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M Divakar
Department of Silviculture and Natural Resource Management Forest College and Research Institute, Tamil Nadu, Agricultural University, Mettupalayam, Tamil Nadu, India

M Prasanthrajan
Department of Silviculture and Natural Resource Management Forest College and Research Institute, Tamil Nadu, Agricultural University, Mettupalayam, Tamil Nadu, India

Correspondence
M Divakar
Department of Silviculture and Natural Resource Management Forest College and Research Institute, Tamil Nadu, Agricultural University, Mettupalayam, Tamil Nadu, India

Composting of tree leaf litter using fruit based effective microorganisms

M Divakar and M Prasanthrajan

Abstract
The litter fall from forest trees is increasing day by day but it has not been utilized effectively. The leaf litters can be converted into compost and added back into the same ecosystem to improve the soil quality and growth of the trees. An attempt was made to prepare good quality compost from different forest tree leaf litter (*Neolamarkia cadamba, Acrocarpus fraxinifolius, Dalbergia sissoo* and *Grewia tiliifolia*) using fruit based Effective Microorganisms (FEM). About one ton of leaf litters were collected separately and added with 2 kg urea. The FEM was applied at the dosage of 3 liters per ton in each compost bed. The changes in compost quality parameters such as temperature, pH, EC, total carbon, total nitrogen, total phosphorus, C/N ratio, total potassium and microbial populations were monitored for 60 days. The condition of compost maturity was indicated by the changes in C/N ratio (around 14:1), stable temperature and normal pH (around 7.0). The pH of the litter material was increased from 6.71 to 7.21 during composting. The nutrient content was increased as the composting progressed. The increase in nitrogen of the compost was around 0.90 % to 1.40 %, phosphorus from 0.03% to 0.42% and potassium from 1.10% to 2.13%. The tree leaf litter of *Neolamarkia cadamba* attained maturity at 45 days of working; *Acrocarpus fraxinifolius* in 60 days. The other two species *Grewia tiliifolia* and *Dalbergia sissoo* leaf litter requires additional days of composting as they were not attained maturity in 60 days which needs further investigation.

Keywords: Tree leaf litter, rapid composting, effective microorganisms

Introduction
Plant litter is dead plant material, such as leaves and twigs that have fallen on the ground. This detritus or dead organic material and their nutrients are added to the top layer of soil. Plant litter is an integral part of the nutrient cycling process and is an indicator of an ecosystem's productivity and stability. Leaf senescence and fall is a major component of litter, and the organic compounds of the litter are physically and chemically broken down by detrivores and decomposers into inorganic nutrients that plants are able to take. This organic layer is then decomposed and released as inorganic soil nutrients. The study of plant litter has received much attention from ecologists because it is an integral factor in ecosystem dynamics, indicative of productivity and influences nutrient cycling and soil fertility.

The annual litter production in the tropical dry evergreen and deciduous forest in India is 13.5 tha^{-1} and 13.2 tha^{-1} respectively. However, Leaf litter production in tropical semi- evergreen forest is 9.0-9.6 t $ha^{-1}yr^{-1}$ and moist deciduous forest is 16 t $ha^{-1}yr^{-1}$ of India. Even though the production of leaf litter is high, so far it was not utilized in the country for the retention of nutrients in the leaf litter to the plants or soils. This might be one of the reasons for the occurrence of forest fires. Many techniques are available to utilize these leaf litters namely composting, vermicomposting, briquetting and mulching.

One of the best ways to manage the leaf litter is composting. Composting is a natural process through which organic wastes are converted into manure by the action of microorganisms. Microbe's converts plant materials such as grass clippings, leaves and twigs to a more usable product called compost which can be used as soil amendment or mulch. Compost also improves soil structure so that soil can easily hold the correct amount of moisture, nutrients and air. It improves the texture of both clay soils and sandy soils, making either type rich, moisture retentive, and loamy.

The process of composting can be accelerated and made more efficient by process modification. The microorganisms in the compost pile require the same basic essentials of most living organisms: nutrients, air and water. If the microbes are abundant, litter will decompose rapidly. Since decomposition is a natural process, it will eventually occur, however slowly. The primary objective of the study is to create an ideal environment for the microorganisms doing the composting. Bacteria are the first to break down plant tissue. Fungi and protozoans soon join the bacteria. Centipedes, millipedes, beetles, and earthworms also

participate by tearing and chewing the materials into smaller pieces making them more suitable for the microbes.

