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Evaluating Leaf Litter Decomposition Rate of Multipurpose Tree Species using Litter Bag Technique

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Abstract: For nonlegume crop production, legume leaves utilized as green manure could be a viable alternative to commercial N fertilizers. The experiment's main purpose was to assess the rate of decomposition of leaf litter from ten tropical trees utilizing evaluation measures such as mass loss, decomposition rate, and relative decomposition rate. The decomposition of legume litter selected for this experiment was *Peltophorum ferrugineum, Albizia lebbek*, *Gliricidia sepium*, *Delonix regia, Leucaena leucocephala*, *Pongamia pinnata, Senna siamea, Acacia nilotica, Prosopis juliflora* and the non-legume of *Azadirachta indica* which was evaluated by litter bag technique. Among all the ten tree species *Acacia nilotica* tree leaf litter showed the highest mass loss% (55.36%), decomposition rate, and relative decomposition rate throughout the decomposition period of 7 weeks and closely followed by *Prosopis juliflora* (55.04%). The decomposition rate is mainly influenced by meteorological factors, soil parameters (soil moisture and soil temperature), and also the chemical composition of the leaf litter and its lignin content.

Keywords: Decomposition, Decomposition rate, Leaf litter bag Technique, Mass loss, Relative decomposition rate

Nutrient-rich tropical tree species are protecting soil and improving crop productivity in heavily weathered soils of the humid and sub-humid tropics. Perennial trees serve an important role in nutrient cycling and energy transfer in soil-plant systems that are being developed sustainably (Soni et al 2020). The addition and breakdown of leaf litter is an important biological process of nitrogen cycling and soil formation that supports the activity of microfauna (Nivethadevi et al 2021b). Organic matter enhances nutrient uptake and also improves soil properties. Organic matter is provided by adding the leaf litter which improves the water holding capacity, microbial activity, and organic carbon content (Ngoran et al 2006, Shailendra Bhalawe et al 2012). In agricultural environments, more diversified soil fauna community causes faster decomposition but has minimal effect on the overall rate of decomposition. The amount of nutrients recycled is based upon the element which is available in the litter and the release of nutrients from litter depends upon the rate of decomposition. The litter addition and decomposition paves way for the immobilized nutrients in the litter to be mineralized and utilized by the roots of crops and plants in due course of time. The decomposition rate of leaf litter is influenced by C: N ratio (Joon Sun Kim 2007), leaf litter composition (Prescott et al 2004) and also environmental factors such as maximum temperature, relative humidity, and soil parameters (soil moisture and soil temperature) (Saryldiz 2003).

The litterbags method is the most commonly employed to measure the rates of decomposition of biomass in an agroforestry system since it allows for field-based decomposition tests. This method involves placing a specified amount of tree biomass in bags with appropriate mesh sizes and depositing it on the soil surface.

MATERIAL AND METHODS

Study site and species: The evaluation of legume leaf litter decomposition was carried out in Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai from January 10 - February 2022, geographically presented at 9° 96' N latitude, 78° 5' E longitude, and at an altitude of 147 m above sea level. The type of soil was sandy clay loam. In several tropical and subtropical countries, the species chosen for the study are widely grown or distributed naturally. During the peak season of leaf shedding, leaf litter was collected from plantations, which included both natural and planted trees (November-March). The experiment was laid out in completely randomised block design and the treatments comprised of T_1=*Peltophorum ferrugineum*, T_2=*Albizia lebbek*, T_3=*Gliricidia sepium*, T_4=*Delonix regia*, T_5 =*Leucaena leucocephala*, T_6=*Pongamia pinnata*, T_7=*Azadirachta indica*, T_8=*Senna siamea*, T_9=*Acacia nilotica*, T_{10}=*Prosopis juliflora*. All the tree species selected for decomposition were belongs to Leguminosae family except *Azadirachta indica* (Meliaceae).

