



## A study of decomposition dynamics of different leaf litter in tropical trees and its enhancement

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### Abstract

The objective of the study was accomplished to determine the rapid decomposition rate of lignin by integrating efficient microbes and changes in the leaf litter of selected tropical tree species in a particular ecosystem. Initial concentrations of lignin, organic matter of litter (OM), Organic carbon (C), nitrogen (N), ash contents were analysed 30, 60- and 90-days using a litterbag experiment. Litterbags containing 50 gm of the shade-dried sample were incubated under laboratory condition. Litter decomposition rates with existing microbes and effect of decomposition rate with *Trichoderma koningiopsis* and nutrient release (N) were analysed in each litterbag. The decomposition rate was highest in *Senna siamea*, (R=0.0051) at 30 days (R=0.0042) at 60 days and (R= 0.0038) at 90days and lowest in *Acacia auriculiformis* (R=0.0035) 30 days, (R= 0.0033) 60 days and (R= 0.0032) 90days compared to other species. Maximum reduction was observed by integrating *Trichoderma koningiopsis*; 90% of lignin has degraded in 30 days; another 15 % reduction in litter weight in 60 days, and the remaining 12% reduction in litter weight in 90 days have occurred. However, the efficiency of microbes could accelerate the decomposition at faster rate and reduce the accumulation and period of degradation. This in turn increases the nutrient release, restoration of ecological balance in nutrient table. Also, it is evident that the decomposition rate is highly dependent on lignin percentages of the biomass.

**Keywords:** C: N ratio, decomposition dynamics, leaf litter, tropical tree, ecosystem, carbon cycle

### Introduction

The decomposition process is an essential for nutrient release and carbon storage to proceeding the biogeochemical cycle in the ecosystem functioning. It is important to probe the effects of different litter and microbial communities according to the tropical climates. Plant litter are the primary source for the decomposition pathway. Litter is a critical factor in ecosystem dynamics because it indicates ecological abundance and can help forecast local nutrient cycles of a particular area and soil fertility (Ochoa-Hueso *et al.*, 2019) [24]. The rate of decomposition of litter is primarily determined by its functional traits, which are the physical and chemical properties that indicate variation in decomposition (Nock *et al.*, 2016) [23]. During the process, litter's chemical properties have changed by the decomposition of structure and soluble components. The by-product of CO<sub>2</sub> reverts into the atmosphere by soil microbial respiration, and the nutrient cycle provides nutrients for tree growth (Krishna and Mohan, 2007). The primary component of tree litters contains N, P, K, and cell wall constituents, which can substantially determine the tree litter quality.

Litter decomposition occurs through several mechanisms, multiple breakdowns of organic compound release into CO<sub>2</sub>, and nutrient compounds proceed through the abiotic and biotic pathway. The intermediate products such as carbohydrate, nitrogenous compound and organic phosphorus are converted to form higher molecular weight of sturdyhumic substrates. This is the primary source of organic carbon, which is converted into a simpler form through mineralization (Prescott, 2010) [25]. Similarly, among the nutrients, Nitrogen has been identified as the primary controlling factor. Many studies have found that the

litter decomposition rate as highly associated to the C: N ratio, C: P ratio, and lignin: N ratio. Variation in the initial C: N ratio occurs due to different N concentrations in litters. The C: N ratio decreases substantially when the C release and the ratio of N increase. The increase of N is triggered mainly by microbe's absorption of inorganic N. Because microbes required nutrients such as N and P to diversify. They can take adequate N to break down and use C-comprising molecules. The C: N ratio is an indicator of mass loss (Kim, 2007) [18] of litter nutrients during decomposition in ecosystems (Liu *et al.*, 2016) [22]. Many studies proven that litter has with high N and P content, and a low C: N ratio can decompose the litter faster. Hence, the decomposition activity can also control by slowly decomposed constituents of cell wall. In which, soil microbes are the primary activator, which speed up the activity by their enzyme. Primarily, the quality of litter has an important regulatory impact on decomposition.

Litter decomposition occurs in two concurrent processes. 1. The process of mineralization and humification by microbial activity and 2. Leaching soluble compounds. Some minerals like N, P, Ca are quickly mineralised, but some materials are complex in nature with unique characteristics, which take many years to decompose, like humus (Devi and Yadav, 2007). These are decided by the quality of litter, physico-chemical factors, and microbial diversity are the most important factors governing litter decomposition (Dechaine, 2005) [6].