In order to make use of these litters and to develop a rapid composting techniques for tree litters, fruit based Effective Microorganisms (FEM) were used in this study. It is a combination of useful regenerative micro-organisms that exist freely in nature and are not manipulated in any way. In general, one or two turning, after two weeks is enough for composting. However periodical turning primarily has the effect of breaking twigs and open up fibres and thus facilitate microbial access into the material. Hence, in this study, turning was given once in 15 days.

Inoculation of a compost pile with FEM needs to be done once or twice, i.e. at the beginning and once again during the process, best during first turning of the compost bed. FEM application on the compost bed might have to be done more frequently, depending on the type and the quantity of raw materials. The prime objective of this study is collection, characterization and assessing the rate of decomposition of leaf litters of *Neolamarkia cadamba*, *Grewia tiliifolia*, *Acrocarpus fraxinifolius* and *Dalbergia sissoo*.

Materials and Methods

Neolamarkia cadamba, Acrocarpus fraxinifolius, Dalbergia sissoo and Grewia tiliifolia litters of about one ton were collected from the respective tree fall at Precision Silviculture plantation, Forest College and Research Institute, Mettupalayam. The collected leaf litters were dried under shade for 24 hours and cut into small pieces of 2-3 cm size manually. The leaf litters (about 1 ton each) were placed as bed in a plain surface under the shade of *Neolamarkia cadamba* tree plantation. The leaf litters were inoculated with 5 liters of cow dung slurry at the beginning of the experiment. The C/N ratio of each litter was adjusted by adding urea. First turning was given at the 15th day of composting. During the first turning, FEM consortia were added to each compost bed at the rate of 3 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 and phyto-toxicity test were conducted from 30th day onwards. About 1 kg 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.

Preparation of FEM

Papaya (500 g), pumpkin (500 g), jaggary (500 g) was taken in an earthen pot containing 20 litres of water. Papaya and pumpkin were cut into small pieces (<1 cm) after removing the skin. After proper mixing, a known quantity of rhizosphere soil was taken from fertile forest plantation and it was transferred into the earthen pot containing papaya, pumpkin and jaggary. Then the pot was covered with white Gada cloth, lid and placed in shade for 10 days. (Prasanthrajan and Doraisamy, 2011) [9].

Monitoring of compost quality parameters

The changes in temperature of the compost bed were monitored using mercury thermometer. 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) [8]. Total carbon was determined by using muffle furnace. Total nitrogen was determined by micro-kjeldahl digestion method (Humphries, 1956) [7]. Total phosphorus was determined by rapid colorimetric method. Total potassium was determined by flame photometry method (Stanford and English 1949) [11]. 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.

$$\text{Germination index} = \frac{\%\ \text{germination} \times \text{mean root length (mm)}}{100}$$

To estimate the maturity of compost, starch iodine test was conducted. In Starch iodine test about one gram of finely powdered compost sample was placed in a 100 ml beaker and a few drops of ethanol were added to wet the samples. About 20 ml of perchloric acid was added to the samples, stirred and filtered through filter paper. Then few drops of the filtrate were placed on a white tile in which 2 drops of iodine reagent was added. Matured compost gives a yellowish colour and very little precipitate; poor or immature compost gives dark colour and heavy precipitation.

Results and Discussions

Composting is the safer and eco-friendly method for recycling. Chemical and physical properties of the compost differ widely, depending on the organic material used for composting. Hence, quality of compost plays an important role to decide the utility of compost.

The pH value of the compost is important, since applying compost to the soil can alter the soil pH, which in turn affect the availability of nutrients to the plant. The pH of the compostable material influences the types of organisms involved in the composting process. Fungi can tolerate wider range of pH than bacteria. The optimum pH range for bacteria is 6.0 to 7.5. The optimum range for fungi is 5.5 to 8.0. Verdonck (1988) [13] reported that organic matter with a wide range of pH (3 to 11) can be composted; however the optimum pH level of organic matter is 6.0 to 8.0. The pH of the leaf litters viz, *Neolamarkia cadamba*, *Grewia tiliifolia*, *Acrocarpus fraxinifolius* and *Dalbergia sissoo* were 6.77, 6.76, 6.72 and 6.71 respectively. During decomposition, the pH increased from 7.15 to 7.19 (Table 1). Thampan (1993) [12] reported that a material that is initially neutral would experience a decrease in pH during the start of composting. This will normally be followed by an increase in the pH, which will be resulted in slightly high alkaline state. The Electrical Conductivity of the compost was stable during the initial period of composting and increased after 30th day of composting, gradually from 0.64 to 0.98 respectively (Table 2). This is in accordance with the results of Yossi Inbar *et al*. (1993) [14], wherein they have reported that the compost was mature enough to be used as an organic manure when Electrical Conductivity was stable. Temperature determines the microbial activity and in turn the maturity of the compost. At the time of composting *Neolamarkia cadamba* attained a maximum temperature of 52°C on 15th day, 45 °C at 30th day and a sharp decline thereafter (Table 3). *Acrocarpus fraxinifolius* records a maximum of 47°Con 15th day which is also a sign of rapid composting. This in accordance with the findings of Harsha (1983) [6].

