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Evaluating Litter Decomposition Rate of Five Tropical Trees using Litter Bag Technique

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ABSTRACT

Replenishment of soil nutrients and organic matter is a serious concern in sustaining livelihood security which is favoured by cycling of nutrients through litter addition. The chief objective of the investigation was, to inspect the decomposition rate of leaf litter of five tropical trees using evaluation tools like mass loss, decomposition rate, and relative decomposition rate. The study was carried out at the tree plantations of Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai-625104, India during summer 2019-2020 for eight weeks. Litter Decomposition of legume and non legume trees viz., *Peltophorum ferrugineum*, *Pongamia glabra*, *Albizia lebbek* and *Delonix regia* along with a non-legume, *Azadirachta indica* was evaluated through litter bag technique. The soil moisture, soil temperature, litter moisture content, mass loss, decomposition rate and relative decomposition rate were studied. The study revealed that *Pongamia glabra* litter showed 70 % mass loss in 8 weeks time with maximum decomposition rate. It was closely followed by *Azadirachta indica*. As *Pongamia glabra* litter is fast decaying, it can help in improvement of soil health through enhancing carbon level, organic matter and also microbial activity.

Key words : *Decomposition rate, Legume litter, Litter bag technique, Pongamia glabra, Relative decomposition rate.*

Introduction

Cycling of nutrients is a primary ingredient in the functioning of forest ecosystems. The presence of litter represents a makeshift accumulation of elements which are progressively released, ensuring the permanent contribution of nutrients to the soil. In tropical region, a larger part of the nutrient reserves are found in the trees and plant biomass. The elements in the leaf litter are rapidly mineralized through decay and decomposition and are absorbed by the roots of crops and plants during monsoon rains. Generally, leaf litter perks up soil quality by adding organic matter which in turn boosts water holding capacity, diverse microbes populations (Ngoran *et al.,* 2006) and, microorganisms contribute a major share in recycling of depleted nutrients back to soil (Cole, 1986) even though litter contains lower nutrients, compared to living plants (Sundarapandian and Swamy, 1999). Inclusion of perennial trees plays a great role in nutrient cycling and energy transfer in soil-plant systems under sustainable development (Soni *et al.,* 2020). Such leaf litter, while decomposing, releases and add a lot of nutrients, carbon which are valuable for crop growth and soil fertility through ways of respiration, disintegration, degradation, biological transformation etc. The litter decomposition is primarily augmented by soil microorganisms and it is influenced by litter quality (Joon Sun Kim, 2007) C: N ratio (Taylor *et al.,* 1989b), biotic

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and abiotic environmental factors (Dickinson and Pugh, 1974). The nutrients released by the decomposition process may be accumulated in the top soil, at times, and also transported to deeper soil horizons. Decomposition of added/natural litter is a vital process in carbon (C) and nutrient cycling in cultivated soil, as this process ultimately links to crop production and also to long-term effects in physical, chemical and biological properties of soil. On the other hand, rate and speed of decomposition vary with climatic conditions as it is being faster in humid tropics and dry tropics. However, the litter decomposition of the widely grown and found in many parts of the tropical countries has been less studied. Accordingly, the chief objective of the present study was to inspect the rate of decomposition of leaf litter of five tropical trees.

Materials and Methods

Study Site and Species

The study site is in semi-arid tropics, and the evaluation of litter decomposition was done in tree plantations of Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai during 2019-20, geographically located at 9^0 96′ N latitude, 78^0 5′ E longitude and at an altitude of 147 m above sea level. The topography of the plantation was medium, and the soil was sandy clay loam.

