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# EX-SITU DECOMPOSITION OF LEAF LITTERS OF TECTONA GRANDIS, EUCALYPTUS TERETICORNIS AND ALBIZIA FALCATARIA

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## ABSTRACT

Decomposition of leaf litters of *Tectona grandis, Eucalyptus tereticornis* and *Albizia falcataria* was studied using the mesh bag technique for a period of 18 months under field and laboratory conditions. The weight loss of litters under field condition was significantly higher than that under laboratory condition. The decay rate of the three litters also varied significantly under both laboratory and field conditions. There was positive correlation between loss in weight of litters, litter moisture content and rainfall; decomposition of all the litters was rapid during south-west monsoon.

In tne field, the dry weight loss of litters after 18 months was 95.7% for teak, 93.9% for *Albizia* and 63.7% for eucalypt. In the laboratory it was 91.9% for teak, 74% for *Albizia* and 59.7% for eucalypt. Teak leaf litter decomposed rapidly as compared to the others; decomposition of eucalypt litter was the slowest.

$CO_2$ evolution from decomposing litters differed significantly between the three species and it was significantly higher in the field than in the laboratory. $CO_2$ evolution was highest during south-west monsoon in all the three litters under both the incubation conditions.

During the study period, there was no significant addition of organic carbon to soil from decomposing teak, *Albizia* and eucalypt litters under laboratory conditions. The addition of OC to soil from eucalypt litter was relatively lower than that from the other two species. Significant differences were noticed between OC content of soils in the plantations of all the three tree species.

In general, the population of various microorganisms associated with the decomposing litters was significantly lower on eucalypt than that on teak and *Albizia.* There were significant differences between number of fungi per g of *Albizia* and eucalypt litters. The number of bacteria per g of *Albizia,* eucalypt and teak litters also differed significantly, irrespective of months or incubation conditions. The population of actinomycetes showed distinct differences between teak and eucalypt.

Among the fungi colonizing the different litters, the fungi imperfecti were predominant as they showed higher percentage distribution in comparison with others. The members of Zygomycetes and Ascomycetes were poorly represented and can be considered as weak colonizers.

It is concluded from the results of this study that 1) the leaf litter of eucalypt is relatively resistant to decomposition in comparison with those of teak and *Albizia*. 2) litter moisture content is crucial for the decomposition of leaf litters under tropical warm humid climate, 3) the rate of decomposition of litters and the microbial activity are higher in the field than in the laboratory, 4) the fungal succession on decaying litters reported here is similar to the general scheme of fungal succession on plant litters proposed by Hudson, and 5) the substrate quality is the major factor which determines the rate of leaf litter decomposition, $CO_2$ evolution, the density of microorganisms associated with the litters and also composition of their fungal floras.

# 1 INTRODUCTION

Litterfall is the primary mechanism for transfer of plant detritus from above-ground parts of forest trees to the soil surface. Decomposition of this detritus provides the main source of energy and nutrients for soil and litter organisms, and is a major pathway for the recycling of nutrients to the plant community (Charley and Richards, 1983). As the major source of a variety of organic matter, the amount and nature of litterfall has an important bearing on soil formation and maintenance of its fertility.

According to Swift *et a/.* (1979) the rates and pathways of litter decomposition are determined by the qualitative and quantitative composition of the decomposer community, their physical environment and the quality of the resources that animals and microorganisms are utilizing. The substrate quality includes not only the concentration and availability of nutrients, but also modifiers such as tannins which affect the activity of heterotrophs.

Slow rate of litter decomposition can result in the accumulation of large nutrient stocks in a soil's surface horizons and nutrient limitations for primary producers (Adams *et a/.,* 1970; Lamb, 1971). Studies on litter decay have indicated that nitrogen and lignin content of plant material are most important in controlling the rates of decomposition (Millar *et a/.,* 1936; Minderman, 1968; Fogel and Cromack, 1977; Meentemeyer, 1978). Decomposition of organic matter has received growing attention in recent years because of its role in nutrient cycling and in supporting saprophagic component of the forest ecosystem.

Intensive studies on litter dynamics in forest ecosystems have been carried out in many parts of the world especially in the temperate zones (Anderson, 1973; Fogel and Cromack. 1977; Meentemeyer, 1978; Bockheim and Leide, 1886; Escudero *et a/.,* 1987). But, only limited data on these aspects are available from tropical forest ecosystems. There is a dearth of information on the litter dynamics of indigenous as well as exotic tree species grown in plantations in India.

In plantations, tree growth is rapid and therefore nutrient demands are high. With short rotation crops on poor soils, soil nutrient depletion is a real possibility, especially in the moist tropics (Evans, 1982). Nutrient uptake and return through litter fall in forest plantations gain importance in this context.

The main objective of the present study was tQ determine the decay rate of leaf litters of three tree species, viz., *Eucalyptus tereticornis* Sm., *Albizia*

*falcataria* (L.) Fosberg.. and *Tectona grandis* L. which are raised in plantations in Kerala. An attempt has also been made to quantify the population of fungi, bacteria and actinomycetes on decomposing litters and also to estimate the addition of organic carbon to soil during the decomposition process. The decay rate and the $C0_2$ evolution from litters were determined under both field and laboratory conditions to make out the effect of different incubation conditions on litter decomposition.

