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An Overview of Leaf Litter Decomposition and Nutrient Dynamics of Multipurpose Tree Species

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The multipurpose tree species is a plant species that is purposefully grown so as to provide two or more than two products and their leaf litter decomposition in our ecosystems has a play major role in nutrient dynamics in the atmosphere. From this review paper examined different leaf litter decomposition assessing methods in which litter bag method is most suitable methods to determination of decomposition rate. Abiotic factors such as temperature, rainfall, humidity, moisture, evaporation rate and soil physical factors such as soil pH, texture directly correlated to soil microbial such as algae, actinomycetes, bacteria and fungi communities to stimulating action for the breakdown of leaf litter composition (like- cellulose, hemicelluloses, tannin, lignin) and transfer of organic matter to nutrients, release of CO_2 to the environment etc.

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1. INTRODUCTION

"The dead plant materials such as leaves, bark, needles, flower and twigs that have fallen on the ground are called litter. As the majority of organic matter (OM) produced by plants is returned to the soil as litter, the transfer of nutrients and energy from living biological components to the soil is the important mechanism of nutrient recycling. In the various components of the plant-soil-microorganism mechanism, decomposition processes have a crucial vital role by releasing a complex organic compound into the simple usable form for plants growth and soil fertility. Tree leaf tissue accounted for more than 70% of above ground litter fall in the ecosystems and rest is composed stem, twigs, flower, fruits and other components. The decomposition is a biological disintegration process of dead organic materials whereby mineralization of complex organic matter into simple inorganic forms" [1]. "Tree leaf litter decomposition has physical, chemical, and biological impact and is an important biological process that regulates the complex nutrient content to simple form and net productivity of ecosystems" [2]. Litter decomposition also affects the soil moisture status, light, and temperature conditions required for the growth of surrounding plants [3], and it impacts the microbial community structure, soil physiochemical properties, and organic matter escapism and content of soil sediments. Generally correlation of main three factors is climatic condition of site, leaf litter quality and soil biota. Out of these, climate plays dominant crucial role followed by leaf litter quality and soil biota as well as release of nutrient are directly correlated to decomposition process [4].

2. STUDIES OF LEAF LITTER DECOMPOSITION PROCESS

Leaf litter decomposition plays a very vital and important role for cycling of nutrient in ecosystems, where different types of flora on the basis of quality influence most significantly. The interaction among soil microbes, climatic conditions and quality of leaf litter will result in the decomposition of litter, in which soil microbes fungi and bacteria are the primary decomposers of leaf litter and broken down into smaller particles and modified mineralized form into inorganic compounds, because microbes feed on the organic remains of dead plants materials [5,6]. After that the following major processes take place.

1. During the decomposition process soluble materials are moved to lower soil layer for further process.
2. Soil microbe's breakdown the larger-pieces of leaf litter into smaller ones.
3. Decomposer recognizes the molecules of litter to change the chemical alteration in soil.

During the decomposition process time, soil fauna, microorganism play a very important role to break the complex compound of leaf litter and change the chemical composition of leaf litter structure and soluble compounds [7,5]. Atmospheric features, like temperature, rainfall, relative humidity and other seasonal variations may impact the existence of soil microbes and other soil features such as pH, organic carbon, nutrient availability, soil texture and structure that significantly affect the rate of litter decomposition as well as leaf litter quality like litter structure, roughness, smoothness, waxes structure, etc. directly influence the activity of soil communities and process during the decomposition [8]. A graphical representation of litter degradation is shown in Fig. 1.

3. FACTORS AFFECTING LEAF LITTER DECOMPOSITION

Leaf litter decomposition depends on various biotic such as chemical composition of litter and soil microorganisms and abiotic factors like temperature, relative humidity, and rainfall. Both factors directly influenced on mineralization and humification process of structural complex of litter such as lignin, cellulose, hemicelluloses, pectin, starch, etc. through microorganisms and gradually mineralization of soluble nutrient compounds into soil by leaching process. However, from the above discussion we can conclude that the main three leading features are regulating the litter decomposition like leaf litter quality traits, composition of soil microorganism activities and physio-chemical environments. [9]. In abiotic process, factor such as temperature is a prime factor in determining the rate of leaf litter decomposition and more sensitive compared to others because abiotic factor like temperature influences soil temperature and soil temperature directly influences—soil microbial activity rises exponentially. The fresh and old leaf litter position is a readily available substrate for soil microorganisms because leaf litter quality directly influences the decomposition process, as it reduces the throughout litter decomposition due to the loss of readily accessible carbon and accumulation of recalcitrant compounds [10], shown in Fig. 1.

