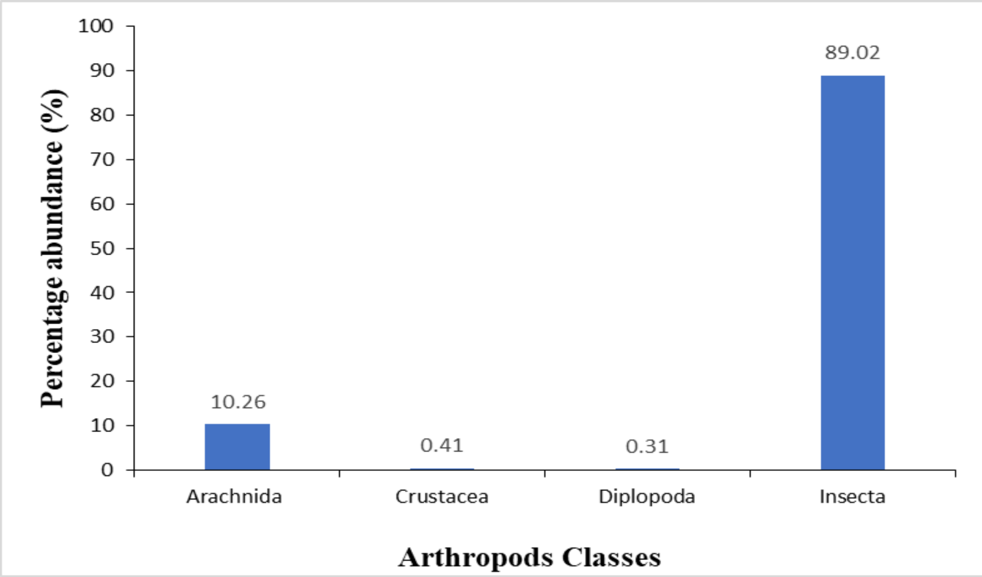

Figure 1: Class-specific percentage abundance of leaf litter arthropods

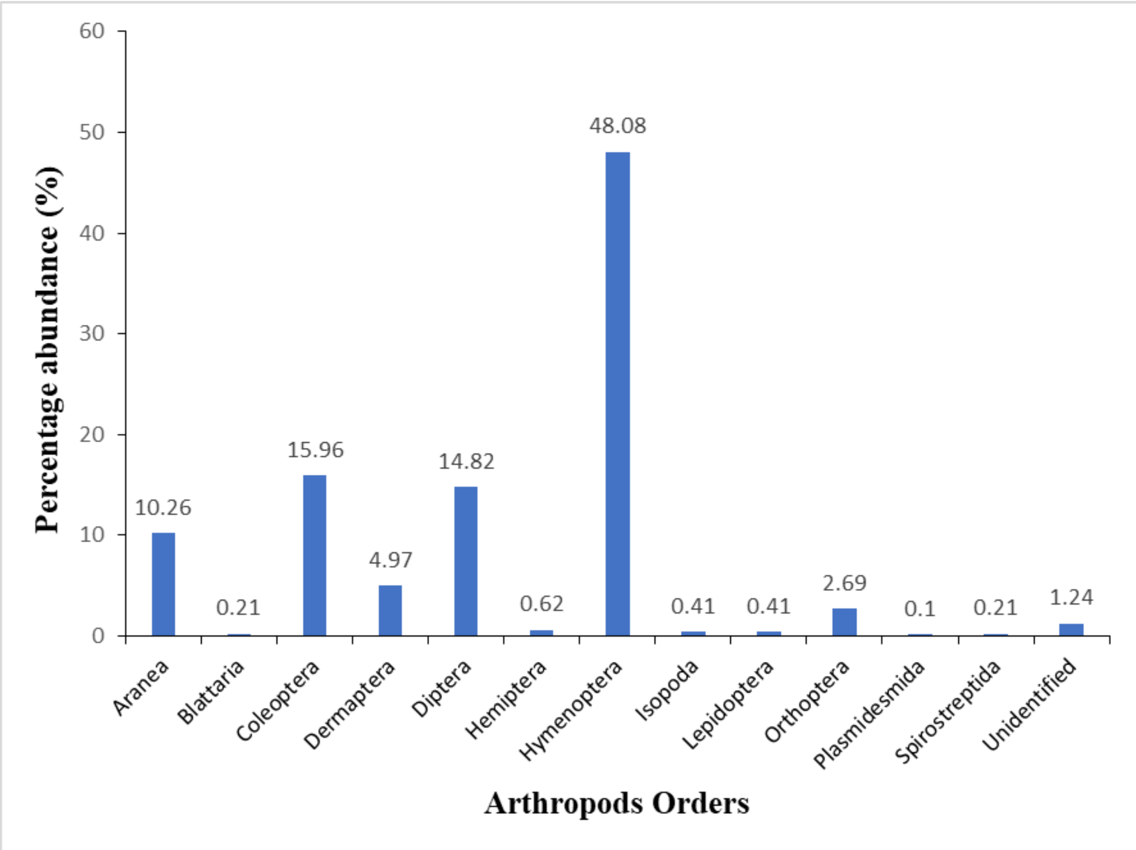

Figure 2: Order-specific percentage abundance of leaf litter arthropods

As demonstrated in Table 2, over the four-week study period, the soil physic-chemical parameters in the Gallery Forest of the Jos Zoological Garden varied over time. The physic-chemical parameters that were recorded and their related abundances are shown in Table 2 in the order that they were recorded. The first measurement was taken at the third collection of leaf litter arthropods, the second measurement at the seventh collection of leaf litter arthropods, and the final measurement at the tenth collection of leaf litter arthropods. When the soil's physic-chemical characteristics were originally measured, they showed a pH of 7.36 (slightly alkaline), a temperature of 22°C, 2.02% organic matter, and a moisture content of 36.70%.

The maximum abundance ever observed was 643 leaf-litter arthropods, which were gathered under all of these conditions. The soil physic-chemical parameters revealed a reduction in the second measurement. It showed that the soil had a pH of 7.01 (slightly alkaline), was 18°C, had 1.75% organic matter, was 24.10% moist, and had 195 leaf litter arthropods in total. These conditions led to the collection of 127 leaf litter arthropods, the lowest abundance ever seen. A total abundance of 965 leaf litter was produced by the soil's mean values for pH, temperature, organic matter, and moisture content, which are 7.11, 20°C, 1.89%, and 27.10%, respectively. As indicated in Table 2, the relationship between soil moisture, soil pH, and the quantity of leaf litter was direct (soil moisture dropped as soil pH declined).

