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Composting technology for *Dalbergia sissoo* and *Grewia tiliifolia* leaf litter

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Abstract
Litter decomposition takes part in nutrient cycling and this phenomena is carried out by disintegration of complex organic matter into a simpler form by the action of microbial community and this process helps in mineralization of soil and also supply vital nutrients to the soil. To utilize litter generated from the tree species; an attempt was made to develop composting technique for the decomposition of *Dalbergia sissoo and Grewia tiliifolia* leaf litter using fruit based Effective Microorganisms. About 500 kg of leaf litters were collected and placed in a shady area as different compost bed. Initially 10 kg cow dung slurry was added for composting. Urea was applied @ 2 kg/tonne at the start of the composting. Moisture content of the compost bed was maintained at 60% by adding water in every alternate day. EM culture was added @ 5 lit/tonne. Periodical turning was given over in every ten days interval. The compost quality parameters were monitored at every 15 days interval. The pH of the compost remained neutral (7.18 to 7.21) throughout the composting period. There was slight increase in EC during the composting; however the Electrical Conductivity was not increased beyond 0.99 dS m^{-1}. Overall the nutrient content of compost (N, P, K) was increased. The carbon and C/N ratio were decreased with the advancement of composting. The Fruit based Effective microbial formulations are successful in converting the *Dalbergia sissoo* into compost in 60 days (C/N ratio, 17.6). The *Grewia tiliifolia* litters were composted in 75 days (C/N ratio, 17.1).

Keywords: Tree leaf litter, rapid composting, fruit based effective microorganisms

Introduction

Mother Nature produces foliage in the monsoon and during summer season, afterward the leaves fall down from the trees and die off, it leads to the process of composting. It has been going on since the beginning of time and is the decomposition of organic materials, such as leaves, grasses and food scraps by microorganisms. The resulted end product is a recycled, earthy smelling, soil like material known as compost. It is a mixture of decayed organic materials decomposed by microorganisms in a warm, moist and aerobic environment, releasing nutrients into readily available forms for plant use. When it added to soil, not only provides essential nutrients but also helps to retain water in sandy soil and breaks up heavy clay soil. Litter decomposition represents one of the largest annual fluxes of carbon (C) from terrestrial ecosystems, particularly for tropical forests, which are generally characterized by high net primary productivity and litter turnover. Litter fall in terrestrial ecosystems signifies a crucial pathway for nutrient return to the soil. Leaf tissue can account for more than 70% of above ground litter fall in forests, and the rest is composed of stems, small twigs and propagative structures (Robertson and Paul, 1999) [12]. Litter decay is the sum of carbon dioxide (CO_2) release and discharge of compounds, which contains both carbon compounds and nutrients (Brady and Weil, 2010) [4]. Litter decomposition proceeds through numerous mechanisms, especially heterotrophic consumption of organic composites in litter (Bezkorovainaya, 2005) [3]. The nitrogen (N), phosphorus (P) and calcium (Ca) released from plant litter through decomposition are accessible for plants and microbial uptake. The role of microbes and plants in the litter degradation process and also the importance of nutrient cycling and mineralisation process have been well explained by previous researcher (Ball, 1997) [2]. Litter fall in terrestrial ecosystems signifies a crucial pathway for nutrient return to the soil. In terrestrial ecosystems, the litter decomposition is an important functional process, governing the cycling of nutrients (Swift *et al.* 1979) [15] and thereby regulating the vegetational productivity. Moreover, litter is the main component of detritus food chain, which enters the decomposition subsystem and is broken down by an array of decomposing organisms.

Freshly fallen leaves pass through several stages from surface litter to well decomposed humus partly mixed with mineral soil which contains 50 to 80% of the nutrients, releases back into the soil. Large-scale plantation forests have been established in the world to meet the demands for timber, fuel material, and other forest products as a result of the increased pressure on natural resources caused by the increasing human population. However, yield decline and land deterioration (such as loss of surface soils, depletion of soil nutrients, soil compaction) may occur when natural forests are converted to plantations of trees. In steep slopes, and low antierodibility of soils are characteristic, many native forests have been cleared and replanted with monoculture plantations (mainly economical species) following clear-cutting, slash burning, and soil preparation. As a consequence, soil degradation (e.g., depletion of soil nutrient pools, low in nutrient availability and biochemical activity, inhibition of soil microorganisms, deterioration of soil structure and erodibility) in such disturbed ecosystem has become serious, and yield decline has been found on sites with repeating monoculture of plantations. Forest litter acts as an input-output system of nutrients and the rates at which forest litter falls and, subsequently, decays contribute to the regulation of nutrient cycling, as well as to soil fertility and primary productivity in forest ecosystems. Forest College and Research Institute, Mettupalayam, Tamil Nadu is owning more than 500 acres of land with native and introduced tree crops which produces enormous quantity of leaf litter. If the litter are composted properly and released back into the system it will not only add nutrients but maintain soil fertility. With this view and continuation of earlier rerach work by (Divakar and Prasanthrajan, 2019) [5], the present investigation was under taken to develop rapid composting technology for *Dalbergia sissoo* and *Grewia tiliifolia* leaf litter using fruit based Effective Microorganisms.