4. ROLE OF TREES AND LEAF LITTER QUALITY

Tree leaf litter contains have different organic compounds, mainly four important soluble organic material present in litter such as phenolics, hydrocarbons, sugars and glycerides, in which soluble sugar, oligosaccharides and primarily monosaccharide are difficult to metabolize. The above proportions of all compounds vary with the plant part such as leaves, stems, roots and bark as well as different tree species. The tree leaf litter chemical composition like nitrogen, phosphorus, potassium and cell wall components like lignin, cellulose and hemicelluloses etc, directly influence the litter decomposition and nutrient release [5,11]. The components account for chief cell wall like lignin content 15 to 40% of total litter quantity. It may be in extreme cases low as 4% or high as 50%. In addition to lignin, other compound like cellulose, hemicelluloses, and pectin are common constituents in tree leaf litter in term of quantity. The amount of cellulose (10 to 50%) of litter quantity is linked with β-1-4 bonds and hemicelluloses are polymers of sugar, which create long chains of molecules organized into fibers [12]. All the components such as litter traits-leaf toughness, N, lignin, poly-phenol, C/N ratio, lignin: nitrogen ratio etc. directly and indirectly influence the decomposition process and various traits, nitrogen and lignin content of plant litter significantly, regulating the decomposition rate [13,14].