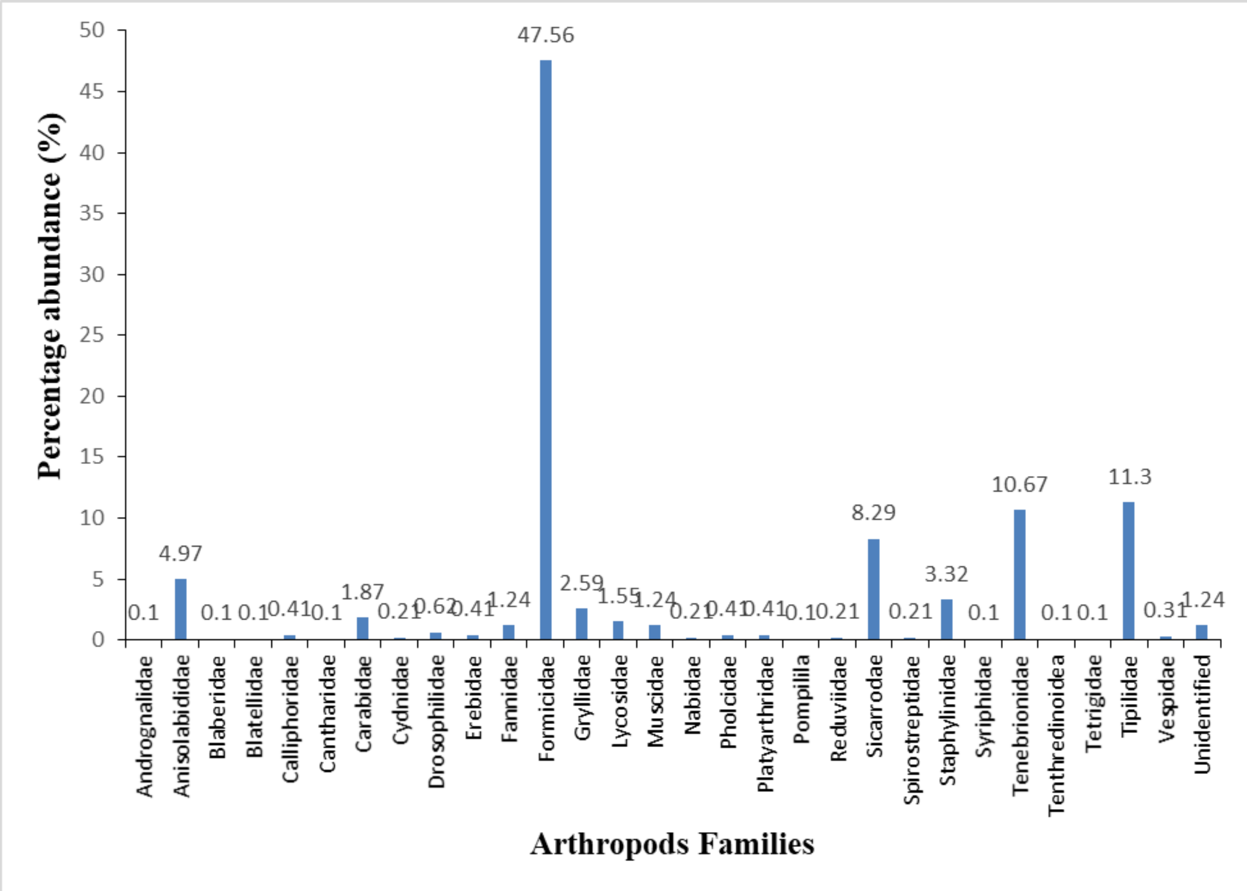

Figure 3: Family-specific percentage abundance of leaf litter arthropods

Table 2: Soil Physicochemical Factors on Abundance of Arthropods in Jos Zoological Garden, Jos.

Mean Soil Physicochemical Factors				
Soil pH	**Soil Temperature (°C)**	**Soil Organic Matter Content (%)**	**Soil Moisture Content (%)**	**Leaf litter Arthropod's Abundance**
7.36	22.00	2.02	36.70	643
7.01	18.00	1.75	24.10	195
6.91	20.00	1.89	20.55	127
Mean= 7.11	Mean=20.00	Mean=1.89	Mean=27.10	Total=965