Litter fall is an essential process for the nutrient cycle on the tropical ecosystem, regulating the sublimation of organic compound, nutrient supply and nutrient maintenance, biodiversity restoration, and other ecological functions. The dynamic rate of decomposition is governed by climatic

conditions (Franklin *et al.*, 2002) <sup>[10]</sup> and the quantity of litter. Generally, the deciduous tree sheds the leaves relatively higher than the conifers during the autumn-winter season. Temperature is a crucial factor in deciding the rates of decomposition. Bisht *et al.*, (2014) <sup>[2]</sup> suggested that the rate of decomposition can be higher during the summer rainy season in both litter types. However, litter can undergo dramatic mass loss during the initial stage of the decomposition (Xu and Hirata, 2005) <sup>[31]</sup>. The higher temperature associated with higher soil moisture retains the microbial activity rate that can create faster decay.

Similarly, the rate of litter decomposition was sluggish in the winter and rapid during the rainy season due to variation in the physicochemical factors and microbial populations. Hao *et al.*, (2010) <sup>[13]</sup> has reported that precipitation is more important than temperature, which affects the decomposition in the terrestrial ecosystem by influencing soil moisture and the activities of decomposers. Many studies observed that coniferous trees, litter decomposition was less responsive to air temperature and humidity. This may be attributed to higher lignin content.

Hence, litter fall is an essential contributor to organic matter replenishment and nutrient contribution to the soil. It is one

of the most key aspects for preserving the soil fertility of various uses of the land system. Leaf litter is the significant component of dead material present on the above-ground organic layers of soil horizons. It is dispersed partially in the soil on the initial stage. The volume of leaf litter contribution has been more in litter fall pattern. The litter contains diverse natural organic compounds in insoluble forms. The ratio of the compounds may vary within the tree parts and species to species by climate, geographic scale and soil characteristics (Austin and Vitousek 2000; Kumar *et al.*, 2012; Zhang *et al.*, 2014) <sup>[1, 32]</sup>. Hence, the study, mainly focused on (i) the litter quality on decomposition rate (ii) effect of decomposition rate, (iii) opportunity to enhancement.

## Materials and methods

### Study location

The field study was carried out in Shri Ram Malhaar, and it is 30 acres plotted layout located in Sarjapura, southeast Bengaluru. The city is situated on the Deccan plateau at a geographical altitude of 920 m (3,020 ft); the latitude and longitude are 12.97°N 77.56°E (Fig 1).



Fig 1: Study area

### Agroclimatic conditions

Study location has tropical savanna climate with four distinctive seasons like spring, summer, autumn and winter. The annual precipitation receives approximately 900mm, proceeding on June, July, August, September, October, November and December, being the wettest month. The primary precipitation occurs in June – September (South-West Monsoon) and secondary precipitation in November and December (North-East Monsoon). The difference of the wettest and driest months is 143 mm 6 inches. The highest temperature occurs in March, April and May; the average summer temperature 36° C (97°F). The lowest temperature

appears in November and December, which drops below 14°C. The average annual relative humidity is 65.2 per cent, and the average monthly relative humidity ranges from 45 per cent in March to 79 per cent in August. Bangalore's winter season extends from December to February. The minimum temperature in winter lasts up to about 10°C, January being the coldest month. The fog could also occur in December and January.

### Annual Litter Collection

For the present study, leaf litters samples collected from August 2019 to July 2020. Litters were measured for

selected ten trees in four seasons by leaf litter sampling bags spread around the canopy of each tree. Ten trees that were dominant in study site were *Thespesia populnea*(TP), *Filiciumdecipiens* (FD), *Acacia auriculiformis* (AA), *Senna siamea* (SS), *Lagerstromia speciose* (LS), *Markhamia lutea* (ML), *Tabebuia aurea* (TA), *Tabebuia rosea* (TR), *Tectona grandis* (TG) and *Artocarpus heterophylus* (AH). The litter trappers placed under each tree to avoid the litter loss by wind problem. The measurement of litter trapper is 10 ×10sqft. The fallen litter consists of dry leaves that are senescent, twig, flower, reproductive parts and fresh leaves and other parts were collected separately. The collected litters which are only leaves is screened manually and leaves of same trees were mixed, different trees were carefully separated and collected in individual bags. And the sample weighed using the digital balance for initial weight. Each tree samples of about 200 gm were packed in the site for further studies. Later it is dried at room temperature in shade to minimize the loss of organic volatile compounds which escape when dried under direct sunlight or oven drying method. After 10 days of shade drying 50 gm x 2 no of each sample is repacked where one pack for storing in freezer and another for immediate physicochemical property studies.

### Chemical analysis

The litter samples were homogenously milled and tested to determine the litter qualities prior to decomposition for Organic matter, organic carbon, Lignin, Nitrogen, C: N ratio and Ash.

### Organic Carbon

Samples were oven-dried at 65 °C to a constant mass and weighed [walkley]. The dry weight was used for the estimation of C concentration using dry combustion method as given by Coleman (1973) [3].

Leaf litter carbon = (Dry weight of litter) × 0.45

### Organic Matter

The organic matter content was calculated by multiplying the content of organic carbon by Van Bemmelen's factor 1.73 (David S, 1960).