## 2. MATERIALS AND METHODS

### 2.1. Study area

The study area is located in the Kerala Forest Research Institute Campus at Peechi (10° 32'N lat and 76° 32'E long). The area is characterised by tropical warm humid climate. The vegetation of the campus is a moist deciduous forest; the most common species being *Tectona grandis L., Xylia xylocarpa* (Roxb.) Taub., *Terminalia paniculata* Roth, *T. crenulata* Roth. *T. bellirica* (Gaertn.) Roxb., *Bombax ceiba* L. and *Bridelia retusa* (L.) Spreng. Mean annual rainfall is approximately 3000 mm. Atmospheric mean temperature varied from a monthly maximum of 29°C in July to 38.2°C in April and'monthly minimum of 21°C in January to 25.9°C in April during 1985-'86. The average relative humidity ranged between 42% in February and 100% in July. Three seasons are recognized, summer (January to mid May), south-west monsoon (mid May to August) and north-east monsoon (September to December). The wettest months are June, July and August.

### 2.2. Litter decomposition

Freshly fallen leaves of *Eucalyptus tereticornis. Albizia falcataria* and *Tectona grandis* (teak) were collected from respective plantations located at Kondazhi (6-yr-old), Vazhachal (10-yr-old) and Vallikayam (25-yr-old) between December 1984-March 1985. Soils were also collected from these plantations separately for litter decomposition studies. All leaves were air dried to constant moisture content. The litter decomposition studies were carried out using the mesh bag technique described by Bocock & Gilbert (1957).

2.2.1. *Laboratory experiment* :

In April 1985, 10 g of air dried leaf litter of each species were transferred separately in 9 cm diam nylon mesh bags- (mesh size 2 mm) and the

openings closed firmly by stitching. A total of 60 such bags were prepared for individual species. The litter bags were incubated over 500 g of plantation soil (of the respective species) taken separately in 19 x 8 cm plastic bowls kept in the laboratory. Control sets contained soils without litter bags. The litter and soil in each bowl were watered with 20 ml of deionized water periodically to maintain 60-70% water holding capacity.

2.2.2. *Field experiment* :

Three plots each of 6 x 1.5 m were selected at the same site in the Kerala Forest Research Institute Campus for conducting field studies on litter decomposition, Approximately 300 kg of soil collected from plantations of each of the three tree species, was spread evenly in the selected plots separately. Sixty litter bags (20x20 cm size, mesh size 2 mm) containing 20 g . of air dried leaf litter of individual tree species were prepared for *Albizia,* eucalypt and teak. During April 1985, these bags were spread randomly over the soil surface inseparate plots allotted to each species.

Sampling was done at monthly intervals between May 1985 and October 1985,the remaining bags being recovered during the months of December 1985 and June and October 1986. Three litter bags of each species were recovered at each sampling from the field and the laboratory. The litter samples were cleaned free of extraneous materials, oven dried at 60°C for 48 h and dry weight determined.

## 2.3. Determination of microbial activity ($C0_2$ evolution)

The rate of $C0_2$ evolution from the decomposing litters, both in the field and the laboratory was determined following the method described by Writkamp (1966b). A 500 ml beaker containing 10 ml of 0.5 N KOH was placed over the litter bag as the $CO_2$ absorbent. Cylindrical metal boxes (26 cm height, 18 cm diam) were used to cover the experimental set up. The lower ends of the metal cylinders were sunk 1.5 - 2.0 cm into the soil. After 4 hrs (10 am - 2 pm), the residual alkali was titrated against 0.1 N HCl using phenolphthalein as indicator and $CO_2$ evolution from litters then calculated. A set of three cylinders placed on the litter-free soil surface served as the control. The difference between the values for soil with the litters and litter-free soil gave the $CO_2$ evolution from the enclosed litter. From the weight of the litters covered by the metal cylinders, the amount of $CO_2$ evolved was converted into mg $CO_2$ g-1 oven dry litter h-1. The experiment was done in triplicate and $CO_2$ evolution determined at monthly intervals between May and October 1985 and thereafter during the months of December 1985, and June and October 1986.

## 2.4. Determination of organic carbon

To determine the organic carbon content of soils, 1 g sample each of treated as well as control soils were drawn at periodic intervals. Treated soils were those over which leaf litters of individual species were incubated in plastic bowls under laboratory condition. Controls Contained litter-free soils Three replicate samples were collected each time. The samples were analysed for OC content using Walkley and Black method outlined by Jackson (1973).