Litter bag technique: Initially, leaf litter was air-dried and brushed to remove the adhering soil particles. Here, 25 grams of leaf litter for each species were taken and replicated in four nylon bags made of 2mm mesh and 20x20 cm size. The litter bag technique was used to study leaf litter decomposition (Mason 1977, Singh and Gupta 1977). The method was used to determine the litter mass loss in the field and then examine the leftover material chemically and biologically (Nivethadevi et al 2022). Furthermore, this technique is extensively used to collect information on simultaneous comparisons of various species, particularly in field conditions. The nylon bags were arranged in the soil such that the lower surface is in complete contact with the soil and the upper surface of the bag was exposed to the sunlight. Powers et al (2009) found that the decomposition of buried litterbags was faster than that of surface litterbags in drier tropical forests. The perforations of nylon bags were sufficiently large enough to facilitate aerobic microbial activity and prevent invertebrates from entering. A total of 40 samples were placed in a cultivated field with optimum moisture in the soil to promote decomposition. Each week, the litter bags were retrieved from the field and cleansed of ingrown roots, debris, and foreign matter, and observations were recorded on weight loss per individual bag, and soil characteristics promoting decomposition such as soil moisture, soil temperature, and environmental factors (maximum temperature, sunshine hours, and relative humidity). I calculated the decomposition rate and relative decomposition rate from the litter samples. A different fresh leaf litter sample was taken to the laboratory for each species to estimate the moisture content of leaf litter on an oven-dry weight basis by using the following formula.

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

Decomposition rate (k): The following formula was used to calculate the decomposition rate (Makkonen et al 2012).

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

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

Relative Decomposition Rate (RDR): The mean relative decomposition rate (RDR) was estimated as per Singh et al (1999).

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

Where W_0 - the mass of litter present at time t_0, W_1 - the 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 seven weeks from the estimated oven-dry weight of the litter samples collected every week.

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

Likewise, during the study period, monitoring of soil moisture and temperature was made regularly. Soil temperature was estimated regularly at 2.00 pm using a conventional mercury bulb thermometer at 15-20 cm soil depth, while soil moisture was estimated regularly at 7.00 am using a soil moisture sensor at 15 cm soil depth. After the fifth week, water was applied to promote the decomposition rate of litter and a light rainfall of (7.4 mm) was received before the first week of decomposition, which influences the rate of decomposition of leaf litter in the first few weeks. The data generated were statistically with DMRT and besides correlation studies (Dafaallah 2017).

RESULTS AND DISCUSSION

The data generated in the decomposition study of nine legumes and one non-legume (*Azadirachta indica*) of tropical tree species. The moisture content of tree species ranges from 52 to 59.5% which is greater than the fifty percent weight of fresh leaf litter (Table 1). The highest moisture content in *Acacia nilotica* (59.5%) reflected the decomposition rates and relative decomposition rates of tropical tree species.

Climate, soil moisture, and soil temperature: Time-course of study decomposition of leaf litter mass % indicated widely varying decomposition of leaf litter in ten multipurpose trees (Table 2). The maximum mean weight loss of leaf litter was in *Acacia nilotica* (32.39%) during the first week to the seventh week of the litter bag study and followed by *Prosopis juliflora* (31.94%). Decomposition of leaf litter in *Pongamia pinnata* was the least in all weeks (24.82%) (Fig. 4). Suguna and Swaminathan (2012) showed evidence that incorporating *Pongamia pinnata* leaf litter enhances soil fertility and has a positive effect on crop growth by influencing yield of barnyard millet (*Echinochloa frumentaceae*), when a 45-day decomposition interval was allowed. Among different times of

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

Treatments	Fresh weight (g)	Dry weight (g)	Moisture content after drying (%)
Peltophorum ferrugineum	100	44.1	55.9
Albizia lebbek	100	43.5	56.5
Gliricidia sepium	100	45.5	54.5
Delonix regia	100	46.6	53.4
Leucaena leucocephala	100	42.5	57.5
Pongamia pinnata	100	46.5	53.5
Azadirachta indica	100	45.4	54.6
Senna siamea	100	48.0	52.0
Acacia nilotica	100	40.5	59.5
Prosopis juliflora	100	41.1	58.9

sampling, the seventh week recorded significantly the highest mean weight loss percentage (51.47%) of all the tree species due to the presence of optimum soil moisture and temperature. The maximum weight loss percentage was in *Acacia nilotica* in the seventh week (55.36%) and followed by *Prosopis juliflora* (55.04%). The differences in mass loss% of leaf litter starting from the first week to the seventh week of decomposition decrease by 10.64, 7.69 4.62, 4.5 and 3.95 percent respectively due to winter conditions. In winters, low temperature and rainfall may have resulted in the low activity of decomposers. The correlation coefficient of four environmental factors (maximum temperature, sunshine hours, relative humidity morning and evening relative humidity) with leaf litter weight loss (%) was analyzed (Fig. 1). The rate of litter mass loss in different species was separately positively correlated with mean values of maximum temperature (r=0.631), relative humidity (morning) (r=0.853*), relative humidity (evening) (0.941**), and sunshine hours (r=0.356).