Total Organic Matter (TOM) = Organic Carbon % × 1.73.

### Lignin and Nitrogen

Individual samples of leaf were subjected to analysis of N (micro-Kjeldahl method of Borosil quartz apparatus and Automatic Distillation Unit) and total lignin content (Klason's method) [rowell].

### Total Ash

The component of ash in leaf litter was determined after exposing the dried powder in a muffle furnace at 550 °C for 24 hours.

### Decomposition rate and Nutrient release

The litter were analysed for nitrogen and rate of decomposition over the period of 30, 60 and 90 days of litter for various trees were estimated through the equation [mudenghi]

$$e^{-kt} = L_f / L_i \quad (1)$$

Where,

$k$  = Rate of decomposition per month,

$t$  = the time interval of sampling  $LR$  expressed in days,

$L_f$  = final litter weight, and

$L_i$  = initial litter weight.

Half-life period ( $t_{0.5}$ ) of the litter decomposed was determined by from  $k$  values using the equation

$$t_{0.5} = 0.693 / -k \quad (2)$$

Nutrient percentage of final was arrived by

$$\% \text{ Nutrient Remaining (NR)} = (C / C_0) (DM / DM_0) \times 10^2 \quad (3)$$

Where  $C$  is the concentration of element in the leaf litter after decomposition,

$C_0$  is the concentration of the initial leaf litter kept for decomposition,

$DM$  is the dry matter at the time of sampling, and

$DM_0$  is the initial dry matter of the litter sample kept for decomposition [11].

$$\% \text{ Nutrient released} = 100 - \% \text{ of original nutrient remaining} \quad (4)$$

### Integration of lignin degrading microbes

Using 5 ml per litre of water of *Trichoderma koningiopsis* (Tricomp) is treated to all litter to maintain 30-40% moisture in litter bag. This innovative microbe is a gamma irradiated strain licensed to BCX Bio Organics, Bangalore for degrading of high lignin containing leaves. Influence of Tricomp in the rate of decomposition and nitrogen was compared with control for 90 days.

### Statistical Analysis

The initial leaf litter concentration of each tree species was compared to understand lignin relationship with other component by Pearson correlation analysis using JASP statistical software version 0.14.1 to measures the statistical correlation between the variables. A  $p$  value of <0.05 was used to analyse the significance, the initial litter concentration, the correlation between the rate of decomposition and mean ± standard error; CV: coefficient of variation was evaluated between the species.

### Results

Initial lignin concentrations were studied in each tree leaf litter, in mg g<sup>-1</sup> of organic matter of litter; initial carbon (C), nitrogen (N), ash content as percentage (%) of organic matter; initial organic matter (OM) as percentage of dry matter; and C/N ratios: mean ± standard error; CV: coefficient of variation (variation between species).

### Initial concentration of litter

The physicochemical properties of initial litter concentration were analysed for ten samples. Among the properties, lignin plays a crucial role in decomposition next to the physical environment. The lignin concentration has ranged from 8.3 to 4.13 mg g<sup>-1</sup> of OM. It was highest in *Acacia auriculiformis*, which had the lowest TOM, TOC, C/N ratio and ash. Conversely, the lowest concentration observed in *Senna siamea*, had the highest range of TOM, TOC, Ash and N. The highest OM was measured for *Senna*

*siamea* (70.82%), followed by *Markhamia lutea* and *Lagerstroemia speciosa*, the lowest was *Acacia auriculiformis* (57.31%). The highest TOC was in *Acacia*

*auriculiformis*, 40.94%, similarly other species also have high level of OC. Furthermore, the lowest was *Senna siamea*, with the range of 33.13% of organic matter.

**Table 1:** Initial concentration of leaf litter

Name of the tree species	Lignin	TOM	TOC	ASH	N	C/ Ratio
<i>T.populnea</i>	6.97± 0.010	69.39± 0.017	40.15± 0.006	7.87± 0.008	1.39± 0.011	28.85± 0.011
<i>F.decipiens</i>	6.72± 0.007	70.11± 0.002	40.53± 0.005	10.98± 0.002	1.52± 0.005	26.66± 0.008
<i>A.auriculiformis</i>	8.32± 0.010	57.31± 0.004	33.13± 0.010	7.16± 0.012	1.94± 0.011	17.07± 0.011
<i>S.siamea</i>	4.13± 0.008	70.82± 0.005	40.94± 0.009	12.62± 0.005	1.79± 0.008	22.87± 0.006
<i>L. speciosa</i>	6.51± 0.002	70.35± 0.011	40.67± 0.008	9.34± 0.008	1.053± 0.011	38.73± 0.010
<i>M. lutea</i>	5.76± 0.003	70.46± 0.009	40.73± 0.006	11.73± 0.008	1.163± 0.005	35.11± 0.002
<i>T.aurea</i>	7.42± 0.005	69.47± 0.005	40.16± 0.009	7.69± 0.00	1.83± 0.002	21.94± 0.009
<i>T. rosea</i>	6.19± 0.003	69.92± 0.005	40.42± 0.005	10.44± 0.011	1.12± 0.005	36.08± 0.004
<i>T. grandis</i>	7.98± 0.003	68.97± 0.006	39.87± 0.005	7.083± 0.004	1.21± 0.002	32.95± 0.005
<i>A.heterophylus</i>	7.73± 0.006	68.54± 0.008	39.62± 0.005	8.52± 0.003	1.27± 0.007	31.19± 0.008
CV%	18.17	5.84	5.84	21.34	22.64	23.93