DISCUSSION

Arthropods are essential to the stability and operation of terrestrial ecosystems (Njila et al. 2022). In this study, arthropods that live in leaf litter were classified into four classes, twelve orders, and thirty families. The habitat, microclimate, and food availability in the leaf litter as well as the protection from predators and harsh weather conditions afforded by the leaf litter can be linked to the 36 genera and 39 species that were collected and identified in this study (Table 1). According to Njila et al. (2022) investigation, many arthropods use the leaf litter layer as a habitat because it provides them with food, a refuge from the elements, and protection from predators, all of which increase their population. In this study, the high abundance of *Camponotus pennsylvanicus*, Tipula species, and Alphitobius species (Table 1) was likely caused by these detritivores' attraction to the fermented byproducts of decomposing leaf litter as they drank these liquids for the purpose of feeding, C. pennsylvanicus, Tipula species, and Alphitobius species congregate at this stage of the decomposition process when the leaf litter begins to ferment. They absorb their liquid meal via their mouthparts. Since no immature forms were found during the survey and some Tipula species have been reported to lay their eggs on fermented material (Njila et al. 2014), the existence of these insects was attributed to their affinity to liquid food (Perez and Barrion-dupo, 2013). Triatoma protracta, Triatoma sanguisuga, Dipogon subintermedius, Tenthredo mesomela, and Tettigidea lateralis were the least common arthropods in this study, while Galerita species, Podabrus pruinosis, Episyrphus species, Blatella lituricollis, Clivina impressefrons, and Gromphadorhina portentosa were the most common (Table 1). Because they are opportunistic predators, the presence of these arthropods may only be temporary (Njila and Hadi, 2015). The torrential rains at the time of sampling may have contributed to these extremely low levels. Many arthropods appear to have avoided the leaf litter due to the recent severe rains. The arthropods might have looked for areas to reside that were drier or they might have been washed away by rain. The variability of the microhabitats and the availability of food in the leaf litter, as well as the canopy provided by trees covering the leaf litter in the gallery forest of the Jos Zoological Garden, could be responsible for the considerable difference in the abundance of leaf litter arthropods in relation to Class, Order, and Family (Figures 1, 2, and 3) observed in this study. This result corroborates the findings of Njila et al. (2022) which showed that mature forests with a closed canopy are more likely to host a diversified and rich fauna than forests in an early successional stage. Insecta and Hymenoptera were also found to be the most abundant taxa of ground dwelling arthropods associated with two habitat types in the Jos Zoological Garden Jos Plateau state, North central Nigeria (Njila and Hadi, 2015). This study's noticeably high abundance of members of the family Formicidae is consistent with observations obtained by Cheli et al. (2010) while studying the community of ground-dwelling arthropods on Peninsula Valdes in Patagonia, Argentina. According to Cheli et al. (2010), the colonial nature of the Formicidae means that when they are collected in an area, they are typically captured in relatively large numbers. This supports the Formicidae's hegemonic position in a habitat. The Gallery forest's soil pH was primarily alkaline (Table 2). This has a favorable correlation with the abundance and variety observed. This is in keeping with the findings of Hamilton (2015) who linked the richness and abundance of arthropod species to alkaline soils, and with the findings of Njila et al. (2022), who found that arthropods prefer alkaline soil to acidic soil in Gallery forest soils. The high rate of litter decomposition, increased microbial activity, and water dilution potential with increasing moisture content were all factors that contributed to the soils' alkaline nature and supported Leonardo (2006) findings regarding the decomposition and micro-arthropod abundance in soil and litter in a Southern Appalachian wetlands complex. All of the soil in the Jos Zoological Garden's Gallery woodland