Materials and Methods

The leaf litters of *Dalbergia sissoo* and *Grewia tiliifolia* were collected from the existing silviculture plantation of the Department of Silviculture and Natural Resource Management of Forest College and Research Institute, Mettupalayam, Tamil Nadu. Bench scale composting of *Dalbergia sissoo*, *Grewia tiliifolia* and mixed leaf litter (*D. sissoo, G. tiliifolia* and grass clipping @ 40:40:20) were conducted using 5 kg litters. The bench scale composting experiments were conducted using cowdung and Fruit based Effective Microorganisms (FEM). As the FEM was effective, the same experiments were conducted in large scale at the compost yard of FC&RI, Mettupalayam. About 500 kg litters of *Dalbergia sissoo, Grewia tiliifolia* and mixed leaf litter (*D. sissoo, G. tiliifolia* and grass clipping @ 40:40:20) were collected from the respective tree plantation of Precision Silviculture field and transported to compost yard. The collected leaf litters were dried under shade for 24 to 48 hours and cut into small pieces of 2-3 cm size manually using sickle. The leaf litters were placed as bed in a plain surface under the shade of *Pongamia pinnata* tree in Compost yard. The leaf litters were inoculated with 5 liters of cow dung slurry and 300 g of urea at the beginning of the experiment. First turning was given at 15th day of composting. During the first turning, FEM were added to each compost bed @ 5 liters / ton. Moisturizing the bed was done for every alternate day to improve the composting and to maintain the optimum moisture content of 60%. Compost maturity test were conducted from 30th day onwards. About 500 g compost sample was drawn at every 15 days to know the changes in pH, EC, carbon, nitrogen, phosphorus, potassium, C/N ratio and microbial populations. Compost maturity test and phyto toxicity assay were conducted at 45th, 60th and 75th day of composting.

Preparation of FEM

Jaggery syrup solution was prepared using 250 g jaggery in 500 ml of water. The fruit wastes pumpkin and papaya of 250 g each were cut into small pieces and made to pulp after removing the outer skin. Then the fruit pulp and jaggery solution were mixed in an earthen pot containing 10 litres of water. After proper mixing, a known quantity of rhizosphere soil (250g) were taken from fertile field of *Dalbergia sissoo* (125 g) and *Grewia tiliifolia* (125 g) and added in to the earthen pot. Then the pot was covered with white cloth, lid and placed in shade for 10 days (Prasanthrajan and Doraisamy, 2011) [11].

Monitoring of compost quality parameters

The pH of the compost sample was determined by pH meter using 1:10 sample water suspension ratios. The EC was determined by the conductivity meter using supernatant liquid obtained from 1:10 sample water suspension ratios (Jackson, 1973) [7]. Total carbon was determined by using Loss of lignition. Total nitrogen was determined by micro-kjeldahl digestion method (Humphries, 1956). Total phosphorus was determined by rapid colorimetric method. Total potassium was determined by flame photometry method (Stanford and English 1949) [14]. The changes in temperature of the compost bed were monitored using mercury thermometer. Changes in microbial population (bacteria, fungi and actinomycetes) were studied by serial dilution/plate count method. Phytotoxicity test was conducted by taking known quantity of compost (100 g) in a plastic cup in which 10 number of green gram (*Vigna radiate*) seeds were sown to study the germination percentage. Germination index was calculated by the following formula.

Germination index = Shoot or root length of control - Shoot or root length of treatment x 100

Results and Discussions

The initial pH of the leaf litters viz, *Dalbergia sissoo*, *Grewia tiliifolia* and mixed leaf litter were 6.72, 6.75 and 6.77 respectively (Table 1). During decomposition, the pH was decreased at the initial stage after that it was slightly increased from 7.18 to 7.21. As the pH values of the matured compost was not exceeded 7.21 it can be applied in to the field. The EC values were increased gradually during the composting process. However the EC values of the matured compost were not exceeded 0.99 dS m^{-1} which is quite safe for field application. During the composting process, the Electrical Conductivity of the compost was stable during the initial period of composting and increased after 30th days of composting, gradually from 0.65 to 0.99 dS m^{-1} (Table 2).