Soil temperature, moisture, and other factors also influence leaf litter decomposition. These are the primary elements that accelerate litter decomposition. During the decomposition process, data on these characteristics were collected for seven weeks in the topsoil (15 cm). Variations in soil temperature and moisture content were observed during the decomposition of leaf litter and revealed a variable tendency. It ranged from 38.5 to 45.8°C. The temperature during the fifth week blunted due to the intermittent irrigation given for hastening the decomposition. The mass loss of all the tree species is correlated with weekly mean of soil temperature (r=0.521). Bothwell et al (2014) reported the similar results k values are positively correlated to temperature. The mean soil moisture content for the decomposition of leaf litter varies every week and ranges from 9.8 to 19.8%. The soil moisture peaked during the third week due to the intermittent irrigation given for increasing the decomposition rate. The mass loss of all the tree species was positively correlated with the weekly mean valves of soil moisture (r=0.836*). Amongst all selected variables, soil moisture was the best predictor of mass loss, explaining variability in mass loss. The correlation between mass loss, relative humidity, and soil moisture suggest that the decomposition rate in tree species is influenced by these two factors. The meteorological parameters are significantly correlated with mass loss of tree species (Table 3).

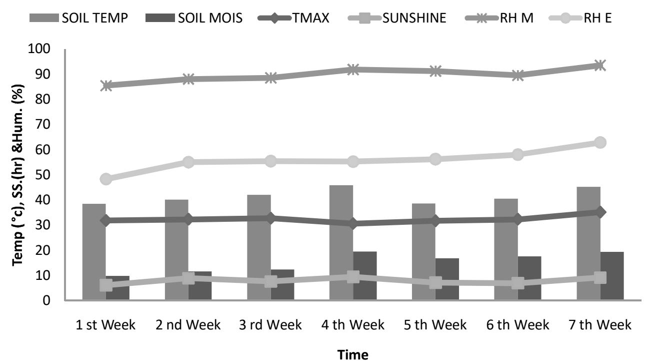

Fig. 1. Meteorological data and soil data recorded during decomposition (January- February 2022)

Table 2. Effect of time of sampling on weight loss in different multipurpose tree species (%)

Tree species	Week							
	1st	2nd	3rd	4th	5th	6th	7th	Mean (%)
Peltophorum ferrugineum	11.28	19.36	23.28	27.4	31.28	39.04	51.68	29.04[bc]
Albizia lebbek	7.32	15.44	19.4	23.52	27.04	34.32	47.76	24.97[d]
Gliricidia sepium	11.04	19.2	22.4	27.2	31.12	38.72	51.44	28.73[bc]
Delonix regia	11.84	19.92	23.76	27.92	31.96	39.84	51.92	29.59[b]
Leucaena leucocephala	11.44	15.52	23.68	27.84	31.84	39.68	51.76	28.82[bc]
Pongamia pinnata	7.04	15.52	19.36	23.44	27.52	33.92	46.96	24.82d
Azadirachta indica	11.32	18.32	21.6	26.32	30.56	38.64	51.28	28.29[c]
Senna siamea	11.2	19.28	23.2	27.6	31.2	39.12	51.52	29.02[bc]
Acacia nilotica	11.96	20.8	27.2	31.68	35.84	43.92	55.36	32.39[a]
Prosopis juliflora	11.92	19.96	25.6	31.6	35.68	43.76	55.04	31.94[a]
SD	1.849	2.059	2.451	2.756	2.856	3.264	2.632	
Mean	10.64	18.33	22.95	27.45	31.40	39.09	51.47	28.76
SEd	0.132	0.267	0.231	0.352	0.541	0.432	0.631	
CD (p=0.05)	0.271	0.546	0.474	0.719	1.104	0.882	1.288	

Means followed by the different alphabets significantly differ in DMRT

Decomposition rate and relative decomposition rate: The weekly percent decomposition rate (k/week) for leaf litter varied between 7.3% (*Pongamia pinnata*) and 11.5% (*Acacia nilotica*) among legumes and 12.1% to 8.1% 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 in the first week (11.2%) and in the last week rate of decomposition progressively decreased. *Acacia nilotica* significantly showed a higher rate of decomposition from the beginning till the end of the study with the maximum litter decomposed at the seventh week followed by *Prosopis juliflora* and *Pongamia pinnata* with least decomposition rate (9.1%) (Fig. 2). It indicates the faster disintegration of the litter and decomposition, which is an ideal phenomenon in selecting green leaf manure for crop production.