## 2.5. Isolation of microorganisms

The microorganisms viz.,fungi, bacteria and actinomycetes were isolated from the decomposing litters of each species at monthly intervals during May *to* October 1985 and thereafter during the months of December 1985 and June and October 1986. The first isolation was made from the freshly fallen litter. Subsequent samplings weremade from among the litter bags incubated under laboratory and field conditions. The dilution plate technique (Parkinson *et a/.*. 1971) was employed for the isolation of microorganisms. The litter was air dried, powdered in an ice cooled blender and 10 g was suspended separately in 100 ml. sterile water in 250 ml conical flasks. The suspension was shaken thoroughly and further diluted to $10^{-3}$ to $10^{-6}$. Dilution of $10^{-3}$,$10^{-4}$ and $10^{-5}$ were used to isolate fungi, actinomycetes and bacteria, respectively. One ml of the suspension was transferred separately to 5 replicate Petri dishes and 20 ml of the respective media for isolation poured in each. There were five replicate Petri dishes for each medium used. Potato-dextrose agar and Martins rose bengal agar were used to isolate fungi, Thornton's agar for bacteria and starch casein agar for actinomycetes. The fungal, bacterial and actinomycet.-ous colonies were counted after incubation at room temperature (28-32°C) for 7, 5 and 10 days respectively. From this data the average number of micro-organis μ s/g oven dry weight of titter was computed. Only the identification of fungi isolated from fitters in the fiefd was attempted.

## 2.6. Climatic data

The atmospheric temperature (maximum and minimum), relative humi-dity and soil temperature were recorded daily in the field and the laboratory. The moisture content of leaf titters was determined using the oven dry method. Rainfall data were collected from the meteorological department of the Kerala Engineering Research Institute, Peechi. The climatic data for Peechi are shown in Figs. 1 & 2.

## 2.7. Statistical analysis

The following exponential decay model was used to estimate the annual decomposition rate of litters.

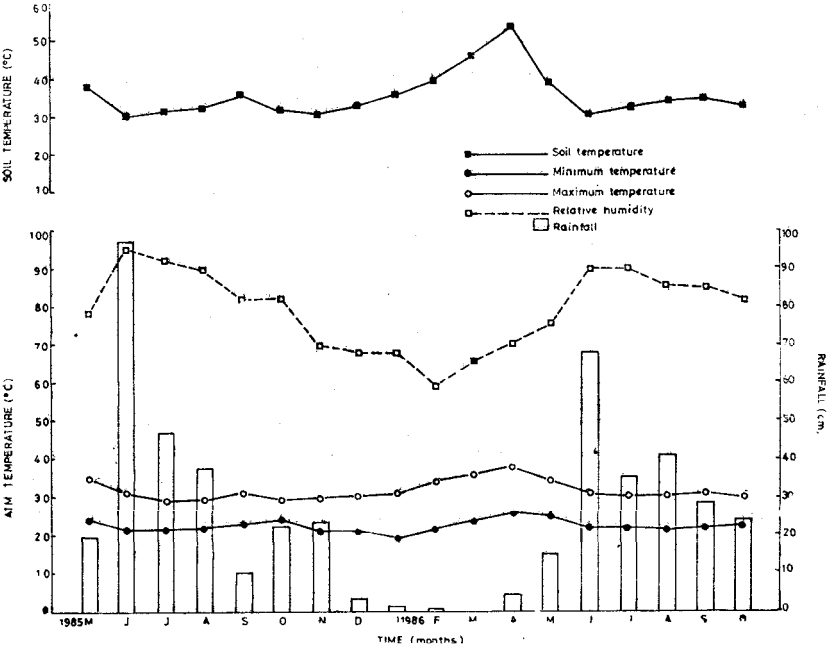


fig. 1. Climatic data (atmospheric temperature, relative humidity, rainfall and soil temperature) recorded at the study site.

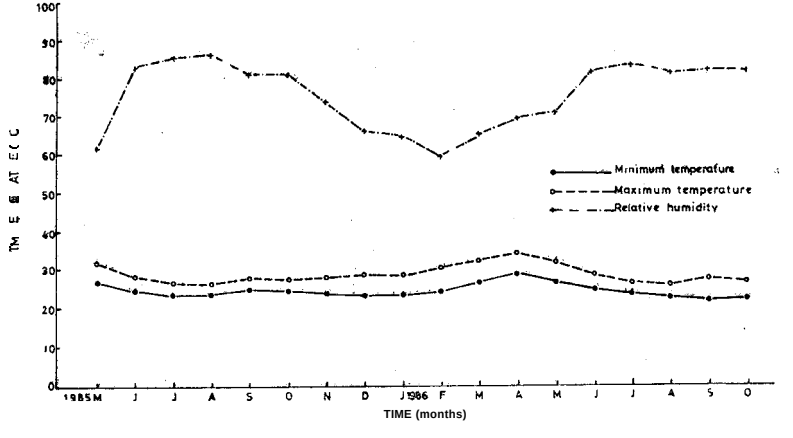


Fig. 2. Variations in ambient temperature and relative humidity in the laboratory during the study period.

