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Succession of Soil Organisms (Microarthropods and Earthworms) During Vermicomposting.

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ABSTRACT

Soil biota plays an important role in supporting nutrient cycling as well as creating and stabilizing soil structure. According to their size, soil organisms are usually classified into microfauna, mesofauna, and macrofauna. Soil Microarthropods have been included in mesofauna and earthworms in macrofauna. The experimental setup involves the study the “Succession of Soil Organisms (especially Microarthropods and Earthworms) in Vermicomposting Unit” during various stages. The investigation includes setting up of experiments to study the density and diversity of soil organisms in *Pongamia pinnata* leaf litter during the initial (10th day), intermediate (20th and 30th day) and final (40th day) stages of vermicomposting process using Berlese-Tullgren’s funnel. Litter organisms such as microarthropods (<10mm) and earthworms were identified for qualitative as well as quantitative abundance. Among the microarthropods in the vermicomposting unit, the dominant ones are acari and collembolans which constitute about 42% and 32% respectively followed by isopods and Pseudoscorpion 6%, coleopterans and hymenopterans 4%, dipterans 3%, araneae 2% and thysanopterans 1%. During the various stages of vermicomposting maximum microarthropods were recorded during the intermediate stages on 20th and 30th days while minimum microarthropods were recorded during the initial (10th day) and final stages (40th day). All the stages were dominated by acari and collembolan population the highest being recorded during the intermediate stages and lowest during the initial and final stages of vermicomposting. In contrast, pseudoscorpion, isopod and araneae population were recorded maximum during the final stages of vermicomposting, while population densities of diptera, coleoptera, thysanoptera and hymenoptera were more or less constant during all the stages of vermicomposting. Earthworm (*Lampito mauritii*) numbers during various stages of vermicomposting shows that no earthworms were recorded during the initial stages while a steady increase in earthworm numbers were recorded during the intermediate (20th and 30th days) and final stages (40th day) of vermicomposting. The implication of this study is that a strong faunal effect on decomposition argues for greater consideration of the role of decomposer organisms in vermicomposting process.

Keywords: Vermicomposting, Berlese-Tullgren’s Funnel, Microarthropod, Earthworm, *Lampito mauritii*, *Pongamia pinnata*, Leaf Litter.

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INTRODUCTION

Soil biota have influence on other organisms through both positive interactions (commensalisms, synergism, and mutualism) and negative interactions (predation, competition, and amensalism) within the food web. They also have influence on the soil through direct (mineralizing nutrients, controlling microbial pathogens, and changing microbial community composition) and indirect (engineering habitats, changing primary production, and transporting microorganisms) interactions with the soil [1]. Soil biota plays an important role in supporting nutrient cycling as well as creating and tabilizing soil structure [2]. According to their size, soil organisms are usually classified into microflora, microfauna, mesofauna, and macrofauna [3].

Soil micro arthropods are abundant small invertebrates that live in the soil and litter layer. They are also considered as members of the mesofauna of soil. Typical micro arthropods include mites, springtails, pseudo scorpions, and insect larvae. Soil arthropods measuring upto 10mm in length can be considered as microarthropods. These include Protura, Diplura and Collembola of the Class Insecta; Symphyla and Pauropoda of the Class Myriapoda; Tardigrada, Copepoda and Isopoda of the Class Crustacea; and Pseudoscorpions, Spiders and Acari of the Class Arachnida [4].

Microarthropods are abundant in most agricultural soils, but their importance is often overlooked [5]. Soil microarthropods play a key role in the regulation of microbial populations, the decomposition of organic matter, and the cycling of nutrients through the comminution of organic substrates within the soils [6].

Microarthropods can influence the microbial activity, directly by feeding on fungal and bacterial biomass, and indirectly by fragmenting litter in such a manner as to increase surface area for microbial colonization. In addition, it is estimated that microarthropods contribute up to 30% of gross N mineralization through direct metabolic processes [7]. Soil microarthropods are often used as bioindicators of agricultural soil quality [8].