The relative decomposition rate (RDR) of different litter species was maximum in *Acacia nilotica* (0.375 g/g/day). The mean RDR of different multipurpose trees ranged from 0.137 to 0.363 g/g/day starting from the first week to the seventh week of the decomposition period (Fig. 3). Comparatively, the rate of decomposition of leaf litter showed a slow but gradual progressive trend was observed in the subsequent weeks. The decomposition rate progressed steadily, further lynching towards complete decomposition during a later stage indicating patterns of decomposition (Semwal et al 2003). However, a further decrease in the mass loss in this study may be attributed to the release of cellulose, lignin, and

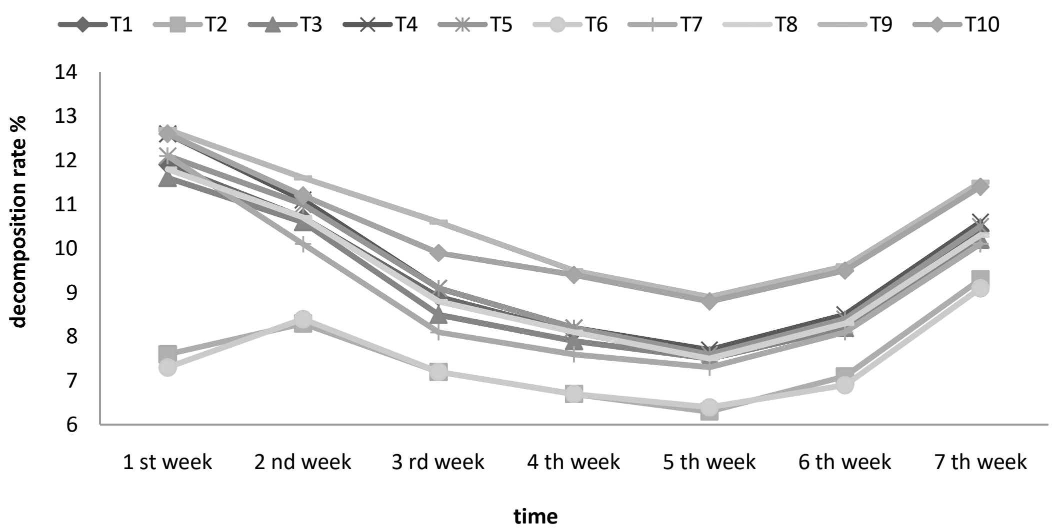

Fig. 2. Weekly decomposition rate (k) on weekly basis (Makkonen et al 2012)

Table 3. Correlation matrix: Effect of meteorological parameters on mass loss %

Tree species	Correlation coefficient					
	Maximum temperature (°C)	Sunshine (Hrs)	Soil temperature (°C)	Soil moisture (%)	Relative humidity morning (%)	Relative humidity evening (%)
Peltophorum ferrugineum	0.647	0.364	0.521	0.828*	0.850*	0.946**
Albizia lebbek	0.654	0.379	0.534	0.828*	0.856*	0.949**
Gliricidia sepium	0.642	0.367	0.519	0.831*	0.852*	0.944**
Delonix regia	0.641	0.359	0.515	0.829*	0.848*	0.945**
Leucaena leucocephala	0.613	0.305	0.518	0.843*	0.846*	0.916**
Pongamia pinnata	0.643	0.38	0.527	0.833*	0.863*	0.951**
Azadirachta indica	0.649	0.344	0.505	0.823*	0.839*	0.935**
Senna siamea	0.64	0.367	0.525	0.832*	0.852*	0.946**
Acacia nilotica	0.597	0.354	0.523	0.852*	0.863*	0.944**
Prosopis juliflora	0.583	0.346	0.518	0.862*	0.864*	0.934**
Mean	0.631	0.356	0.521	0.836*	0.853*	0.941**