$x/x^o = e^{-kt}$ (Olson, 1963)

where, 'x' is the weight of litter remaining after time 't', '$x^o$'is the initial weight of litter, 'e' is the base of natural logarithms and 'k', the decomposition rate constant. This exponential model was also used to calculate the half life of litter (time required for 50% loss of initial weight) and the time required for 95% weight loss. Statistical significance between rates of decomposition of different litters under field and laboratory conditions was assessed by the 't' test by comparing regression coefficients.

Correlation analysis was carried out to bring out the relation between loss in weight of litters and litter moisture content and other atmospheric and soil parameters. This analysis was also used to test the significance of correlation between $CO_2$ evolution and number of litter microorganisms and climatic factors.

Statistical significance of loss in weight of litters between months was tested by one way ANOVA. Three way ANOVA was used to examine the significance of difference in $CO_2$ evolution and number of microorganisms/g of litter between litters, incubation conditions and months. The differences in OC content of soils under different litters were analysed by 3 factor ANOVA.

# 3. RESULTS AND DISCUSSION

## 3.1. Litter decomposition

Dry weight loss of leaf litters due to decomposition after a period of 18 months (May 1985 to October 1986) under field and laboratory conditions is shown in Tables 1 & 2 and Figs. 4 & 5. Results in respect of each species are discussed separately.

### 3.1.1. *Albizia falcataria*

The weight loss of *Albizia* litter under field condition was 93.9% after 18 months, the highest being in June 1985 and lowest in October 1985. The mass loss was 43.7% (of the total weight loss) and 31.4% during south-west (SW) and north-east (NE) monsoons, respectively.

In the laboratory, 74% of *Albizia* litter decomposed during the same period. The maximum weight loss occurred in September 1985 and minimum in July 1985. The weight loss during SW monsoon was 37.3% and during NE monsoon

3.1.2. *Eucalyptus tereticornis*

Eucalypt leaf litter lost 63.7% of its initial weight in the field. The highest weight loss was recorded during June 1985 and lowest in September 1985. The mass loss during SW monsoon was 49.5% and during NE monsoon 17.3%.

The weight loss of eucalypt litter was 59.7% in the laboratory; it was maximum in August 1985 and minimum in September 1985. The weight loss was 27.3% and 9% during SW monsoon and NE monsoon, respectively.

3.1.3. *Tectona grandis*

Outdoors, 95.7% of the teak litter decomposed, with a peak in weight loss during June 1985. The lowest mass loss was recorded in October 1985. The weight loss during SW monsoon was 50.4% and during NE monsoon 25.4%.

In the laboratory, teak litter lost 91.9% of its initial weight. The highest and lowest values were recorded during August 1985 and September 1985, respectively. Dry weight loss during SW monsoon was 29.8% and during NE monsoon I0 4%.

The rate of decomposition of teak, *Albizia* and eucalypt leaf litters recorded during this study fits the exponential decay model proposed by Olson (1963), well. The $R^2$ values were highly significant ($P < 0.01$) in all cases both under field and laboratory conditions (Table 2). The predicted values of decomposition conform with the actual values The 'k' values (annual decomposition rate constant) were 1.67, 0.74 and 2.0 (field condition) and 0.97, 0.54 and 1.4 (laboratory), respectively for *Albizia.* eucalypt and teak litters (Table 2).

Table 1. Percentage weight loss of *Albizia,* eucalypt and teak leaf litters after different periods of incubation.

| S. NO. | Litter species | May 1985 | June | July | Aug. | Sept. | Oct. | Dec. | June 1986 | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|
| | FIELD | | | | | | | | | |
| 1 | *Albizia falcataria* | 5.2 | 20.8 | 36.0 | 41.0 | 47.4 | 48.9 | 70.5 | 76.7 | 93.9 |
| 2 | *Eucalyptus tereticornis* | 3.5 | 19.7 | 22.5 | 31.5 | 32.9 | 40.1 | 42.5 | 54.5 | 63.7 |
| 3 | *Tectona grandis* | 5.3 | 26.5 | 42.7 | 48.2 | 56.4 | 58.7 | 72.5 | 87.4 | 95.7 |
| | LABORATORY | | | | | | | | | |
| 1 | *Albizia falcataria* | 8.3 | 18.3 | 19.0 | 28.0 | 44.7 | 46.0 | 48.3 | 66.7 | 74.0 |
| 2 | *Eucalyptus tereticornis* | 1.7 | 5.3 | 8.0 | 16.3 | 17.0 | 18.7 | 21.7 | 45.0 | 59.7 |
| 3 | *Tectona grandis* | 1.7 | 10.4 | 14.0 | 27.4 | 28.6 | 30.0 | 37.0 | 81.4 | 91.9 |

Table 2. Dry weight loss and decomposition parameters of *Albizia,* eucalypt and teak leaf litters.