Among soil arthropods, mesofauna are often the best represented group in terms of abundance, richness and diversity, and play an important role in decomposing organic matter, recycling and increasing nutrient availability and stability [9]. The most abundant soil mesofauna are the Acari (mites) and Collembola (springtails) [10], which can exhibit strong control on ecosystem functioning [11]. Collembola and oribatid mites constitute a diverse and numerically important part of the soil mesofauna [12], have been proposed as bioindicators. The microarthropod population varies from place to place [13], depending upon factors like soil moisture, soil organic matter, cultivation practices, temperature, pH, salinity, nitrate, phosphate and CaCO_3 [6]. Large fauna of collembola have been reported from soils containing higher content of organic matter [10].

Many studies have shown that the density and diversity of microarthropods increase in soils with earthworms [14, 15]. Larger soil animals such as earthworms and arthropods comminute plant litter, thereby increasing the surface area [16]. Faunal activity also helps to incorporate organic material in the soil, which provides better contact between the organic residues and the soil environment. The general conclusion is that a decrease in particle size and/or comminution by the soil fauna increases decomposition rate [17].

Plant litter decomposition is an important biological process driven by a range of complex and interacting physical factors, such as climate, substrate, soil organisms, and physical and chemical properties of soils [18]. Mechanisms of soil faunal contribution to litter decomposition include digestion of substrates, increase of surface area through fragmentation, and acceleration of microbial inoculation to materials [19]. Soil microarthropods as prevalent components of the soil fauna, have been shown to increase the rates of litter decomposition, nutrient cycling and primary productivity in forest ecosystems [9].

Arthropods are usually retrieved from soil/litter samples with Berlese-Tullgren funnels. In these funnels, a source of heat (i.e. a light bulb) is placed above the sample, and a collecting vial filled with a killing solution (e.g. 70% ethanol) is placed below the sample. Light from the bulb has a double effect because light per se forces photophobic organisms to move away from the source, and light heats the sample. As the sample dries, a temperature and humidity gradient is created between the upper and lower surfaces of the sample. As this gradient moves downwards, animals are forced down into the collecting liquid [20].

Darwin [21] published his last scientific book entitled “*The formation of vegetable mould through the action of worms with observations on their habits*”, a result of several decades of detailed observations and measurements on earthworms and the natural sciences, covers the importance of burrowing and casting (bioturbation) activity of earthworms in soil fertility and plant growth.

An important result of earthworm activity is the creation of channels and pores throughout the soil volume [22]. By burrowing into the soil, earthworms provide channels that allow circulation of air and permit infiltration of water [23] and by incorporation of organic matter into mineral soil they produce an intimate mixing of soil layers providing potential for improved plant growth [24].

The vermicomposting process includes two different phases involving the activity of earthworms, (a) an active phase during which earthworms process wastes, thereby modifying their physical state and microbial composition [25], a maturation-like phase marked by the displacement of the earthworms towards fresher layers of undigested waste, during which the microbes take over the decomposition of the earthworm-processed waste [26].

Vermicompost is finely divided peat-like material with high porosity, aeration, drainage, water-holding capacity, and low C:N ratio produced from organic wastes stabilized by interactions between earthworms and microorganisms, under aerobic conditions. Vermicompost contain nutrients in forms that are readily available for plant uptake [27], such as nitrates, exchangeable phosphorus, and soluble potassium, calcium, and magnesium . Vermicompost is also rich in microbial populations and diversity, particularly fungi, bacteria, and Actinomycetes.

The present work has been designed to study the “Succession of Soil Organisms (especially Microarthropods and Earthworms) in Vermicomposting Unit” during various stages. The investigation includes setting up of experiments to study the density and diversity of soil organisms in *Pongamia pinnata* leaf litter during the initial, intermediate and final stages of vermicomposting process.

MATERIALS AND METHODS

The experimental setup involves the study of succession of soil organisms especially microarthropods and earthworms in vermicomposting unit.