had low temperatures (Table 2). However, Table 3 shows that the Gallery Forest of the Jos Zoological Garden has the highest soil temperature observed and the largest arthropod abundance. This is likely because, at warmer temperatures, arthropods reproduce and mature more quickly, which increases their abundance. This is in line with Kiritani's (2006) assertion that some insects may produce more generations as a result of increased temperatures likely stimulating adult reproduction. In general, the weather during the study period and the shade given by the trees in the Gallery Forest may be blamed for the low temperature of the soils. The other significantly lower temperatures that revealed lower arthropod abundances may be because of the lower temperatures' effects on metabolism and reproduction. This is corroborated by research by Block et al. (1990), which showed that as ambient temperatures drop near the low end of the arthropod species' thermal range, each individual's total metabolism declines and their ability to move becomes increasingly constrained. The Gallery woodland of the Jos Museum Zoological Garden had a low amount of soil organic matter (Table 2). The quantity and variety of arthropods that were collected were adversely affected by this. Due to excessive rainfall during the study period, the soil may have been washed away, and the Gallery Forest of the Jos Zoological Garden's predominant tree species may also have contributed to the low proportion of soil organic matter. This is consistent with the findings of Wiwatwitaya and Takeda (2005), who linked seasonal fluctuations in soil arthropod abundance, and the findings of Funderburg (2001), who stated that soils that have grown under forest vegetation typically have comparatively low levels of organic matter and that there are at least two explanations for these levels: trees create a lot smaller root mass per acre than grass plants, and trees do not die back and decay every year. However, it is crucial to remember that soil organic matter typically excludes surface plant litter, or new vegetal waste (Njila et al. 2022). The Jos Zoological Garden's Gallery Forest had high soil moisture levels throughout. The highest level of soil moisture observed had the most leaf litter arthropods (Table 2). Thus, there was a correlation between this and the high number of leaf-litter arthropods. This is consistent with the finding of Sylvain et al. (2014) that increased soil moisture increased the abundance of practically all taxa (nematodes and arthropods) in their study. This is further reinforced by the research of Njila et al. (2022), who found that places with high levels of moisture in the leaf litter are regarded as refuges for desiccation-intolerant species and permit continued reproduction (abundance) and foraging activity. The significant amount of rain that fell during the sampling period could be blamed for the high soil moisture content. However, the frequent flooding of the pitfall traps caused by the continuous rain throughout the study period limited the collection of arthropods in the traps, which in turn reduced the number of leaf litter arthropods that could be gathered.

CONCLUSION

Within the Gallery Forest of the Jos Zoological Garden, there were considerable differences in the species diversity and richness of leaf litter arthropods. In the absence of human activities like cattle grazing and the continuous deforestation there, the Gallery Forest may host a large variety of leaf litter arthropods. In this study, it was discovered that carpenter ants (Camponotus pennsylvanicus) of the Class: Insecta, Order: Hymenoptera, and Family: Formicidae was the most predominant taxon. The majority of the colonies of C. pennsylvanicus in the forest were discovered in decomposing wood. As a result, their presence might be considered a key bio-indicator of the forest's health. The Jos Zoological Garden's Gallery Forest was also studied for its soil physic-chemical parameters, including soil moisture, temperature, pH, and organic matter. High soil moisture content and an alkaline soil pH favored the abundance of leaf litter arthropods, whereas low soil temperature and low soil organic matter content was unfavorable to the abundance of leaf litter arthropods as a direct consequence.

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