| S. No. | Litter species | Decomposition time (months) | Dry weight loss(%) | | Annual decomposition rate constant(k) | | Time required for decomposition (months) 50% (half life) ($t_{50}$) | | 95%(to95) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Field | Lab | Field | Lab | Field | Lab | Field | Lab |
| 1 | *Albizia falcataria* | 18 | 93.9 | 74.0 | 1.67 ($R^2$= 0.94)** | 0.97 ($R^2$= 0.96)** | 5.0 | 8.6 | 21.5 | 37.0 |
| 2 | *Eucalyptus tereticornis* | 18 | 63.7 | 59.7 | 0 7 4 ($R^2$= 0 96)** | 0.54 ($R^2$= 0 94)** | 11.2 | 15.5 | 48.5 | 66.7 |
| *3* | *Tectona grandis* | 18 | 95.7 | 91.9 | 2.0 ($R^2$= 0.97)** | 1.4 ($R^2$= 0.92)** | 4.2 | 5.9 | 18.0 | 25.7 |

** P<0.01

The half life of the leaf litters in the field was as follows: *Albizia.* 5 months; eucalypt, 11.2 months and teak, 4.2 months. The time required for 95% weight loss outdoors was estimated to be 21.5 months, 48.5 months and 18 months respectively for *Albizia.* eucalypt and teak.

The half life of these litters under laboratory condition was 8.6 months for *Albizia,* 15.5 months for eucalypt and 5.9 months for teak. The time required for 95% weight loss indoors was predicted to be 37 months for *Albizia.* 66.7 months for eucalypt and 25.7 months for teak (Table 2).

All the three species showed an initial rapid phase of decomposition followed by a slower phase. Relative loss rates were highest during SW monsoon, both indoors and outdoors. The statistical analysis showed that the decomposition rate of each species in the field was significantly higher than that in the ($P<0.01$) laboratory (Table 3). The decay rate of the three litters was also significantly different ($P < 0.01$) under both the incubation conditions (Table 3). There was also significant difference in weight loss ($P<0.01$) of the litters during different months. The F values were 22.1 *(Albizia)* 36.9 (eucalypt) and 11.2 (teak) under field condition and 6.7 *(Albizia)*

17.7 (eucalypt) and 41.7 (teak) under laboratory conditions. The loss in weight of litters outdoors was positively correlated with litter moisture content *(Albizia,* r=0.90, P<0.01; eucalypt, r=0.78, P<0.05; teak, r=0.87, P<0.01) and rainfall *(Albizia,* r=0.86, P<0.05; eucalypt, r = 0.85. P<0.05, teak, r=0.84, P<0.05). The weight loss indoors was also positively correlated with litter moisture content *(Albizia,* r=0.78, F<0.01; eucalypt, r =0.87. P<0.01; teak, r=0.97. P<0.01). However, no positive correlations were found between weight loss of litters and soil temperature, atmospheric humidity and atmospheric temperature.

The higher decomposition rate of litters in the field in comparison with that in the laboratory is evidently due to the differences in soil and atmospheric conditions. The litter moisture content, atmospheric temperature (maximum and minimum), soil temperature and relative humidity (Figs. 1.2 & 3) were always higher outdoors. Leaching of nutrients due to rainfall may have also accelerated the rate of decomposition in the field. Additionally, the activity of soil flora and fauna might have been higher on the litter kept for decomposition outdoors.

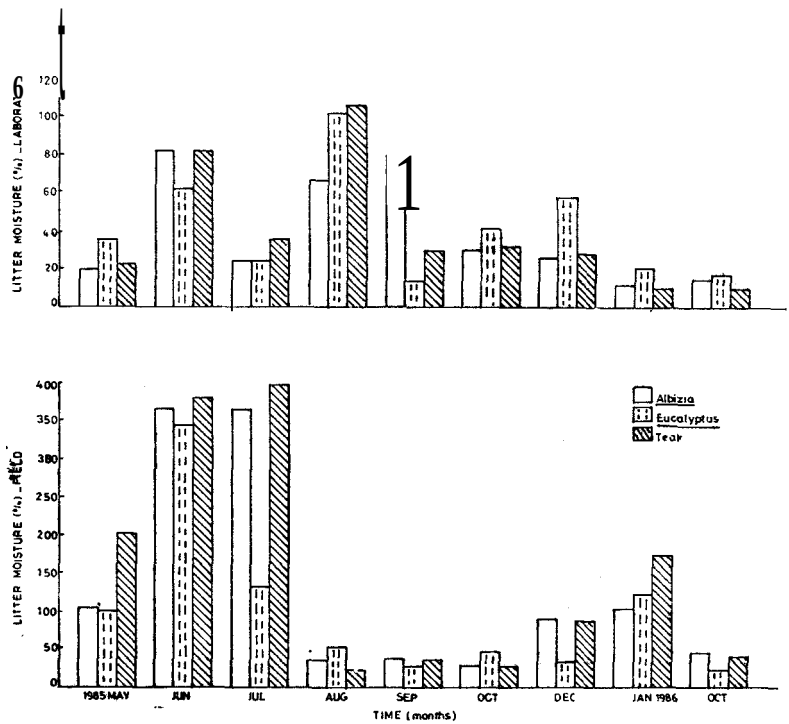


Fig. 3. Moisture content (%) of leaf litters under field and laboratory conditions.