Table 1: Changes in pH during the decomposition of leaf litter

Treatments	Changes in pH					
	Initial	15th day	30th day	45th day	60th day	75th day
T1	6.72	6.61	6.69	6.87	7.16	7.18
T2	6.75	6.59	6.72	6.91	7.19	7.21
T3	6.77	6.55	6.78	6.84	7.18	7.20
SED	0.0306	0.0205	0.0125	0.0170	0.0191	0.0265
CD	0.0848	0.0571	0.0346	0.0472	0.0532	0.0735

T1 – *Dalbergia sissoo* leaf litter + EM, T2 – *Grewia tiliifolia* leaf litter + EM, T3 – Mixed leaf litter + EM

Table 2: Changes in Electrical Conductivity (dS m^{-1}) during the decomposition of leaf litter

Treatments	Changes in EC (dS m^{-1})					
	Initial	15th day	30th day	45th day	60th day	75th day
T1	0.68	0.72	0.77	0.85	0.92	0.95
T2	0.67	0.73	0.81	0.87	0.95	0.99
T3	0.65	0.77	0.80	0.88	0.93	0.96
SED	0.0111	0.0098	0.0170	0.0153	0.0137	0.0094
CD	0.0307	0.0272	0.0472	0.0424	0.0382	0.0262

T1 – *Dalbergia sissoo* leaf litter + EM, T2 – *Grewia tiliifolia* leaf litter + EM, T3 – Mixed leaf litter + EM

During the composting of the leaf litters *viz*, *Dalbergia sissoo, Grewia tiliifolia* and mixed leaf litter, more reduction of carbon was recorded in compost of *Dalbergia sissoo* leaf litter. The total carbon content of the compost was decreased with the advancement of composting. The carbon content of *Dalbergia sissoo* leaf litter was 26.4% at the initial which were 16.9% at the end of 75 day of composting (Table 3). *Grewia tiliifolia* leaf litter had initial carbon content of 33.2% which were reduce to 20.2% at the end of 75 days of composting. Mixed leaf litter had 33.1% initial carbon and it got reduced to 19.7% at the end of 75 days of composting.

In general, the total nitrogen content was increased during the composting process. The total nitrogen content of *Dalbergia sissoo* litter compost was 1.06% and 1.45% in mixed leaf litter compost (Table 4). The nitrogen content of *Dalbergia sissoo* leaf litter was 0.63% at the initial 1.06% at the end of 75 day of composting. *Grewia tiliifolia* leaf litter had initial nitrogen content of 0.73% which was increased to 1.18% at the end of 75 days of composting. Mixed leaf litter had 0.92% initial nitrogen which gradually increased to 1.45% at the end of 75 days of composting. The total nitrogen content of the compost was increased with the advancement of composting. In soils, nitrogen is associated with the soil organic material, which contains about 5% of the total nitrogen (Brady and Weil, 2010) [4]. This organic nitrogen is not available for plants, so the microorganisms decay the organic matter into smaller particles through the discharge of ammonium.

Table 3: Changes in total carbon (%) during the decomposition of leaf litter

Treatments	Changes in total carbon (%)					
	Initial	15th day	30th day	45th day	60th day	75th day
T1	26.4	21.4	19.9	18.7	17.5	16.9
T2	33.2	31.5	29.6	27.9	24.5	20.2
T3	33.1	28.9	26.7	24.8	22.9	19.7
SED	0.2494	0.1795	0.1631	0.1247	0.3091	0.2582
CD	0.6926	0.4984	0.4532	0.3463	0.8583	0.7169

T1 – *Dalbergia sissoo* leaf litter + EM, T2 – *Grewia tiliifolia* leaf litter + EM, T3 – Mixed leaf litter + EM

Table 4: Changes in total nitrogen (%) during the decomposition of leaf litter

Treatments	Changes in total nitrogen (%)					
	Initial	15th day	30th day	45th day	60th day	75th day
T1	0.63	0.68	0.74	0.80	0.99	1.06
T2	0.73	0.80	0.85	0.91	1.01	1.18
T3	0.92	0.99	1.01	1.10	1.35	1.45
SED	0.0610	0.0699	0.0231	0.0499	0.0337	0.0189
CD	0.1694	0.1941	0.0641	0.1385	0.0935	0.0524