Setting up of Vermicomposting Unit

Vermicomposting unit was set up in a plastic container of 12 litre capacity as per the VERMITECH procedure [28], by first placing a basal layer of ‘vermibed’ comprising blue metal (1-2 inches) followed by a layer of coarse sand to a total thickness of 2-3 inches to ensure proper drainage. On top of this is added a moist layer of good garden loamy soil of about 8-10 inches.

Inoculation of Earthworms

Earthworms belonging to anecic variety, *Lampito mauritii* of about 15 Nos. (Clitellates) were collected from Periyar University Campus, Salem and inoculated into the vermicomposting unit. The plastic containers were regularly watered during the period of study to maintain moisture of $50\pm 2\%$.

Vermicomposting of *Pongamia pinnata* leaf litter

Pongamia pinnata (Common Name: Pongam Tree, Family: Fabaceae) leaf litter were collected from Periyar University Campus, Salem and cut into smaller pieces of about 10mm in size. About 500 grams of leaf litter was thoroughly mixed with 500 grams of fresh cow dung (1:1 ratio) and placed in the vermicomposting unit for decomposition. Soil organisms were extracted using Berlese-Tullgren’s funnel at various intervals on 10th, 20th, 30th and 40th day of vermicomposting process.

Extraction of Soil/Litter Organisms by Berlese-Tullgren's Funnel

The extraction of organisms from *Pongamia pinnata* litter samples during the initial (10th day), intermediate (20th and 30th day) and final stages (40th day) of vermicomposting process was done using Berlese-Tullgren funnel set up in the laboratory. About 100gms of the above leaf litter was added into the Berlese-Tullgren's funnel and the litter organisms such as microarthropods (<10mm) and earthworms were extracted and identified for qualitative as well as quantitative abundance. In Berlese-Tullgren's funnel, a source of heat (i.e. a light bulb) was placed above the sample, and a collecting vial filled with a killing solution (e.g. 70% ethanol) was placed below the sample. Light from the bulb has a double effect because light per se forces photophobic organisms to move away from the source, and light heats the sample. As the sample dries, a temperature and humidity gradient is created between the upper and lower surfaces of the sample. As this gradient moves downwards, animals were forced down into the collecting liquid. The entire experiment was performed in triplicate.

Observation & Recording of Soil Organisms

Soil organisms were observed under a dissection microscope. Density and diversity of Soil Microarthropods such as Acari, Areneae, and Pseudoscorpion of class Arachnida; Collembolan, Coleopteran, Thysanoptera, Diptera and Hymenoptera of Class Insecta; Isopoda of Class Crustaceae and earthworm population (*Lampito mauritii*) were recorded during initial (10th day), intermediate (20th and 30th day) and final stages (40th day) of vermicomposting process.

Statistical Analysis

All data were expressed as Mean \pm Standard Error.

RESULTS AND DISCUSSION

The microarthropod population density and diversity are shown in Table-1 and Figure 1. Among the microarthropods in the vermicomposting unit, the dominant ones are acari and collembolans which constitute about 42% and 32% respectively followed by isopods and pseudoscorpion 6%, coleopterans and hymenopterans 4%, dipterans 3%, araneae 2% and thysanopterans 1%.

During the various stages of vermicomposting, maximum microarthropods were recorded during the intermediate stages on 20th and 30th days while minimum microarthropods were recorded during the initial (10th day) and final stages (40th day). All the stages were dominated by acari and collembolan population the highest being recorded during the intermediate stages and lowest during the initial and final stages of vermicomposting. In contrast, pseudoscorpion, isopod and araneae population were recorded maximum during the final stages of vermicomposting, while population densities of diptera, coleoptera, thysanoptera and hymenoptera were more or less constant during all the stages of vermicomposting (Table-1 & Figure-2). Plant litter decomposition is the process of biological disintegration of litter during which mineralization of complex organic compounds into simple inorganic forms occurs. It includes leaching, break up by soil fauna, transformation of organic matter by microorganisms and transfer of organic and mineral compounds to the soil [29].