The species selected for the study is widely either grown or spread naturally in many tropical and subtropical countries. The collection of leaf litter was done from the plantations, which encompassed both natural and planted trees, during the peak period of leaf shedding (November-March). The trees which exhibited no evidence of growth abnormalities and damage were identified for the purpose. The tree species studied were,

i) *Pongamia glabra* (L.) Pierre, - family-Fabaceae. It grows to about 15–25 m (50–80 ft) in height with a large canopy that spreads equally wide.
ii) *Albizia lebbek* (L.) Benth: family Fabacea widely cultivated and naturalized in other tropical and subtropical regions. It grows to a height of 18–30 m tall
iii) *Peltophorum pterocarpum* (DC.) Backer ex K. Heyne - Golden or yellow flamboyant; Syn. *Peltophorum inermis* and *Peltophorum ferrugineum*) also belongs to Fabaceae, native to tropical South-Eastern Asia and a popular ornamental tree grown around the world. It is a deciduous tree growing to 15-25 m tall.
iv) *Delonix regia* (Boj.) Raf. (flamboyant) is a 10-15 m tall tree native to Madagascar and spread to the world in tropical and subtropical regions, belongs to the Fabaceae family
v) *Azadirachta indica* A. Juss. It belongs to the family Meliaceae, grown throughout tropical and subtropical regions. This tree is famously popular for its medicinal values and healing properties. It is used in various products like shampoos, creams, ointments, etc. It is also used as a natural pesticide.

Litter bag technique

Litter decomposition was studied using the litter bag technique (Mason, 1977; Singh and Gupta, 1977) for four months. This method allowed the determination of litter mass loss in the field and the subsequent chemical and biological examination of the residual material (Palma *et al.,* 2002). Furthermore, this technique is frequently used to obtain information on simultaneous comparisons of different species, especially under field conditions

Leaf litters were air-dried initially, brushed to remove, adhering soil particles, and finally dried at 80 ^oC for 24 hrs and mixed thoroughly. Here, 50 grams of leaf litter for each species were taken and placed into nylon bags with 1mm mesh size, which was large enough to permit aerobic microbial activity and allow free entry of small soil animals, and also prevent the entry of invertebrates. It is considered one sample and accordingly, for five species and eight weeks, a total of 40 samples were placed in the cultivated field with adequate moisture in the soil to facilitate decomposition. One bag for each species was collected at weekly intervals. Every week, the litter bags were drawn from the field and transported to the laboratory, there it was first cleaned of ingrown roots, brushed free of debris, foreign materials, and then oven-dried at 80 ^oC for 24 hrs in a paper bag to constant weight. After drying the litter mass, each bag was weighed individually before the start of subjecting the litter to decomposition. From the litter samples, we also estimated decomposition rate and relative decomposition rate. Apart from this, a separate litter sample for each species was brought to the laboratory for estimating the moisture content of litter on oven-dry weight basis.

Decomposition rate (k)

It was calculated by using the formula suggested by Makkonen *et al.* (2012) as follows:

$(k) = -\ln (M_t / M_0) / t$

Where M_t = final litter mass and M_0 = initial litter mass and t = time in weeks

Relative Decomposition Rate (RDR)

It was computed after Singh *et al.* (1999). The mean relative decomposition rate (RDR was calculated by using the formula:

$$\text{RDR (g/g/day)} = \ln (W_1\text{-}W_0) / (t_1\text{-}t_0)$$

Where W_0 - mass of litter present at time t_0, W_1 - mass of litter at time t_1, and t_1-t_0 - sampling interval (days).

The loss in weight [mass loss (%) and remaining mass (g)] of all leaf litter was observed continuously for eight weeks from estimated oven dry weight of the litter samples collected every week.

Remaining mass = Initial weight - oven dry weight in g.

$$\text{Mass loss (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Besides, observations on periodical soil moisture and temperature were recorded during the study period. Soil temperature was estimated by using a traditional mercury bulb thermometer at 15-20 cm soil depth every week at 2.00 pm and soil moisture was estimated by using both the moisture box method and soil moisture PR2 profile probe connected with Delta T (HH_2) device at 20 cm soil every week at morning 7.00 am. To ensure decomposition of litter during the 8 weeks' time, two wetting (20mm irrigation) were given in the first week and in the mid of the 3rd - 4th week. It also received one rain during the period. The data generated were statistically tested for DMRT, Standard Deviation and Coefficient of variation besides correlation studies (Dafaallah, 2017).