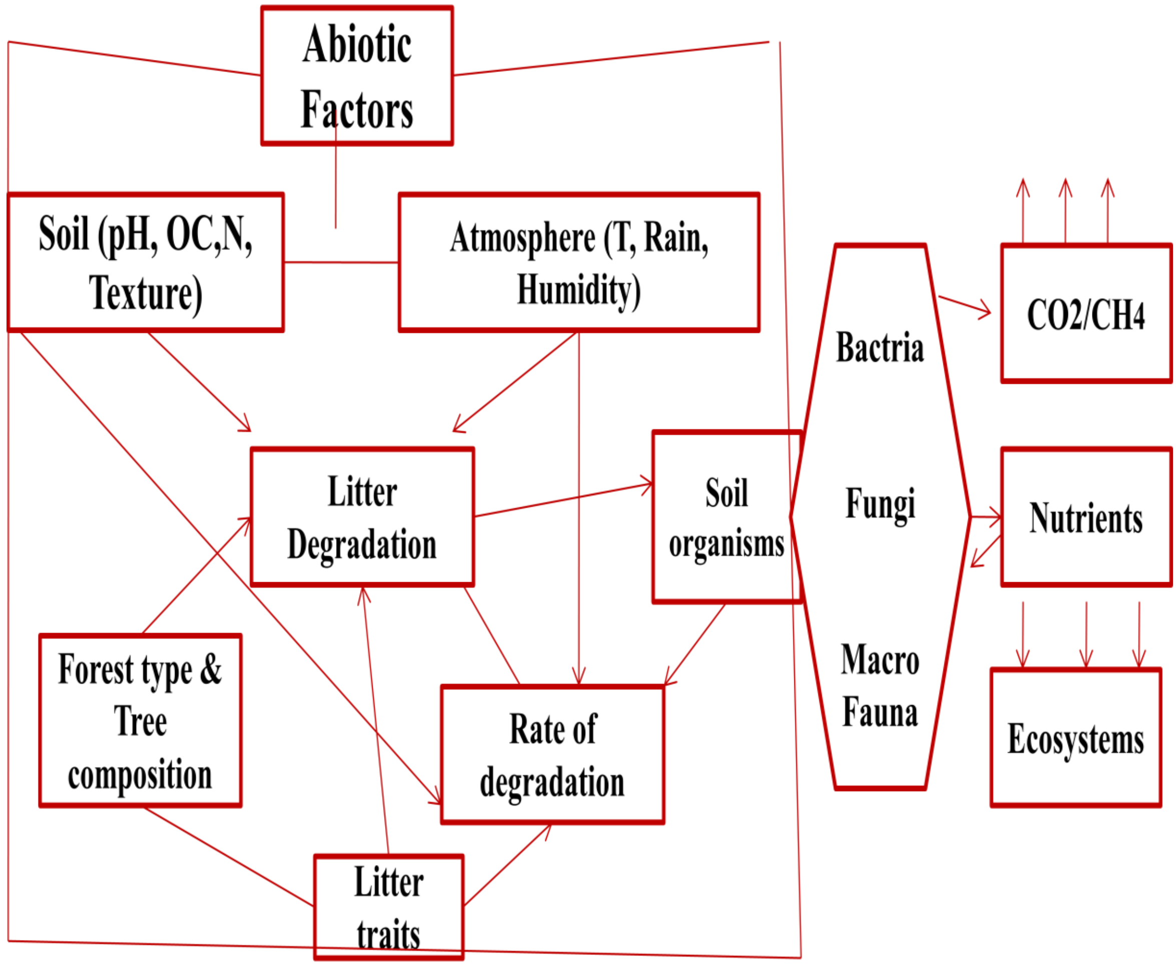

Fig. 1. Graphical representation of factors affecting litter degradations

5. ROLE OF SOIL PROPERTIES AND SOIL FAUNA

Different soil physical and chemical characteristics like soil texture, soil pH, cation exchange capacity, organic matter, nutrients contents, bulk density, etc. have a significant role in leaf litter decomposition process. In decomposition process, soil texture stimulates nutrients and water dynamics, porosity, permeability and soil surface area. Soil organic matter quality and quantity also play important role to increasing the population density of soil macro-organism, which plays important role in jumble the leaf litter and decomposition rate [15,16,17]. Table 1 shows, the significant role of major soil fauna and microbes such as algae, actinomycetes, bacteria and fungi communities, etc. to stimulate microbial action such as physical breakdown of leaf litter, transfer of organic matter to nutrients, release of CO_2 to the environment, etc. [18,19,20,21]. Some soil micro-arthropods include small invertebrate animals with an exoskeleton and segmented body found on or near the surface of soil and in plant litter. Their population range is between 10^3 m^{-2} in agriculture soils and 10^6 m^{-2} in forest soils. It is a very essential part of the ecosystems due to their significant role in organic compound decomposition process and mineralization activity, nutrient cycling and pedogenesis [22]. The labile structural compound like cellulose, sugar, amino acid quickly cleaved and absorbed by exo-enzymes and rapid decay [23].

6. ROLE OF ATMOSPHERE FACTORS

“From the studies of different literature we conclude that the atmosphere factors such as temperature, moisture, humidity, rainfall directly influence the chemical component of soil structure and affect the leaf litter decomposition rate in the soil” [24]. “It is also reported that the rate of decomposition of leaf litter is slow in winter season and faster in rainy season, due to the presence of sufficient rainfall, soil moisture and microbial load” [25].

7. WEIGHT LOSS PERCENTAGE AND NUTRIENT DYNAMICS OF DIFFERENT MULTIPURPOSE TREE SPECIES

The time-course study indicated the actual weight loss percentage and nutrient dynamics. Fig. 2 showed the seven different multipurpose tree species such as *Tectona grandis* (T_1), *Eucalyptus tereticornis* (T_2), *Dendrocalamus strictus* (T_3), *Terminalia bellirica* (T_4), *Cassia fistula* (T_5), *Casuarina equisetifolia* (T_6) and *Terminalia arjuna* (T_7) [26]. Maximum decomposition of leaf litter occurred in the *T. grandis* (19.90%) in during first fortnight of July to first fortnight of January which was followed by *D. strictus* (17.80%) and least was in *C. equisetifolia* (15.80%). Among the different time of sampling of multipurpose tree species first fortnight of July (26.20%) to first fortnight of September (18.50%) recorded significantly highest weight loss and decomposition percentage compare to another time course. The factors which affect the rapidity of decomposition of litter may be said to be of two kinds, exterior ones, chiefly the nature of climate and soil and interior ones i.e., the chemical and physical qualities of the litter [27]. Role of major soil fauna and microbes such as algae, actinomycetes, bacteria and fungi communities, etc. to stimulate microbial action such as physical breakdown of leaf litter, transfer of organic matter to nutrients, release of CO_2 to the environment, etc. [18,19]. Nutrient dynamics are directly correlated to breakdown process of leaf litter of multipurpose tree species because higher decomposition rate of little released more nutrient from litter to soil and environment [26,27].

8. LEAF LITTER DECOMPOSITION ASSESSING METHODS

For determination of leaf litter decomposition and decay rate, various methods are used by the authors like mass balance method, litter bag method, tethered leaves method and Cohort layered screen method etc.

1. **Mass balance method** is used to evaluate the leaf litter decay on the assumption of constant fraction, k of the detrital leaf litter quantity decays because mass balance technique depends on natural litter fall and it does not efficiently explain the role of atmosphere factors like temperature and moisture [28,29].

$$\ln (X_t / X_0) = - kt$$

Where, X_0 = weight of litter at time 0, X_t = weight of litter at time t, t- time (usually in year), k- decomposition rate constant.

2. **In litter bag method**, mess size more than 2 mm most suitable to permit the entry of many macro-fauna for contact of leaf litter

and decay process and litter bag of 20x20 cm are common for all size of leaf litter materials [30].