Microarthropods are abundant in leaf litter, but their importance is often overlooked [5]. They play a key role in the regulation of microbial populations, the decomposition of organic matter, and the cycling of nutrients through the comminution of organic substrates [30].

In the present study, microarthropods are dominated by acari and collembolans (Table-1, Figure-1 and Plate-1). This confirms with earlier reports that the most abundant soil mesofauna are the Acari (mites) and Collembolans (springtails) [6, 10, 12]. Large fauna of collembola have been reported from soils containing higher content of organic matter [10].

Mites are the most abundant of the soil arthropods. Most mites are beneficial, feeding on microorganisms and other small animals. They assist with decomposition by browsing on preferred fungi, thus preventing any one species from becoming dominant, and by transporting the spores through soil. Springtails

perform similar functions [31]. Increased numbers of mites and collembolans during the intermediate stages of vermicomposting could possibly be due to large number of bacteria and fungi available for feeding. Microbial grazing by Mites and Collembolans influences microbe Abundances, although the extent of grazing pressure appears to determine how microbe affected: when grazing pressure is high, microbial activity is depressed, but when grazing pressure is moderate, microbial Abundance can be enhanced, at least in some instance [19].

In the present study, the proportion of collembolans and mites were 74% in all stages of vermicomposting (Table-1). At the same time, other mesofauna, e.g., Coleoptera, Hymenoptera, Isopod, Pseudoscorpion, Diptera and Araneae that were less abundant (26%) might be subordinate in decomposition of leaf litter [32]. An increase in predatory microarthropods like Pseudoscorpion, Isopod and Araneae during intermediate and later stages of vermicomposting may be due to the availability of microbivores and fungivores like acari and collembolans for feeding (Table-1 and Figure-2).

Microarthropods can influence the microbial activity, directly by feeding on fungal and bacterial biomass, and indirectly by fragmenting litter in such a manner as to increase surface area for microbial colonization. In addition, it is estimated that microarthropods contribute up to 30% of gross N mineralization through direct metabolic processes [7].

Larger soil animals such as earthworms and arthropods comminute plant litter, thereby increasing the surface area [16]. Faunal activity also helps to incorporate organic material in the soil, which provides better contact between the organic residues and the soil environment. The general conclusion is that a decrease in particle size and/or comminution by the soil fauna increases decomposition rate [17].

Today, the viability of using earthworms as a treatment technique for numerous waste streams has been well established. Vermicompost is considered as an excellent product since it is homogeneous, has desirable esthetics, reduced level of contaminants, plant growth hormones, higher level of soil enzymes, and greater microbial population, and tends to hold more nutrients over a longer period without adversely impacting the environment [33].

Earthworms are voracious feeders on organic waste and while utilizing only a small portion for their body synthesis they excrete a large part of these consumed waste material in a half digested form. Since the intestine of earthworms harbor wide ranges of microorganisms, enzymes, hormones, etc., these half-digested substrates decompose rapidly and are transformed into a form of vermicompost within a short time [33].

Table 1: Microarthropod population density and diversity in leaf litter of *Pongamia pinnata* during various stages of vermicomposting (nos/100gms of leaf litter) (Mean ± SE)

Vermi-composting stages	Acari	Collem bola	Coleo ptera	Thysano ptera	Diptera	Pseudo scorpion	Araneae	Hymeno ptera	Isopod	Total
Initial (10 th Day)	9.66± 1.20	9.33± 0.66	1.00± 0.57	1.00± 0.57	1.33± 0.66	0	0	0.33± 0.33	0	22.65
Intermediate (20 th Day)	29.33± 1.76	18.66± 0.66	2.33± 0.33	1.00± 0.57	3.33± 0.33	0.66± 0.33	0.66± 0.33	2.33± 0.33	0.33± 0.33	58.63
Intermediate (30 th Day)	15.33± 1.76	13.33± 2.40	2.66± 0.33	0	0.66± 0.66	2.66± 0.33	1.33± 0.33	3.00± 0.57	4.33± 0.88	43.30
Final (40 th Day)	12.66± 1.76	10.66± 1.20	0.33± 0.33	0	0	6.00± 0.57	1.00± 0.57	1.33± 0.33	5.00± 1.00	36.98
Mean	16.74± 4.35	12.99± 2.06	1.58± 0.54	0.50± 0.28	1.33± 0.71	2.33± 1.34	0.74± 0.28	1.74± 0.58	2.41± 1.30	40.39± 7.45