Results and Discussion

The data generated from the litter decomposition study are presented below with various sub headings. The range of initial moisture content (oven-dry) in legume tree leaf litter was from 4.64 to 8.65%, but it was nearly one-third of total litter weight, indicating *Azadirachta indica* leaves retain more moisture than other four trees which are legumes (Table 1). This was reflected in the decomposition rate of this species. The least moisture content in leaf litter was observed in *Delonix regia* while *Pongamia glabra* had the highest value.

Soil moisture and temperature

Leaf litter decomposition is regulated by abiotic environmental factors like soil temperature, soil moisture etc. The data recorded on both these parameters for eight weeks in the top soil (15 cm) during the process of decomposition were presented in (Table 2 & 3). Variations in both the parameters were observed between species and the changes in soil temperature and soil moisture content during the period of decomposition of leaf litter were noticed and which reflected a mixed trend. It ranged from 37.5 to 49.6^0 C with a variation of 0.7-12.1^0 C. The data collected had a CV value of less than 10 %, indicating its reliability. The temperature during the fourth week blunted due to the intermittent irrigation given for hastening the decomposition.

Soil moisture ranged from 4.7% to 22.5% varied with different species. The weekly mean ranged from 7.14 to 18.22 %. The soil moisture peaked during the third week due to the intermittent irrigation given for hastening the decomposition. The coefficient of variation for soil moisture is less than 25 % through the weeks indicating the dependability of the values observed in the field for the parameter. A positive correlation was observed between soil

Table 1. Initial moisture content of leaf litter of different tree species

Species	Initial weight (g)	Final weight (g)	Moisture content (%) after oven drying
Pongamia glabra	100	91.35	8.65
Albizia lebbek	100	93.72	6.28
Peltophorum pterocarpum	100	92.56	7.44
Delonix regia	100	95.36	4.64
Azadirachta indica	100	65.96	34.04

Table 2. Changes in soil temperature (^{0} C) during litter decomposition period

Tree species	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8
Pongamia glabra	41.5	44.8	46	37.5	41.5	37.5	39.5	40.5
Albizia lebbek	40.5	41.5	45.8	38.5	42	42	42	41
Peltophorum ferrugineum	42.5	45.8	48.5	35.8	42.5	42.5	41.5	41
Delonix regia	42	41.5	40.5	37.8	40.7	41.5	44	42.5
Azadirachta indica	42	46.5	49.6	40.5	41.5	40.5	40.5	41
SD	0.8	2.4	3.5	1.7	0.7	2.0	1.7	0.8
Mean	41.7	44.0	46.1	38.0	41.6	40.8	41.5	41.2
CV %	1.82	5.40	7.63	4.48	1.61	4.87	4.09	1.84

Table 3. Changes in soil moisture (%) content during litter decomposition period

Tree species	Week1	week 2	week 3	week 4	week 5	week 6	week 7	week 8
Pongamia glabra	9.6	11.9	22.5	9.4	11.9	19.4	10.4	9.5
Albizia lebbek	8.4	9.5	19.5	16.7	19.5	11.6	10.6	7.5
Peltophorum ferrugineum	11.6	8.5	16.5	9.3	11.9	12.4	8.7	6.8
Delonix regia	12.4	22.5	15.4	12.5	12.6	14.2	7.5	7.2
Azadirachta indica	13.2	9.5	17.2	14.3	12.5	15.5	9.6	4.7
SD	2.0	5.8	2.8	3.2	3.3	3.1	1.3	1.7
Mean	11.04	12.38	18.22	12.44	13.68	14.62	9.36	7.14
CV %	18.04	46.80	15.50	25.65	23.90	21.04	13.69	24.03

moisture and temperature during each week up to eight week with the values of 0.89, 0.55, 0.53, 0.13 and 0.05 respectively while during the other weeks it had negative values.