3. **Tethered leaves method**: This techniques similar to the litter bag method. In this method, specific leaf litter is tightly packed with nylon thread or monofilament fishing line and permit the leaf intake by macro-invertebrates such as crabs and snails [31].

4. **Cohort layered screen method** is most appropriate and accurate evaluation of leaf litter decomposition and decay rate. It takes normally three to more years for leaf litter decay studies because there are separate techniques to determination of actual litter fall and decay condition through 1x1 m fiberglass or aluminum window screen with a mesh size of 2-3 mm are used [32].

Chemical analysis for nutrient assessing: For determination of nutrient content, various procedures are used. In the initial, after removing the extraneous materials such as soil particles, macro-organism and other fine particles of roots, the samples washed under running water and finally rinsed with distilled water. After that leaf litter transferred to paper bags and oven dried at 70 ^{0}C for 48 h and recorded the mass residues and powdered using a precision balance. After that decomposed leaf litter materials analyzed chemically to ascertain the concentration of N, P and K by Micro-Kjeldahl method, spectrophotometer method and flame photometer method [33,34].

Table 1. Role of soil fauna and microbes in leaf litter decomposition

S.no.	Decomposer communities	Roles	References
1.	Soil fauna	Microalgae fix nitrogen and produce organic matter via photosynthesis	[17]
		Increase the surface area of substrate for microbial use	[20]
		Releases soil enzymes, which can help to process root-driven carbon, small organic matter, and fresh aboveground litter, as energy source for bacteria (for example, fungi)	[16,21]
		Augment the nutrient in soil by adding nitrogenous compounds present in their excreta and dead tissue	[21]
2.	Soil microbes	Decompose the fragmented litter and release nutrients	[19]
		Release soil enzymes for the purpose of breaking the larger compounds	[18]

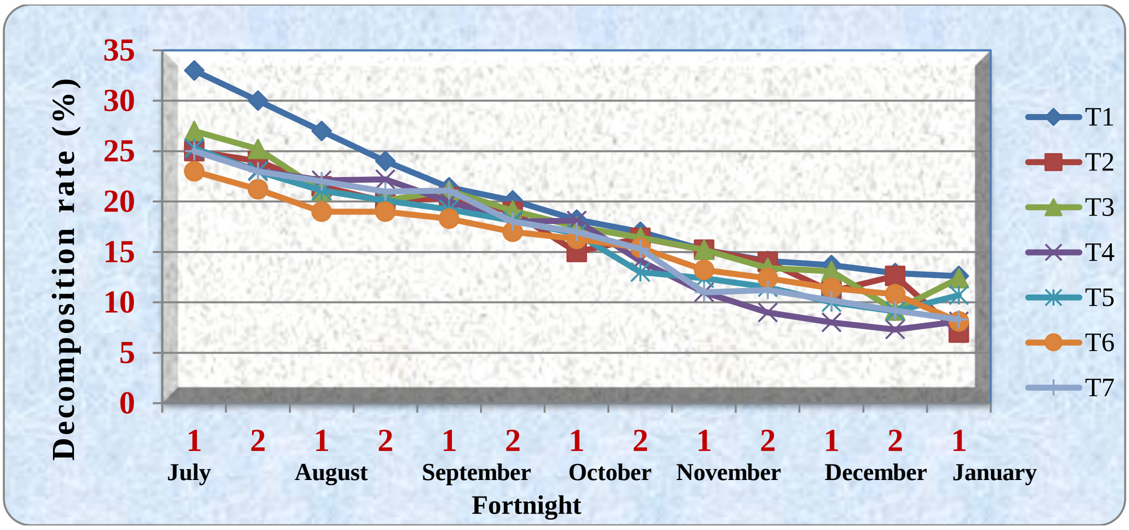

Fig. 2. Effect of time of sampling on weight loss (%) in different multipurpose trees

9. CONCLUSION

Leaf litter decomposition of multipurpose tree species significantly plays a role in the ecosystem, as it is a most important way of nutrient dynamics, specially C, N and other nutrients in the ecosystem. Different multipurpose tree leaf litter decomposition is a very high complex process that involves a number of soil physical factors like soil pH, soil texture, humification and some are chemical factors such as composition of leaf litter-cellulose, hemicelluloses, pectin, lignin, chitin, etc. and last and most important biological factors like atmosphere factor and soil fauna and microbes. However, from the study it is very difficult to understand that which one is the most important factor for litter decomposition. All the physical, chemical and biological factors are inter-correlated to each other for appropriate leaf litter decomposition and decay. From this review paper focuses on different factors that affect the leaf litter decomposition and decay as well as different methods emphasized for assessing litter degradation and nutrient analysis.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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