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed) and NS- Non significant

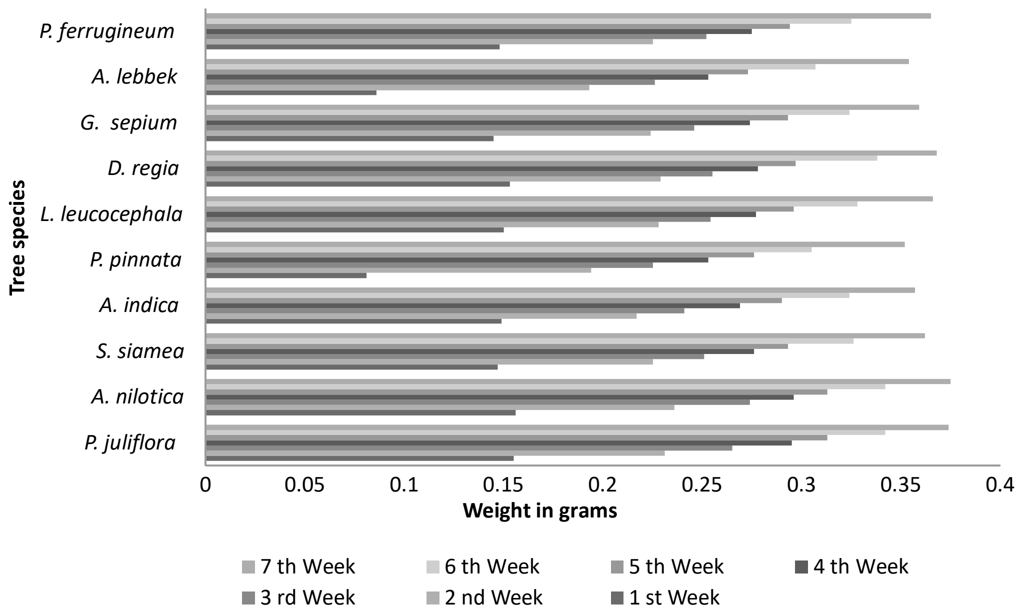

Fig. 3. Relative decomposition rate (g /g /day)

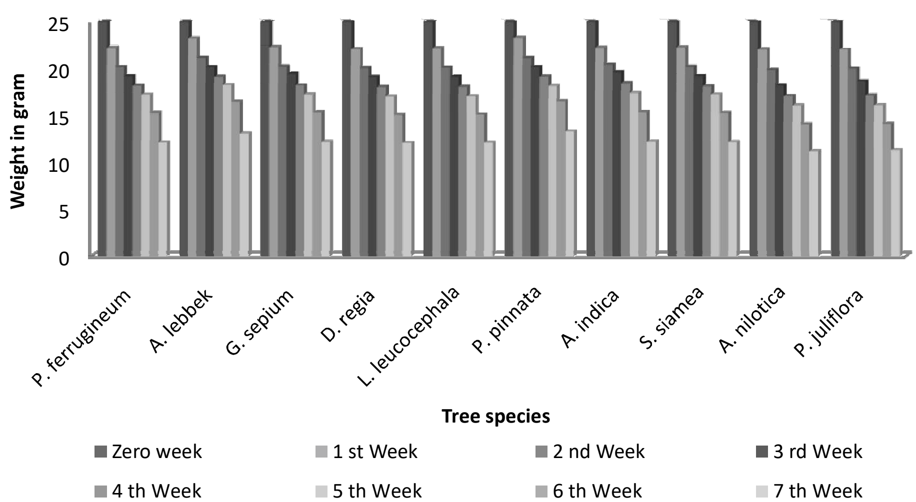

Fig. 4. Remaining mass (g) of decomposing leaf litter over time

tannin at the advanced stage of leaf litter decomposition. All the leguminous tree species showed comparatively quicker mass loss as observed in multipurpose tree species of the central Himalayas (Semwal et al 2003) and the possible variation in mass loss between legume and non-legume might be due to the litter quality, climatic conditions (Jairo et al 2017, Petit-Aldana et al 2019). Many studies observed difference in leaf decomposition rates between species is heavily influenced by litter quality. The higher decay rate of *Melia azedarach* litter could be an indicator of superior litter quality when compared to other species (Mahmood Hossain et al 2011). This study was taken up in winter 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.

CONCLUSION

The rate of decomposition varies significantly by tree species. *Peltophorum ferrugineum, Albizia lebbek, Gliricidia sepium, Delonix segia, Leuceana leucocephala, Pongamia pinnata, Azadirachta indica, Senna siamea, Acacia nilotica, and Prosopis juliflora* leaf litter decomposition was observed for up to seven weeks. The rate of decomposition was significant in leaf litter nylon bag methods. Meteorological and soil characteristics have the greatest impact on the decomposition process. The amount of nutrients released by leaf litter into the soil is determined by litter quality, climatic circumstances, individual nutrient levels, and their interactions during the decomposition process. The added minerals may aid in the maintenance of soil fertility, which is becoming increasingly important in agroforestry systems. Among the studied tree species, *Acacia nilotica* have the highest decomposition rate.

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