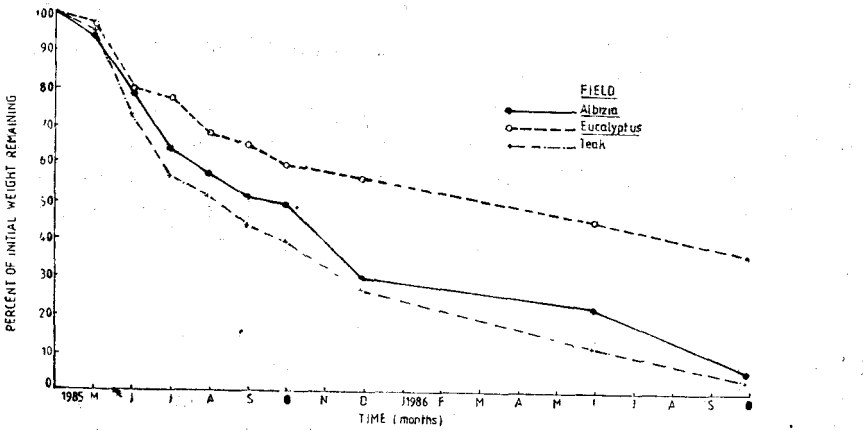


Fig. 4. Percentage of initial weight of *Albizia,* eucalypt and teak litters remaining after different periods of incubation (field).

Table 3. t-values for differences between the regression coefficients (litter decomposition)

| S. No. | Litter/Incubation conditions | t-values |
|---|---|---|
| | FIELD | |
| 1 | *Albizia* vs *Eucalyptus* | 6.743** |
| *2* | *Albizia* vs Teak | 2.843** |
| 3 | Teak vs *Eucalyptus* | 15.711** |
| | LABORATORY | |
| 1 | *Albizia* vs *Eucalyptus* | 13.458** |
| *2* | *Albizia* vs Teak | 4.686** |
| 3 | Teak vs *Eucalyptus* | 9.039** |
| | FIELD vs LABORATORY | |
| 1 | *Albizia* vs *Albizia* | 6.893** |
| 2 | *Eucalyptus* vs *Eucalyptus* | 4.575** |
| 3 | Teak vs Teak | 5.110** |

** P< 0.01

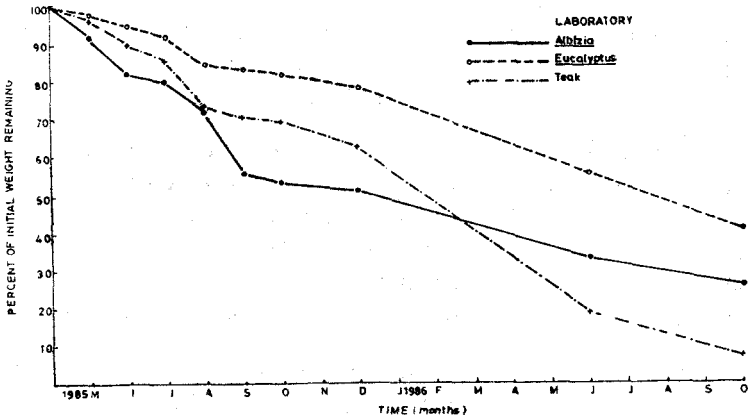


Fig. 5. Percentage of initial weight of *Albizia,* eucalypt and teak litters remaining after different periods of incubation (laboratory)

A sharp decline in weight of litters during the early stages of decomposition can be due to the initial high leaching of soluble chemical components and also due to the most favourable environmental conditions for decomposition (Singh 1969a. Anderson. 1973; Williams and Gray, 1974).

It is clear from the results that the rate of decomposition of teak leaf litter was faster both under field and laboratory conditions. when compared to litter from the other two tree species. Decomposition of eucalypt litter was the slowest. The decomposition rate of *Albizia* litter was slightly slower when compared to teak. The 'k' values of eucalypt litter were 0.74 (outdoors) and 0.54 (indoors) which are far less in comparison with those of *Albizia* (1.67, 0.97) and teak (2.0, 1.4) under similar conditions. The half life as well as the time required for 95% weight loss of eucalypt litter were comparatively much longer than the other two litters (Table 2). These observations show that eucalypt litter is relatively resistant to decomposition in comparison with teak and *Albizia* litters.

Swift *et a/,* (1979) suggested that the decomposition process is regulated by three groups of variables: I) the nature of the decomposer community, 2) the characteristics of the organic matter which determine its degradability (resource quality) and 3) the physico-chemical environment which operates at macroclimatic and edaphic or micro-scales. The decomposrates of all materials are governed by these variables though their relative importance can vary from site to site. Variations in the decay rate of leaf litters of different species under the same environmental conditions as reported in this study can be attributed to the differences in physical and chemical

characteristics of the litters as emphasised by Swift *et a/.* (1979). There are several reports on the differences in decay rates of detritus derived from diverse plant species (Melin, 1930; Bocock and Gilbert, 1957; Singh, 1969 a; Wiegert and McGinnis, 1975; Pandey and Singh, 1982).