Table 1: Changes in pH during the composting of leaf litters

Treatments	Changes in pH				
Initial	Initial	15th day	30th day	45th day	60thday
T_1	7.18	6.77	6.56	6.78	6.85
T_2	7.19	6.76	6.59	6.73	6.89
T_3	7.21	6.72	6.60	6.70	6.81
T_4	7.15	6.71	6.60	6.68	6.88
SED	0.004	0.010	0.160	0.012	0.007
CD	0.010	0.024	0.391	0.030	0.010

T_1 - *Neolamarkia cadamba*+ FEM ; T_2 - *Grewia tiliifolia*+ FEM ; T_3 - *Acrocarpus fraxinifolius*+ FEM ; T_4 - *Dalbergia sissoo* + FEM

Table 2: Changes in Electrical Conductivity (EC) during the composting of leaf litters

Treatments	Changes in EC (dS m^{-1})				
	Initial	15th day	30th day	45th day	60th day
T_1	0.65	0.78	0.82	0.89	0.95
T_2	0.67	0.74	0.80	0.88	0.98
T_3	0.64	0.69	0.75	0.85	0.97
T_4	0.68	0.71	0.76	0.86	0.95
SED	0.004	0.009	0.004	0.007	0.019
CD	0.010	0.022	0.010	0.017	0.040

T_1 - *Neolamarkia cadamba* + FEM; T_2 - *Grewia tiliifolia* + FEM; T_3 - *Acrocarpus fraxinifolius* + FEM; T_4 - *Dalbergia sissoo* + FEM

Table 3: Changes in temperature (°C) during the composting of leaf litters

Treatments	Changes in temperature (°C)				
	Initial	15th day	30th day	45th day	60th day
T_1	41	52	45	38	32
T_2	37	45	40	35	36
T_3	38	47	42	39	33
T_4	39	42	39	36	34
SED	1.47	2.17	0.40	1.69	0.47
CD	3.60	5.31	0.99	4.15	1.15

T_1 - *Neolamarkia cadamba* + FEM; T_2 - *Grewia tiliifolia* + FEM; T_3 - *Acrocarpus fraxinifolius* + FEM; T_4 - *Dalbergia sissoo* + FEM

The total carbon content of the compost showed a decreasing trend with the advancement of composting. The release of carbondioxide leads to a reduction in C/N ratio (Broker *et al*. 1991) [3]. During composting more reduction was recorded in compost of *Neolamarkia cadamba, Acrocarpus fraxinifolius* (16.4% and 15.1%) (Table 6).*Neolamarkia cadamba* and *Acrocarpus fraxinifolius* attains a higher amount of total nitrogen content of 1.4 % (Table 5). It was in accordance with the Bhoyar *et al*. (1979) [2] found that most of the ammonification process occurred during the compositing at temperatures between 40°C and 50°C.

Table 4: Changes in total carbon (%) during the composting of leaf litters

Treatments	Changes in total carbon (%)				
	Initial	15th day	30th day	45th day	60th day
T_1	32.1	27.5	25.5	24.8	22.9
T_2	34.2	31.5	29.6	27.9	24.5
T_3	33.5	31.8	29.7	28.4	21.1
T_4	24.5	21.4	19.9	18.7	17.5
SED	0.348	0.402	0.362	0.274	0.047
CD	0.853	0.983	0.886	0.672	0.115

T_1 - *Neolamarkia cadamba* + FEM; T_2 - *Grewia tiliifolia* + FEM; T_3 - *Acrocarpus fraxinifolius* + FEM; T_4 - *Dalbergia sissoo* + FEM