Mean ± standard error; CV: coefficient of variation (variation between species).

The TOM and TOC ranged from similar coefficient variations of 5.84%; it has not shown much significant variation between the species. The N concentration was highest in *Acacia auriculiformis* (1.94%), lowest range in *Lagerstroemia speciosa* was the 1.05%, the variation between the species of N content and C/N ratio was 22.40 % and 23.95%, respectively. *Lagerstroemia speciosa* was contained the highest C/N ratio, and *Acacia auriculiformis* was the lowest range. The highest ash content was in *Senna siamea*, 12.62%, and the least was in *Tectona grandis*, 7.08% of OM, showing significant variation between the species. Among the litter properties, the initial content of lignin, N was higher in *Acacia auriculiformis*, and TOM, TOC, ash content was highest in *Senna siamea*, and C/N ratio highest in *Lagerstroemia speciosa* (Table 1).

**Decomposition rate with existing microbes**

Gradual weight loss pattern was observed throughout the study period; the initial 30 days were the highest mass loss, followed by slower in the next 60 days and lowest in 90 days. The decomposition rate (R=0.0035) was lowest in *Acacia auriculiformis* compared to other species as it has a higher lignin value (8.3gm.). The leaf litter weight is 44.9 gm after 30 days from the 50 grams of initial weight, and the lignin value becomes 7.45gm. And the required period for decomposition is  $t_{0.5}$ =193 days. The decomposition rate

in the litter was observed faster in *Senna siamea*, (R=0.0051) with the final leaf litter weight of 42.8 gm, and the half-life of litter ranged  $t_{0.5}$ =134 days (Table 2 and 3). The decomposition rate (R=0.0042) was highest in *Senna siamea* compared to other species as it has a higher lignin value (8.3gms). The leaf litter weight is 44.9 gms after 30 days from the 50 gms of initial weight, and the lignin value becomes 7.45 gm and the required period for decomposition is  $t_{0.5}$ =193. The rate of decomposition was found highest in *Senna siamea* for 60 days from the final litter weight of 38.85 gm, and the lignin value decreased to 3.20gms. The lowest decomposition occurred in *Acacia auriculiformis* (R= 0.0033) from the weight of 40.9gm, and the lignin value reduced to 6.97gm (Fig 2).

At the 90 days of the interval, the decomposition rate was highest in *senna siamea* (R=0.00387) from the weight of 35.30 gms, and the slower rate was in *Acacia auriculiformis* R=0.00324 (37.35gms). And the rate of lignin reduced to 3.04 and 6.71gms. Comparatively, the highest reduction occurred in *Senna sieamia* and lowest *Acacia auriculiformis* (R=0.0032), followed by ML>TR>FD>TP>TA>AH>TG. As a result, to explain the weight loss pattern of litter, a negative exponential model ( $e^{-kt} = Lf/Li$ ) was applied. The reduction rate has occurred with the percentage of (30-60) 11.82% and (60-90) 5.57%, respectively.

**Table 2:** Decomposition rate with existing microbes

Name of the tree species	30 days			60 days			90 days		
	Lf (gms)	k	lignin value after 30 days	Lf (gms)	k	Lignin value after 60 days	Lf (gms)	k	lignin value after 90 days
<i>T.populnea</i>	44.25	0.004	6.168	40.25	0.004	5.696	36.7	0.003	5.477
<i>F.decipiens</i>	44.15	0.004	5.934	40.1	0.004	5.471	36.65	0.003	5.258
<i>A.auriculiformis</i>	44.9	0.004	7.453	40.9	0.003	6.947	37.35	0.003	6.710
<i>S.siamea</i>	42.8	0.005	3.535	38.85	0.004	3.196	35.3	0.004	3.042
<i>L. speciosa</i>	44.05	0.004	5.735	40	0.004	5.280	36.5	0.003	5.071
<i>M. lutea</i>	43.6	0.005	5.023	39.6	0.004	4.594	36.15	0.004	4.398
<i>T.aurea</i>	44.45	0.004	6.596	40.45	0.004	6.108	36.9	0.003	5.882
<i>T. rosea</i>	43.85	0.004	5.429	39.85	0.004	4.983	36.3	0.004	4.779
<i>T. grandis</i>	44.75	0.004	7.142	40.75	0.003	6.642	37.25	0.003	6.410
<i>A.heterophylus</i>	44.625	0.004	6.899	40.6	0.003	6.405	37.15	0.003	6.175