Previous investigations carried out elsewhere have shown that in general, the rate of decomposition of eucalypt leaves is slower than that of many broad leaved species (Hatch, 1955; McColl, 1966, Wood, 1970, 1971). Soni (1985) reported that the decomposition rate of leaf litter of eucalypt was slower than that of teak and *Butea monosperma* (Lamk ) Taub. at Jabalpur. The present findings are in conformation with these observations.

Plant litters with high initial nitrogen content and low lignin are reported to decompose rapidly (Fogel and Cromack, 1977; Singh anb Gupta, .I977; Meentemeyer. 1978; Melillo *et a/.,* 1984). Data on nutrient content of E. *tereticornis* and *T. grandis* litters showed that the nitrogen and lignin content of these litters do not vary significantly (Singh, 1968; Singh, 1969 b: Singh, 1984; Singhal, 1986). So, the differences in decay rate between these two litters are not due to the variations in nitrogen and lignin content. However, no such comparison was possible for *Albizia* for want of data on nitrogen and lignin content in litter

It is possible that, the slow rate of decomposition of eucalypt litter is due to the presence of polyphenols like ellagic, chlorogenic and gallic acids and volatile terpenes in their leaves (de Moral and Muller, 1969). The presence of polyphenols in leaves is known to reduce decomposition rates of litters by inhibiting the microbial enzyme action (Benoit and Starkey, 1968, Williams and Gray, 1974). As the leaf litters with polyphenols are reported to be distasteful to the soil fauna, the mechanical breakdown of litters will also be affected (Jensen, 1974). Moreover, the leaves of eucalypts are hard textured and they have a waxy coating on the surface (Ramakrishnan, 1985). The physical properties of leaves such as toughness and particle size are also known to influence decomposition (Swift *et a/.* 1979). Detailed studies in this line are, however, warranted to ascertain the reasons for the low decomposability of eucalypt leaves.

Trees efficient in biological nitrogen fixation are known to have high initial N content and low C:N ratios (Sharma and Ambasht. 1987; Sandhu *et a/.,* 1990), As a tree legume, this statement may also be true for *A. falcataria.* But the decomposition rate of *Albizia* litter is found to be slower when compared to teak litter, in this study. This is quite interesting when we consider the differences in physical structure of the leaves of these two trees. Sandhu *et a/.* (1990) have reported that decomposition rate of leaf litters of *Leucaena leucocephala,* another tree legume, was slower than that of teak at Varanasi.

These observations are in accordance with the report that the decomposition rates of lignin of the nitrogen rich litters are significantly lower than those of nitrogen poor (Herman *et a/..* 1977: Berg *et a l .* 1982).

The 'k' value of *E. tereticornis* litter recorded in this study is lower than that recorded for *E. camaldulensis* (k=l.5) and *Eucalyptus* sp. (k—1.05) in Dhera Dun, India (Sharma and Pande. 1989; Bahuguna *et al.,* 1990). However, the dry weight loss of eucalypt litter reported here (63.70%, after 18 months) is much higher than that of other *Eucalyptus* spp., recorded in Australia (Table 4).

Table 4 Comparison of decomposition rate of *Eucalyptus tereticornis* leaf litter in the present study with the data collected from the literature

| Tree species | Decomposition time (months) | Dryweight loss(%) | Locality | Reference |
|---|---|---|---|---|
| *Eucalyptus marginata* Donn exSm. | 12 | 38 | Australia | Hatch, 1955 |
| *E. maculata* Hook | 12 | 36 | Australia | McColl, 1966 |
| *E. regnans* F. Muell. | 12 | 26-45 | Australia | Ashton. 1975 |
| *E. pauciflora* Sieb. ex Spreng. | 12 | 46-53 | Australia | Macauley, 1975 |
| *E. diversicolor* F. Muell. | 18 | 50 | Australia | O'Connell, 1981 |
| *E. marginata* | 18 | 44 | Australia | O'Connell & Menage, 1983 |
| *E. calophylla* R. Br. ex Lindl. | 18 | 39.9 | Australia | O'Connell & Menage, 1983 |
| *E. delegatensis* R. T. Baker | 22 | 45 | Australia | Woods & Raison, 1983 |
| *E. pauciflora* | 22 | 42 | Australia | Woods & Raison, 1983 |
| *E. obliqua* L'Herit | 12 | 30 | Australia | Baker & Attiwill.1985 |
| *E. camaldulensis* Dehnh. | 12 | 82 | India | Bahuguna *et al.,* 1990 |
| *E. tereticornis* Sm. | 18 | 63.7 | India | Present study |

The weight loss of teak litter recorded here(95.7% after 18 months) is comparable to the weight loss of teak litter (90% after 12 months) reported by Singh and Ambasht (1 980) from Varanasi. The 'k' value (2) is also close to the 'k' value for teak litter (2 3) reported by Singh (1978). The annual weight loss of teak litter in Thailand and Nigeria is reported to be 95% and 100% respectively (Aksornkoae *et al..* 1972; Egunjobi, 1974).