Table 5: Changes in total nitrogen (%) during the composting of leaf litters

Treatments	Changes in total nitrogen (%)				
	Initial	15th day	30th day	45th day	60th day
T_1	0.90	0.94	1.00	1.10	1.40
T_2	0.75	0.80	0.85	0.91	0.96
T_3	0.93	1.08	1.10	1.12	1.40
T_4	0.59	0.68	0.74	0.80	0.92
SED	0.081	0.045	0.077	0.080	0.101
CD	0.199	0.110	0.189	0.198	0.246

T_1 - *Neolamarkia cadamba* + FEM; T_2 - *Grewia tiliifolia* + FEM; T_3 - *Acrocarpus fraxinifolius* + FEM; T_4 - *Dalbergia sissoo* + FEM

The C/N ratio of compost pile 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 35.7 to 45.6. After composting, the C/N ratio of *Neolamarkia cadamba* leaf litter compost and *Acrocarpus fraxinifolius* leaf litter compost was 16.4 and 15.1 respectively. The corresponding ratios were attained on the 45thand 60th day of composting of the leaf litters. Asija *et al.* [1], (1984) also recorded a decrease in C/N ratio with the increase in the period of decomposition (Table 6).

Table 6: Changes in C/N ratio during the composting of leaf litters

Treatments	Changes in C/N ratio				
	Initial	15th day	30th day	45th day	60th day
T_1	35.7	29.3	23.2	22.5	16.4
T_2	45.6	39.4	32.5	30.5	25.5
T_3	36.0	29.4	26.5	20.3	15.1
T_4	41.5	31.5	24.9	20.3	19.0
SED	1.28	0.35	0.27	0.004	0.34
CD	3.14	0.87	0.67	0.010	0.84

T_1 - *Neolamarkia cadamba* + FEM; T_2 - *Grewia tiliifolia* + FEM; T_3 - *Acrocarpus fraxinifolius* + FEM; T_4 - *Dalbergia sissoo* + FEM

The compost of *Neolamarkia cadamba* and *Acrocarpus fraxinifolius* litter had total phosphorus content of 0.36 and 4.2% and other two species had low P, which was in accordance with the results of Asija *et al*. (1984) as the phosphorus content increases which results in quick composting. *Neolamarkia cadamba* and *Grewia tiliifolia* compost bed a higher amount of total potassium content of 1.98 and 2.13% (Table 7).

Table 7: Changes in total potassium (%) during the composting of leaf litters

Treatments	Changes in total potassium (%)				
	Initial	15th day	30th day	45th day	60th day
T_1	1.11	1.23	1.45	1.72	1.74
T_2	1.12	1.20	1.42	1.96	2.13
T_3	1.12	1.21	1.40	1.91	1.94
T_4	1.10	1.23	1.46	1.74	1.98
SED	0.0082	0.0125	0.0183	0.0245	0.0127
CD	0.02	0.0305	0.0447	0.0599	0.0311

T_1 - *Neolamarkia cadamba* + FEM; T_2 - *Grewia tiliifolia* + FEM; T_3 - *Acrocarpus fraxinifolius* + FEM; T_4 - *Dalbergia sissoo* + FEM

Table 8: Changes in total phosphorus (%) during the composting of leaf litters

Treatments	Changes in total phosphorus (%)				
	Initial	15th day	30th day	45th day	60th day
T_1	0.03	0.09	0.15	0.19	0.30
T_2	0.03	0.12	0.19	0.27	0.36
T_3	0.04	0.11	0.26	0.31	0.42
T_4	0.03	0.10	0.17	0.21	0.26
SED	0.015	0.012	0.013	0.0125	0.0261
CD	0.036	0.03	0.033	0.0305	0.064

T_1 - *Neolamarkia cadamba* + FEM; T_2 - *Grewia tiliifolia* + FEM; T_3 - *Acrocarpus fraxinifolius* + FEM; T_4 - *Dalbergia sissoo* + FEM

The composting is an aerobic process, in which diverse microbes are involved. By changing the microbial diversity, the composting process can be altered. Most of the organic material consists of macromolecules, which cannot be penetrated easily. Therefore, microorganisms secrete enzymes, which degrade the polymers to small organic materials. According to Golueke, (1992) [5] and Sivapalan *et al*. [10]. (1994), low colony forming unit's value must be taken as an indicator of matured compost. Death cells of microbes in turn, increase the nitrogen content. The Initial phase of composting was dominated by fungal population, there were steady increase in fungal population up to 30th days of composting and a reduction thereafter. The bacterial population was steadily increased in the compost up to 30th day of composting. The actinomycetes population was gradually increased during the composting process. The lowest value recorded was 25.0 X 10^3CFU and highest value recorded was 27.0 X 10^3 CFU.