**Table 3:** Half-life period  $t_{0.5}$  analysis

Name of the tree species	Litter initial weight (Li) in grams	30 days Reduction rate for litter (in %)	Litter final weight (Lf) in grams	Decomposition rate $k = \ln(Lf/Li)t$
<i>T. populnea</i>	50	11.5	44.25	0.00407

<i>F. decipiens</i>	50	11.7	44.15	0.00415
<i>A. auriculiformis</i>	50	10.2	44.9	0.00359
<i>S. siamea</i>	50	14.4	42.8	0.00518
<i>L. speciosa</i>	50	11.9	44.05	0.00422
<i>M. lutea</i>	50	12.8	43.6	0.00457
<i>T. aurea</i>	50	11.1	44.45	0.00392
<i>T. rosea</i>	50	12.3	43.85	0.00437
<i>T. grandis</i>	50	10.5	44.75	0.00370
<i>A. heterophylus</i>	50	10.75	44.625	0.00379

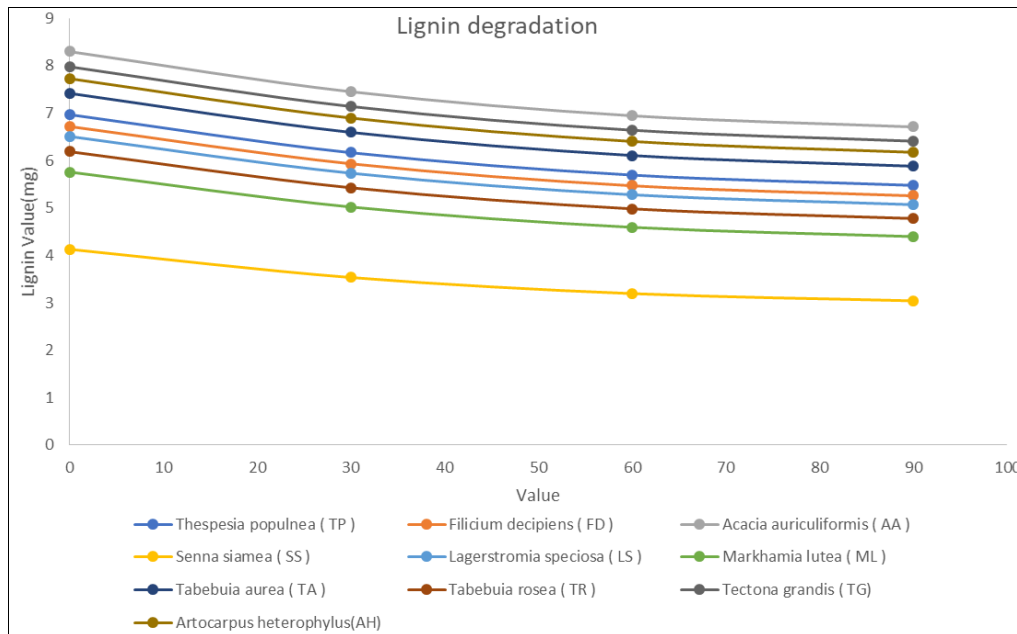


Fig 2: Lignin degradation with existing microbes

**Nutrient release**

Estimating litter nutrient release is possible by integrating litter deposition, nutrient concentration, and decomposition rates. The percentage of nutrient released after 90 days of decomposition was calculated from the remaining nutrients concentration and litter nutrient mass, which was found that, the Highest Percentage of nutrients released (44.4%) from Lagerstroemia speciosa with the organic matter of 55.6%,

followed by AA>TP>FD>TA>SS>AH>TR>ML. The lowest percentage of nutrient (N) released (31.6%) in Tectona grandis (68.3%) from the initial weight of organic matter and nitrogen content and the activities of existing microbes. During the process of decomposition, carbon is utilized by the microbes as part of respiration and the same is reflected in the decrease of overall nitrogen content (Table 4).