T1 – *Dalbergia sissoo* leaf litter + EM, T2 – *Grewia tiliifolia* leaf litter + EM, T3 – Mixed leaf litter + EM

The C/N ratio was decreased during the composting process. The lowest C/N ratio recorded was 13.5 in mixed leaf litter and highest was 17.1 in *Grewia tiliifolia* leaf litter. This ratio provides an indication of the kind of compost and how it can be managed while mixed to the soil. Initially the C/N ratio of the leaf litters was between 35.9 to 45.5: 1. After a period of decomposition (75 days), the C/N ratio of *Dalbergia sissoo* leaf litter and mixed leaf litter was 15.9 and 13.5 respectively.

Leaf litter decomposition can be calculated from the C/N ratio. High-quality leaves (nutrient-enriched leaves) will generally decompose more rapidly than low-quality leaves (nutrient-deficient leaves). In general, the decomposition rate is high in species with extreme ash and nitrogen contents and minimum C/N ratios and lignin contents (Singh 1969) [13].

Table 5: Changes in C/N ratio during the decomposition of leaf litter

Treatments	Changes in C/N ratio					
	Initial	**15th day**	**30th day**	**45th day**	**60th day**	**75th day**
T1	41.9	31.5	26.9	23.5	17.6	15.9
T2	45.5	39.4	34.8	30.7	24.2	17.1
T3	35.9	29.1	26.4	22.5	16.9	13.5
SED	3.7939	3.1109	0.8587	1.3357	0.7745	0.1883
CD	10.5339	8.6373	2.384	3.7084	2.1505	0.5229

T1 – *Dalbergia sissoo* leaf litter + EM, T2 – *Grewia tiliifolia* leaf litter + EM, T3 – Mixed leaf litter + EM

The total phosphorus was increased during the composting process but there was not much increase in the phosphorous content. During composting process, the total phosphorus content of the leaf litters viz, *Dalbergia sissoo* leaf litter and *Grewia tiliifolia* leaf litter varied from 0.03% to 0.37% (Table 6). Mixed leaf litter attained an amount of total Phosphorus content of 0.32%. Litter decomposition provides a very small concentration of orthophosphate to plants (Verhoef and Brussaard, 1990) [16]. With regard to changes in potassium, the lowest potassium content was 1.55% in *Grewia tiliifolia* leaf litter and highest 1.65% in *Dalbergia sissoo* leaf litter. Mixed leaf litter had 1.56% (Table 7). Potassium and magnesium are essential nutrients for higher plants; however, they rarely limit microbial actions and are quickly removed from decaying litter (Anderson and Ingram, 1983) [1].

Table 6: Changes in total phosphorus (%) during the decomposition of leaf litter

Treatments	Changes in total phosphorus (%)					
	Initial	**15th day**	**30th day**	**45th day**	**60th day**	**75th day**
T1	0.03	0.10	0.16	0.21	0.26	0.29
T2	0.05	0.12	0.20	0.28	0.35	0.37
T3	0.04	0.11	0.15	0.19	0.28	0.32
SED	0.0125	0.0465	0.0238	0.0183	0.0170	0.0238
CD	0.0346	0.1290	0.0661	0.0507	0.0472	0.0472

T1 – *Dalbergia sissoo* leaf litter + EM, T2 – *Grewia tiliifolia* leaf litter + EM, T3 – Mixed leaf litter + EM

Table 7: Changes in total potassium (%) during the decomposition of leaf litter

Treatments	Changes in total potassium (%)					
	Initial	**15th day**	**30th day**	**45th day**	**60th day**	**75th day**
T1	1.16	1.20	1.24	1.32	1.54	1.65
T2	1.13	1.20	1.22	1.36	1.43	1.55
T3	1.14	1.22	1.25	1.34	1.45	1.56
SED	0.0111	0.0229	0.0075	0.0216	0.0335	0.0377
CD	0.0307	0.0634	0.0207	0.0600	0.0930	0.0935

T1 – *Dalbergia sissoo* leaf litter + EM, T2 – *Grewia tiliifolia* leaf litter + EM, T3 – Mixed leaf litter + EM

Temperature plays an important role as it determines the microbial activity and in turns the maturity of the compost. Temperature of the compost pile increased during the initial stage of composting and reached the maximum at certain point after that it got decreased. The temperature of the mixed leaf litter compost reached the maximum of 47 °C at 30th day (Table 8). Microbes can also be limited by soil moisture. As the temperature rises, soil moisture has a progressively more significant role in retaining high rates of microbial activity (Peterjohn *et al*. 1994) [10].