A time-course study of remaining mass of decomposing litter over 8 weeks' time indicated wide variations in decomposition rates in all the leaf litters (Fig. 1). Maximum retention of mass was observed in *Pongamia glabra* with retention of 30.0 %. It was followed by *Delonix regia*, *Peltophorum ferrugineum* and *Albizia lebbek* with values of 46.8 %, 43.2 % and 42.6% in that order. However, the non-legume, *Azadiachta indica* was also capable of retaining less mass (35.2%), indicating its ability in faster decomposition. The similar trend was also followed in the mass loss over time. The species *Pongamia glabra* leaf litter has been a fast decomposing and could contribute to the addition of soil organic matter and other nutrients that may help better crop growth.

The mass loss that occurred in all the species showed amelioration of loss through the period of study (Table 4). During the first week, the mean mass loss was only 10.9% for all the species studied, but at the end of the eight week it peaked to 60.4 %. It indicated the gradual loss of the added leaf litter

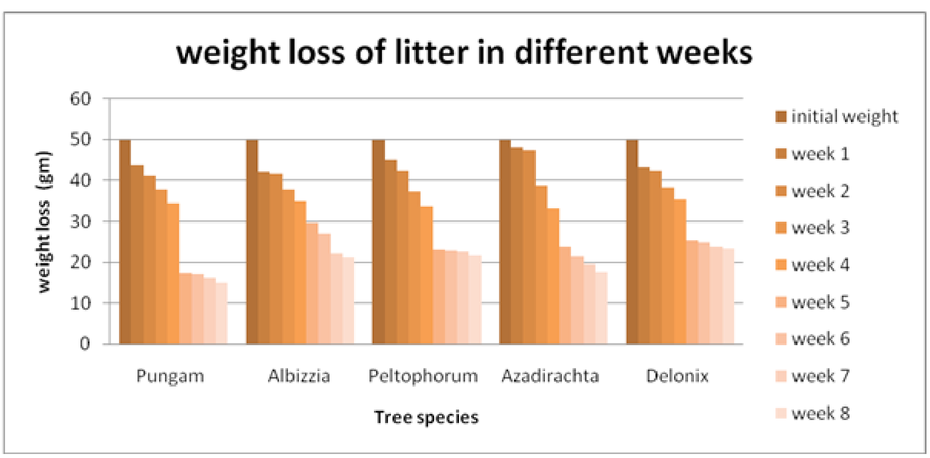

Fig. 1. Remaining mass (g) of decomposing leaf litter over time

over time. *Pongamia glabra* had maximum mass loss in the 8th week (70%) followed by *Azadirachta indica* (64.8%). Among the species, *Delonix regia* exhibited a slow decomposition with least value for mass loss.

Decomposition rate and Relative decomposition rate

The weekly decomposition rate (*k*/week) for leaf litter varied between 0.0458 (*Peltophorum ferrugineium*) and 1.425 (*Pongamia glabra*) among legumes and 0.159 and 1.356 for non-legume, *Azadirachta indica*. The leaf litter decayed in a steady phase starting from the first week till the end of the study. The mean weekly decomposition rate (*k*) for legumes leaf litters started at 0.051 in the first week and progressed steadily and reached a maximum decomposition rate (*k*) of 1.299 at the end of the study. Non-leguminous *A. indica* leaf litter decomposed at a slow pace during the first week but steadily progressed at the eighth week with a rate of 1.356. It indicated the slow start of decomposition of *Azadirachta indica* litter which later progressed rapidly. Among the legume litters, *Pongamia glabra* showed remarkably higher rate of decomposition from beginning till the end of the study with the maximum litter decomposed at the eighth week showed in (Table 5 & 6). It indicates the faster disintegration of the litter and decomposition, which is an ideal phenomenon in selecting green leaf manure for crop production. The other three legumes behaved uniformly in the rate of decomposition.