Table-2 shows the earthworm population (*Lampito mauritii*) in vermicomposting unit extracted from litter layer using Berlese-Tullgren’s funnel. No earthworms were recorded during the initial stages while a steady increase in earthworm numbers were recorded during the intermediate (20th and 30th days) and final stages (40th day) of vermicomposting. Initially, the *Pongamia pinnata* leaf litter used for vermicomposting reaches the thermophilic stage and then it reaches mesophilic stage in about 2 weeks’ time. Therefore, the earthworms may have been restricted in the soil layer beneath the litter layer during the initial thermophilic stage and later seen in the litter layer during mesophilic stages of vermicomposting. Anecic variety of

earthworms like *Lampito mauritii* has been known to create burrows in soil layer and could have taken refuge during the early thermophilic stage. After the initial thermophilic stage, a continuous increase in earthworm population has been recorded until the end of vermicomposting process. The Pongam tree leaves with a relatively high content of N are more palatable and therefore more readily accepted by earthworms [34].

Table 2: Earthworm population in leaf litter of *Pongamia pinnata* (N/100 gms) during various stages of vermicomposting process (nos/100gms of leaf litter) (Mean ± SE)

Vermicomposting stages	Earthworm Population (<i>Lampito mauritii</i>)
Initial (10 th Day)	0
Intermediate (20 th Day)	3.66±1.20
Intermediate (30 th Day)	4.33±0.88
Final (40 th Day)	7.66±1.45

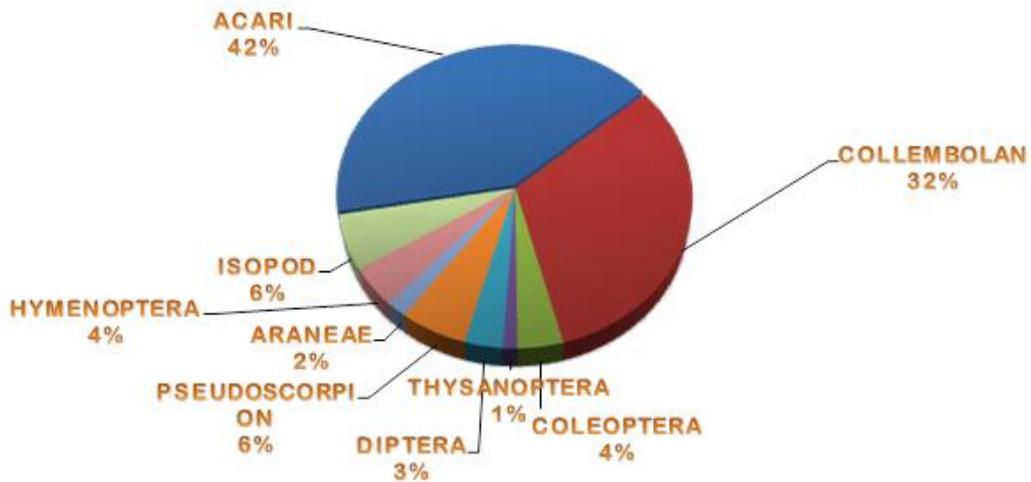


Figure 1: Microarthropod population density and diversity during vermicomposting in leaf litter of *Pongamia pinnata*