Loreau (2001) [8] suggested that microbial diversity has a positive influence on nutrient cycling proficiency and ecosystem processes. Among the soil organisms, bacteria and fungi have excellent characteristics of biomass and respiratory metabolic rate and have more involvement in the organic matter decay procedure (Persson, 1980) [9]. During the first phase of bacterial growth, it gradually increased and reached a maximum at the second phase. During the third phase the bacterial growth gradually decreased. The bacterial population was increased up to 30th day during the composting process and decreased thereafter. The maximum number of bacterial population was recorded in mixed leaf litter at 30th day (Table 9). During the first phase of fungal growth, it gradually increased and reached a maximum at the second phase. During the third phase the fungal growth gradually decreased. The actinomycetes population was gradually increased during the composting process and reached its maximum at final phase of composting.

Table 8: Changes in temperature (ºC) during the decomposition of leaf litter

Treatments	Changes in temperature (ºC)					
	Initial	**15th day**	**30th day**	**45th day**	**60th day**	**75th day**
T1	30	39	42	36	34	29
T2	33	40	45	35	36	30
T3	34	41	47	38	32	28
SED	1.6330	1.6997	0.7454	1.1547	2.0548	0.8165
CD	4.5340	4.7191	2.0695	3.2060	5.7051	2.2670

T1 – *Dalbergia sissoo* leaf litter + EM, T2 – *Grewia tiliifolia* leaf litter + EM, T3 – Mixed leaf litter + EM

Table 9: Changes in bacterial population during the decomposition of leaf litter

Treatments	Changes in bacterial population (CFU x 10^5)					
	Initial	**15th day**	**30th day**	**45th day**	**60th day**	**75th day**
T1	21	25	29	24	20	18
T2	19	24	28	23	19	15
T3	20	29	35	27	23	19
SED	2.8674	1.4142	0.4714	0.9428	1.1055	1.4142
CD	7.9614	3.9265	1.3088	2.6177	3.0695	3.92565

T1 – *Dalbergia sissoo* leaf litter + EM, T2 – *Grewia tiliifolia* leaf litter + EM, T3 – Mixed leaf litter + EM

The Phytotoxicity test was conducted to monitor the changes in the maturity of the compost during the decomposition of tree leaf litters *Dalbergia sissoo*, *Grewia tiliifolia* and mixed leaf litter. The vigour index of green gram was decreased during the decomposition process. The lowest value recorded was 153 in *Dalbergia sissoo* and highest value recorded was 545 in mixed leaf litter. For *Grewia tiliifolia* it was 343 (Table 10). Lower value shows the toxicity in compost was less compare to other leaf litter.

Table 10: Phytotoxicity Assay

Treatments	Changes in vigour index of seedlings				
	Control	**15th day**	**30th day**	**45th day**	**60th day**
T1	1420	1120	760	420	153
T2	1624	1310	1160	606	343
T3	1910	1674	1228	992	545
SED	24.944	11.888	23.1223	14.267	5.888
CD	69.258	33.008	64.200	39.613	16.348

T1 – *Dalbergia sissoo* leaf litter + EM, T2 – *Grewia tiliifolia* leaf litter + EM, T3 – Mixed leaf litter + EM

Conclusion

Composting experiments were conducted to evaluate the rate of decomposition of leaf litters namely *Dalbergia sissoo*, *Grewia tiliifolia* and mixed leaf litter with fruit based Effective Microorganisms. Initially the leaf litters were composted with help of cow dung as microbial inoculums and it was too slow in the decomposition. So, conventional Effective Microorganisms (EM) was prepared using papaya, pumpkin and jaggary to enhance the composting process. In our study, application of EM enhanced the composing process and reduced the composting period from 75 days to 60 days. *Dalbergia sissoo* leaf litters were successfully composted in 60 days using fruit based Effective Microorganism @ 5 liters/tonne of leaf litter. Mixed leaf litters (*Dalbergia sissoo, Grewia tiliifolia and Grass clippings)* were also successfully composted in 60 days (C/N ratio 16.9) using fruit based Effective Microorganism @ 5 liters/tonne of litter. *Grewia tiliifolia* leaf litters were successfully composted in 75 days using fruit based Effective Microorganism @ 5 liters/tonne of litter. The decomposition rate of *Grewia tiliifolia* leaf litter is slow as it may need specific lignolytic microorganisms for quick decomposition.

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