The relative decomposition rate (k/day) of legume leaf litter is uniform through the course of study with the values dwindling around (0.60 g/g/day) except for the first week when it was slightly higher with 0.91 g/g/day. On contrary, RDR for non-legume, *Azadirachta indica*, had a slow start during the first two weeks and then it progressed steadily. Between the weeks, first week had a mean RDR of 0.778 g/g/day and ended at 0.542 at the 8th week with a moderate hype in the fifth week. (0.748 g/g/day).

Comparatively, a rate of decomposition of leaf litter showed a slow but gradual progressive trend for the subsequent weeks. The Mass loss at the end of the study was six times greater than that of the beginning week. It is evident that the decomposition rate progressed steadily, further lynching towards

Table 4. Mass loss (%) over time

Tree species	Initial weight	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8
Pongamia glabra	100	12.2	17.4	24.2	31.0	65.2	66.0	67.8	70.0
Albizia lebbek	100	15.6	16.8	24.4	30.2	40.6	45.8	55.2	57.4
Peltophorum pterocarpum	100	10.0	15.4	25.4	32.6	53.8	54.0	54.8	56.8
Delonix regia	100	13.2	15.0	23.4	29.2	49.6	50.4	52.2	53.2
Azadirachta indica	100	3.6	5.2	22.2	33.6	52.4	57.2	61.2	64.8
SD		4.6	5.0	1.2	1.8	8.8	7.6	6.3	6.8
Mean		10.9	14.0	23.9	31.3	52.3	54.7	58.2	60.4
CV %		41.76	35.78	5.00	5.69	16.90	13.93	10.78	11.26

Table 5. Weekly decomposition rate (k) on weekly basis (Makkonen et al. 2012)

Tree species	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	Mean
Pongamia glabra	-0.0565	-0.384	-0.597	-0.763	-1.157	-1.247	-1.337	-1.425	-0.878[a]
Albizia lebbek	-0.0737	-0.381	-0.599	-0.758	-0.925	-1.044	-1.194	-1.273	-0.789bc
Peltophorum ferrugineum	-0.0458	-0.374	-0.604	-0.773	-1.034	-1.115	-1.190	-1.267	-0.803[bc]
Delonix regia	-0.0615	-0.372	-0.593	-0.752	-0.997	-1.083	-1.166	-1.232	-0.780[c]
Azadirachta indica	-0.0159	-0.324	-0.586	-0.780	-1.021	-1.147	-1.256	-1.356	-0.817[b]
Mean for tree legumes	-0.0594	-0.378	-0.598	-0.762	-1.028	-1.122	-1.222	-1.299	
SD	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	
Mean	-0.051	-0.367	-0.596	-0.765	-1.027	-1.127	-1.229	-1.311	
CV %	43.17	6.69	1.13	1.48	8.19	6.84	5.63	5.99	

Note: Means followed by same alphabets are DMRT values, and were non- significant as per Duncan's multiple range tests**.**

complete decomposition during later stage indicating patterns of decomposition as observed by Semwal *et al.* (2003). The legume species, *P. glabra* had only 30 % remaining mass after eight weeks, which is 40-42% higher than other legume trees studied. Furthermore, the decay rate was comparatively greater in legumes than non-legume *Azadirachta indica.* The results corroborate the claims of Ibrahim *et al.* (2010) that the early stage is usually met by a comparatively better decrease in mass which is usually attributed to leaching of readily soluble substances and non-lignified carbohydrates in legumes but contradicts with the decay rate of *Azadirachta indica*. As litter decomposition is influenced by abiotic factors like temperature and moisture, the positive correlation between these two parameters during the study period except for 3/8 weeks had influenced the decomposition of litter. Further, the application of water during the first week and also during mid of the 3rd - 4th week would have triggered the decomposition process. However, further decrease in mass loss in this study may be attributed to the release of cellulose, lignin and tannin at the advanced stage of leaf litter decomposition as supported by Bloomfield *et al.* (1993)