Table 4: Nutrient release from the remaining nitrogen

Name of the tree species	OM before decomposition (DM)	TOM (DM0)	Nitrogen just before decomposition (C0)	Nitrogen after decomposition (C)	%Nitrogen remaining (NR) (C/C0)(DM/DM0) × 100	% Nitrogen released (100 - NR)
<i>T. populnea</i>	67.12	69.39	1.23	0.73	57.40	42.59
<i>F.decipiens</i>	69.83	70.11	1.42	0.82	57.97	42.02
<i>A. auriculiformis</i>	54.26	57.31	1.83	0.99	57.13	42.86
<i>S. siamea</i>	67.17	70.82	1.52	0.88	61.04	38.95
<i>L. speciosa</i>	65.18	70.35	0.99	0.51	55.60	44.39
<i>M. lutea</i>	68.17	70.46	1.02	0.65	65.86	34.13
<i>T. aurea</i>	65.19	69.47	1.56	0.89	60.79	39.20
<i>T. rosea</i>	64.19	69.92	0.92	0.54	63.93	36.06
<i>T. grandis</i>	62.19	68.97	1.12	0.69	68.32	31.67
<i>A. heterophylus</i>	64.19	68.54	1.09	0.63	61.71	38.28

**Discussion**

**Initial concentration of litter**

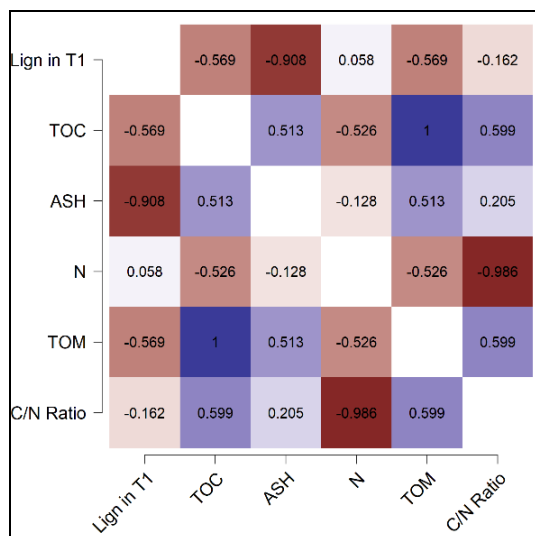
The initial litter concentration was showed significant variation between the species: particularly lignin, TOM, TOC and N, ash, C/N ratio. Similar variation was found between the species have mentioned in the previous study conducted in Africa, Guendehouz *et al*, (2014) [12], but which had a lower percentage of variation than the present

study. The N, C: N ratio and lignin of the present study was observed the highest variation than the study conducted in USA (Cusack *et al*, 2009) [4]. Some specific variation of initial composition was observed based on lignin. Trees with a higher lignin content had a low percentage of TOM, TOC, ash and C: N and reversely, species with higher lignin content had a high percentage of N. Due to high resistance to enzyme activity and interfering with the degradation of

other chemical components in leaf, thereby slowing the decomposition process (Semwal *et al.*, 2003) [29]. Alternatively, the variation may be the ratio of syringyl and guaiacyl lignin. Tripathi *et al.* (2006) [30] concluded that high lignin content had low N in the initial chemical composition of different woody trees. Pearson correlation result also revealed that lignin was strongly negatively correlated with TOC and TOM ( $r = -0.569$ ;  $p < 0.05$ ), C/N ratio  $r = -0.162$ ;  $p < 0.05$  and slightly positive correlation with ash content ( $r = 0.908$ ;  $p < .001$ ) with the variability ( $r^2 = 0.82$ ) of 82%. The concentration of OC content was higher than the findings of innagi *et al.* (2017) [17] conducted an alder tree. Generally, species that have a higher initial concentration of organic carbon can decompose slowly. Hoorens *et al.*, (2003) [14]. Reported that the initial litter OC content was correlated to the remaining litter mass ( $r = 1.000$ ;  $p < 0.001$ ) strongly positive correlation with TOM with the variability of ( $r^2 = 1$ ) 100% (Fig 1). According to the study, high N compounds have high lignin content, N and lignin play a crucial role in controlling decomposition.

Moreover, the species that comes under the family of leguminous can have high nitrogen content. Similarly, low nitrogen element has a high C/N ratio due to the production of secondary metabolites (Rodriguez *et al.*, 2015) [26], which shows a strong negative correlation with N and C/N ratio ( $p < 0.001$ ) with the variability of 97%. These findings indicated that the ash, TOM and C: N ratio explains much variability with lignin, TOC and N than the other nutrients in the leaf litter. The effect size for ash ( $r^2 = 0.82$ ) indicated the level of ash value accounted for the large portion (82%) of the variability in the lignin. The effect size for TOC ( $r^2 = 1$ ) indicated that the level of ash value accounted for the large portion (100%) of the variability in the TOM. The effect size for N ( $r^2 = 0.97$ ) indicated that the level of ash value accounted for the large portion (97%) of the C: N variability (Fig 3).