Table 9: Changes in bacterial population during the composting of leaf litters

Treatments	Changes in bacterial population (CFU x 10^5)				
	Initial	15th day	30th day	45th day	60th day
T_1	21.0	29.0	35.0	28.0	20.0
T_2	17.0	23.0	28.0	22.0	16.0
T_3	20.0	24.0	30.0	23.0	19.0
T_4	21.0	26.0	28.0	25.0	20.0
SED	1.58	1.39	0.40	3.67	4.02
CD	3.86	3.41	0.99	8.99	9.83

T_1 - *Neolamarkia cadamba* + FEM; T_2 - *Grewia tiliifolia* + FEM; T_3 - *Acrocarpus fraxinifolius* + FEM; T_4 - *Dalbergia sissoo* + FEM

Table 10: Changes in fungal population during the composting of leaf litters

Treatments	Changes in fungal population (CFU x 10^4)				
	Initial	15th day	30th day	45th day	60th day
T_1	19.0	32.0	49.0	43.0	31.0
T_2	25.0	38.0	56.0	52.0	31.0
T_3	19.0	29.0	42.0	48.0	28.0
T_4	24.0	37.0	53.0	48.0	26.0
SED	0.94	1.47	1.90	2.87	1.22
CD	2.30	3.60	4.65	7.04	2.99

T_1 - *Neolamarkia cadamba* + FEM; T_2 - *Grewia tiliifolia* + FEM; T_3 - *Acrocarpus fraxinifolius* + FEM; T_4 - *Dalbergia sissoo* + FEM

Table 11: Changes in actinomycetes population during the composting of leaf litters

Treatments	Changes in actinomycetes population (CFU x 10^3)				
	Initial	15th day	30th day	45th day	60th day
T_1	4.0	7.0	7.0	21.0	26.0
T_2	5.0	8.0	8.0	23.0	26.0
T_3	4.0	6.0	7.0	21.0	27.0
T_4	4.0	6.0	7.0	20.0	25.0
SED	0.78	0.94	1.63	1.02	0.40
CD	1.91	2.30	4.00	2.51	0.99

T_1 - *Neolamarkia cadamba* + FEM; T_2 - *Grewia tiliifolia* + FEM; T_3 - *Acrocarpus fraxinifolius* + FEM; T_4 - *Dalbergia sissoo* + FEM

A compost maturity test was conducted using green gram seeds. The seeds sown in 60 days old compost recorded 80 to 90 % germination whereas the germination percentage was 50 to 70 % in 15 days old compost. *Neolamarkia cadamba* and *Acrocarpus fraxinifolius* compost have shown the germination index as approximately equal to the control. As per Emeterio Iglesias Jimenez *et al*. (1950) [4], the germination index of >70% with compost extracts determined the maturity of compost (Table 12).

Table 12: Compost maturity test - germination study

Treatments	Changes in germination (%) of seedlings				
	Control (Soil)	15thday compost	30th day compost	45th day compost	60th day compost
T_1	100	70	80	90	90
T_2	90	60	70	80	80
T_3	90	50	70	80	90
T_4	80	50	50	60	80
SED	6.66	33.74	14.71	10.80	12.24
CD	16.31	82.58	36.01	26.43	29.96

T_1 - *Neolamarkia cadamba* + FEM; T_2 - *Grewia tiliifolia* + FEM; T_3 - *Acrocarpus fraxinifolius* + FEM; T_4 - *Dalbergia sissoo* + FEM

Conclusion

Initially the leaf litters were composted with the help of cow dung. It was not up to the satisfactory level and the time taken for decomposition was high. So conventional fruit based Effective Microorganisms (FEM) was prepared to enhance the composting process. *Neolamarkia cadamba* leaf litters were successfully composted in 45 days using fruit based Effective Microorganisms @ 3 liters/ton of litter. *Acrocarpus fraxinifolius* leaf litters were successfully composted in 60 days using fruit based Effective Microorganisms @ 3 liters/ton of litter.*Grewia tiliifolia* and *Dalbergia sissoo* requires additional days of composting. It requires further investigation, as the FEM (@ 3 liters/ton of litter) might not be sufficient for decomposition. It may need some specific lignolytic or cellulolytic microorganisms for decomposition.

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