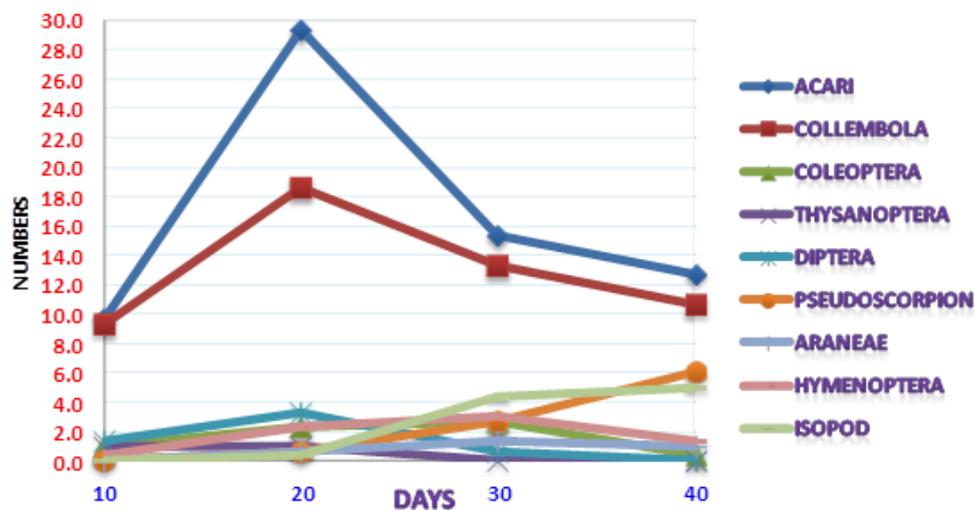


Figure 2: Microarthropod population density and diversity during various stages of vermicomposting in leaf litter of *Pongamia pinnata*

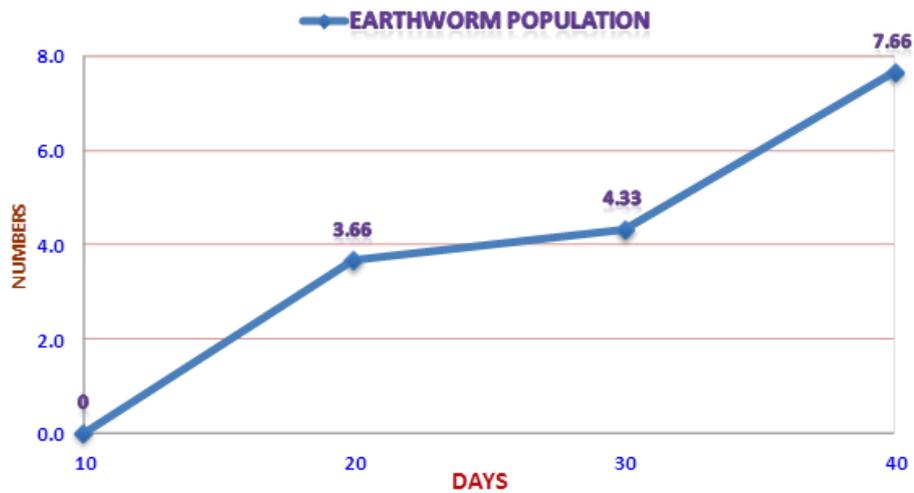


Figure 3: Earthworm (*Lampito Mauritii*) population during various stages of vermicomposting in leaf litter of *Pongamia pinnata*

CONCLUSIONS

The present investigation concludes that the succession of soil organisms during various stages of vermicomposting plays an important role in decomposition of leaf litter. Acari and collembolans are dominant Microarthropods followed by other groups. Initial and intermediate stages were dominated by microbivores and detritivores like acari, collembolans and later stages by predatory microarthropods like pseudoscorpions, isopods and Araneae. Earthworm population were initially low and steadily increased during later stages of vermicomposting. Overall abundance of soil organisms such as earthworms and arthropods comminute plant litter, thereby increasing the surface area for microbial colonization. Faunal activity also helps to incorporate organic material in the soil, which provides better contact between the organic residues and the soil environment. The general conclusion is that a decrease in particle size and/or comminution by the soil fauna increases decomposition rate. These soil organisms can be important in controlling the rate of litter decomposition and altering nutrient cycling. The implication of this study is that a strong faunal effect on decomposition argues for greater consideration of the role of decomposer organisms in vermicomposting process.

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