**Pearson's r heat map**



**Fig 3:** Pearson's r heat map-correlation of initial litter concentration

**The rate of litter decomposition and nutrient release**

Depends upon the species litter quality, environmental condition and existing microbial activity, the decomposition rate may change, which is either in an exponential or a linear pattern. As with the present study results, Hossain *et*

*al.*, 2011 [15] also reported that a gradual weight loss pattern occurs throughout the experiment period. High litter mass was observed in the initial 30 days due to the leaching of soluble compounds (Ibrahima *et al.*, 2008) [16] indicates the initial stage. The further decrease suggests the release of a recalcitrant substance indicates the advanced stage. It observed that the constant range of decomposition  $k = 0.0051-0.0035$  in 30 days,  $k = 0.0042-0.0033$  in 60 days and  $k = 0.0038-0.0032$  in 90 days. Similarly, the exponential reduction of constant  $k$  value from the initial to later was discussed by Dhanya *et al.*, (2013) [8]. But most components decompose at a significantly faster rate in the initial growth period. The highest decomposition rate has been denoted in *Senna sieamea*  $R = 0.000518 - 0.0038$  (30-90 days) from the final weight of 44.9-35.8 in gms due to low lignin and high TOM + TOC + Ash and moderate N content.

**Table 5:** Pearson's Correlations for decomposition rate

			r	p
Days	-	lignin value	-0.967 *	0.033
Days	-	Litter weight	-0.993 **	0.007
Days	-	Decomposition rate	-0.972	0.152
lignin value	-	Litter weight	0.990 **	0.010
lignin value	-	Decomposition rate	1.000 *	0.018
Litter weight	-	Decomposition rate	0.980	0.127

As a result, species with greater initial litter OC concentrations decomposed fast. Likewise, Kucera (1959) has mentioned that high ash + N and lower C/N ratio in species had high decomposition ratio and the species have average ash + N + lignin, and normal C/N seem transitional rate of decomposition as like in the present study. Hence, a high percentage of N and other components with low lignin content is considered high-quality litter (Sakala *et al.*, 2000) [28]. The lowest decomposition rate was found in *Acacia auriculiformis* with the range of  $R = 0.0035- 0.0032$  from the remaining weight of 44.9 gms, which contain the high lignin +N and low TOM + TOC + Ash + C/N. Laskowski and Berg (2006) [21] have mentioned that a high amount of lignin can slow the decomposition rate than the litter contain a high concentration of starch. High lignin content has the potential to greatly influence the litter decomposition rate by their recalcitrant component, which needs special microorganisms for degradation (Giebelmann *et al.*, 2011) [11]. The lowest N had the highest C/N ratio in *Lagerstroemia spicosa*. A similar result has been reported by Cusack *et al.* (2009) [4]. The average lignin and ash content, lignin and C/N ratio decomposition rate occur at a transitional rate (Krishna, and Mohan, 2011) [19].

Lignin, litter weight and decomposition rate was strongly negatively correlated with the no. of degrading days ( $r = -0.96$ ); ( $r = -0.99$ ); ( $r = -0.97$ ) the  $p$  value was  $p < 0.05$ ; litter weight and decomposition rate was strongly positively correlated with lignin ( $r = 0.98$ ;  $r = 1$ ); decomposition was strongly positively correlated with litter weight  $r = 0.980$ . The effect sizes for lignin ( $r^2 = 0.92$ ), litter weight ( $r^2 = 0.98$ ), decomposition rate ( $r^2 = 0.57$ ) indicated that the level of decomposition process value accounted for a large portion (92%, 98% and 57%) of the variability in lignin, litter weight and decomposition weight (Table 5).

Nutrient release of decomposed litter is pivotal; the period of the nutrient release may differ based on the concentration of litter of each species, and microbial populations infesting the litter can have immobilised N, which leads to the

attribution for the variation of nutrient release between the species. The initial rapid decrease of lignin content (Figure 3) is observed which is due to the loss of the available forms of nutrients at the initial stages of decomposition (Krishna, MP, & Mohan M, 2017) [19]. Also increased concentration of nitrogen at different stages of decomposition in all season, was contributed to microbial colonization in the residual leaf litter.

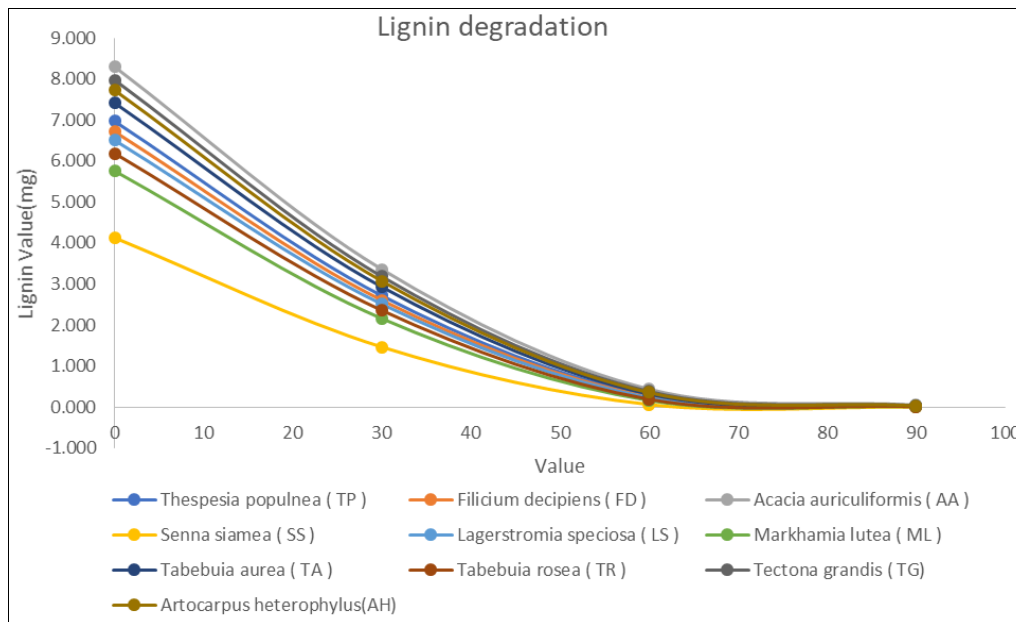
**Decomposition rate with integrating microbes**