In this study, all the leguminous tree species showed comparatively quicker mass loss as observed in multipurpose tree species of the central Himalayas by Semwal *et al.* (2003) and the plausible variation in mass loss between legume and non-legume might be due to the litter quality, climatic conditions (Torreta and Takeda, 1999). As many literatures provide support that dissimilarity in leaf decomposition rates among species depends on greatly on litter quality, and the higher decay rate of *A. indica* litter could be an indicator of higher litter quality compared to other species (Mahmood Hossain *et al.,* 2011). Widyati Slamet *et al.* (2017) found that application of leaf litters of *Leucaena leucocephala* is effortlessly tattered and by the addition of green leaf manure would support mineralization and also help to build soil fertility in the context of the cultivated field management. Suguna and Swaminathan (2012) provided support that incorporation of *Pongamia glabra* leaf litter improves soil fertility and has a favorable effect on crop growth it influenced yield of barnyard millet (*Echinochloa frumentaceae*), when a decomposition period of 45 days was allowed. This study was taken up in summer and the occurrence of summer baking of leaf litter and availability of adequate moisture due to rain or artificial application of water would result in rapid mass loss of semi-decomposed materials that ensures complete break-down of litter at a rapid rate.

The per day decay rate was uniform for the litter of all species tested. Legume litter had an early start of decomposition in the first week itself and then, declined and fell plateau, but for non-legume, *Azadirachta indica,* it was the second week, which simply explains the variation between the species and chemical composition of the leaf. The initial chemical compositions varied across the studied leaf litters and also the growing nature of the tree. Amongst all selected variables, soil moisture was the best predictor of mass loss, explaining variability in mass loss. Low soil moisture combined with low temperature in winter may decrease the activity of decomposer organisms, resulting in a slower rate of decomposition (Tripathi and Singh, 1992a) but in the present study it was low moisture with high moisture in summer that might have favoured decay. Further, alternating dry and wet conditions, intermittently, summer rains and its connected variables seem to have more authoritative control over litter

Table 6. Relative decomposition Rate (g /g /day) on weekly basis

Tree species	Week1	Week2	Week3	week4	Week5	Week6	Week7	Week8	Mean
Pongamia glabra	-0.87	-0.62	-0.58	-0.55	-0.93	-0.79	-0.69	-0.63	-0.71[a]
Albizia lebbek	-1.11	-0.60	-0.58	-0.54	-0.58	-0.55	-0.56	-0.51	-0.63[ab]
Peltophorum pterocarpum	-0.71	-0.55	-0.60	-0.58	-0.77	-0.64	-0.56	-0.51	-0.62[ab]
Delonix regia	-0.94	-0.54	-0.56	-0.52	-0.71	-0.60	-0.53	-0.48	-0.61[b]
Mean for legumes	-0.91	-0.58	-0.58	-0.55	-0.75	-0.65	-0.59	-0.53	
Azadirachta indica	-0.26	-0.19	-0.53	-0.60	-0.75	-0.68	-0.62	-0.58	-0.50[c]
SD	0.3	0.2	0.0	0.0	0.1	0.1	0.1	0.1	
Mean	-0.778	-0.500	-0.570	-0.558	-0.748	-0.652	-0.592	-0.542	-0.61
CV %	-41.54	-35.30	-4.64	-5.72	-16.82	-13.95	-10.78	-11.33	

Note: Means followed by same alphabets are DMRT values, and were non- significant as per Duncan's multiple range tests.

decay. A correlation between mass loss and soil moisture suggests that the decomposition rate in tree species is influenced by soil moisture content.

Among the tree legumes, *Pongamia glabra* litter showed 70 % maximum mass loss with markedly higher rate of decomposition and relative decomposition rate from beginning to the end of the study, it was followed by *Azadirachta indica*. Hence, *Pongamia glabra* is capable of replenishing the soil health at a faster decomposition rate of the added litter and in eight weeks, it would ensure better soil health and fertility.

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