Several species of *Trichoderma* produce a large number of extracellular enzymes to degrade the complex process of plant cell wall biopolymers (Druzhinina *et al*, 2010) [9]. *Trichodermakoningsiopsis* (Tricomp) is a gamma irradiated strain integrated to degrade high lignin-containing leaves. Saini *et al*, (2015) [27] reported that the production of secondary metabolites and extracellular enzymes by microbes are considered primary decomposers of

lignocellulose. With the efficient decomposition, litter weight was reduced by 65%, and 90 % of lignin has degraded at 30 days; another 15 % reduction in litter weight at 60 days and the remaining 12% reduction in litter weight at 90 days have occurred (Fig 3). There is a significant negative correlation between the days and litter weight  $r = -0.92$ ;  $p < 0.5$ , lignin  $r = -0.933$ ;  $p < 0.05$ , decomposition rate  $r = -0.872$ ;  $p < 0.5$ . Lignin positively correlated with litter weight  $r = 0.987$  and decomposition rate  $r = 0.997$  with  $p < 0.05$ . Litter weight positively correlated with decomposition rate  $r = 0.901$ ;  $p < 0.05$ . These findings indicated that lignin, litter weight and decomposition rate explain much more of the variability in degrading days. The effect sizes for lignin ( $r^2 = 0.87$ ), litter weight ( $r^2 = 0.84$ ), decomposition rate ( $r^2 = 0.76$ ) indicated that the level of decomposition process value accounted for a large portion (87%, 84% and 76%) of the variability in lignin, litter weight and decomposition weight (Table 6).

**Table 6:** Decomposition rate with integrating microbes

Name of the tree species	30 days			60days			90days		
	Lf (gms)	k	lignin value after 30 days	Lf (gm)	k	Lignin value after 60 days	Lf (gm)	k	Lignin value after 90 days
<i>T. populnea</i>	19.5	0.031	2.71	12	0.023	0.27	6	0.023	0.021
<i>F. decipiens</i>	19.4	0.031	2.60	11.90	0.023	0.24	5.90	0.023	0.018
<i>A. auriculiformis</i>	20.25	0.030	3.36	12.75	0.022	0.43	6.75	0.022	0.048
<i>S. siamea</i>	17.75	0.034	1.46	10.25	0.026	0.06	4.25	0.027	0.001
<i>L. speciosa</i>	19.3	0.031	2.51	11.80	0.024	0.22	5.80	0.023	0.015
<i>M. lutea</i>	18.75	0.032	2.16	11.25	0.024	0.16	5.25	0.025	0.008
<i>T. aurea</i>	19.75	0.030	2.93	12.25	0.023	0.31	6.25	0.023	0.027
<i>T. rosea</i>	19.05	0.032	2.35	11.55	0.024	0.19	5.55	0.024	0.011
<i>T. grandis</i>	19.95	0.030	3.18	12.45	0.023	0.38	6.45	0.022	0.038
<i>A. heterophylus</i>	19.87	0.030	3.07	12.37	0.023	0.35	6.37	0.022	0.033



**Fig 4:** Lignin degradation after integrating microbes

**Conclusion**

These findings provide evidence on the differences in litter quality, the variation in decay rates of litter by chemical fractions and reducing the duration of decomposition that occurs by introducing microbes for ten tree species in the tropical ecosystem. The primary chemical controller for decomposition process in litter is lignin. Hence, accelerating the decomposition of complex organic polymers is possible

by integrating extracellular enzymes and secondary metabolites producing microbes of *Trichoderma koningsiopsis*.

Employment of microbes in decomposition process decreased 90 % of the lignin content in the initial stage of 30 days. This study suggests that integrating with TRICOMP (product from BCX Bio Organics, Bengaluru) can enhance soil fertility by degrading lignin content.

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