According to Olson (1963). the decomposition parameter 'k' for tropical forests ranges slightly more than one to slightly more than four in any given stand. The 'k' values in respect of teak and *Albizia* titters recorded in the present study are within this range.

The loss in weight of leaf litters was always high during SW monsoon, the peak being in June 1985 under field conditions. This is indicative of favourable conditions for decomposition like high litter and soil moisture, high relative humidity and congenial atmospheric temperature. The atmospheric humidity ranged between 79-100% during SW monsoon and the highest rainfall was recorded during this period. The litter; moisture content was maximum for all the litters during this season. These conditions favour high microbial activity resulting in very rapid decomposition of litters. The high rate of decomposition during rainy season in tropical conditions has been reported by several workers (Singh *et a/.*,1979, 1980; Pandeyand Singh, 1982). According to Meentemeyer (1978) the two most important factors controlling litter decomposition are probably the prevailing climatic 'environment and substrate quality. Among climatic variables, rainfall and temperature have been found to be of major importance (Witkamp, 1966a; Singh and Gupta, 1977).

Indoors, the highest weight loss occurred during August 1985 and lowest during September 1985 in the case of eucalypt and teak litters. This again was related with high and low moisture content in litters. In correlation analysis, the weight loss of litter was positively correlated with litter moisture and rainfall under field conditions and litter moisture under laboratory conditions. The influence of litter/soil moisture on litter breakdown has been stressed by several workers (Witkamp and Van der Drift, 1961 ; Witkamp, 1963: Nagy and Macauley, 1982; Orsborne and Macauley 1988; Das and Ramakrishnan, 1985). According to Van der Drift (1963) moisture is more important than temperature in litter decomposition. Pandey and Singh (1982) reported positive correlation between decomposition rates and rainfall in an oak-conifer forest in Kumaun Himalaya.

The low soil and litter moisture and low relative humity might have been the major reasons for low rate of decomposition of litters during NE monsoon and summer.

The rate of decomposition of leaf litters was significantly influenced by variation in litter moisture during the different months in this study. The atmospheric temperature did not show apparent effect and its influence may be through changes in litter moisture. The results of the present study confirm observations of Madge (1965) that moisture is often a limiting factor for breakdown of angiosperm tree litter in the tropical forests.

### 3.2. $CO_2$ evolution from decomposing leaf litters

The carbon dioxide evolution from decomposing leaf litters during different months is shown in Figs. 6 and 7.

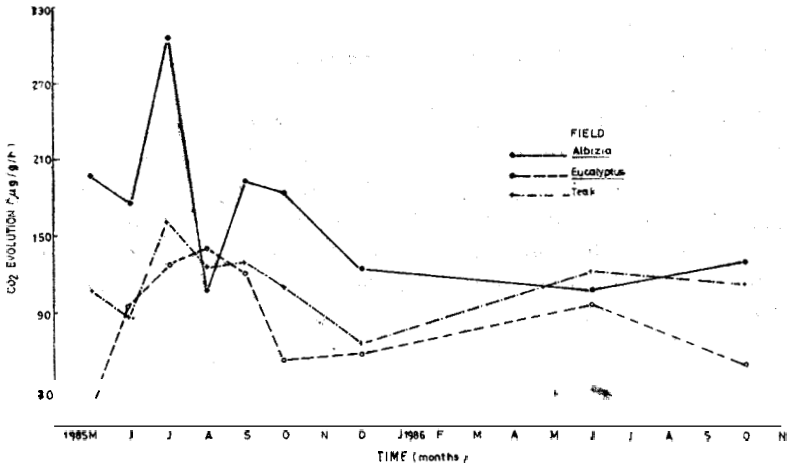


Fig. 6. Monthly variation in $CO_2$ evolution from leaf litters under field conditions.

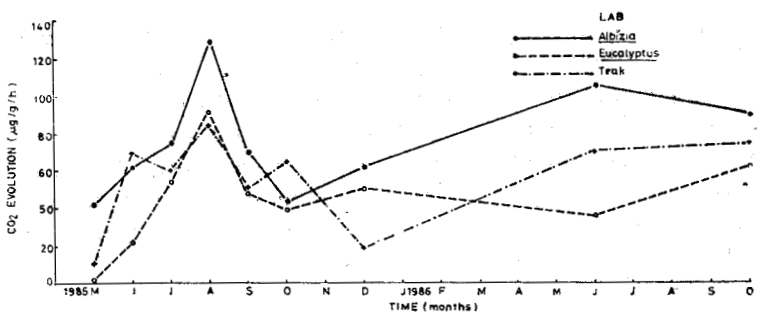


Fig. 7. Monthly variation in $CO_2$ evolution from leaf litters under laboratory conditions.

#### 3.2.1. Field

$CO_2$ evolution ranged between 107.7 to 304.7 µg/g/h, in *Albizia.* 66.0 to 159.7µg/g/h in teak and 21.0 to 137.1 µg/g/h in eucalypt litter during different periods of observation. The maximum evolution of $CO_2$ was recorded during July 1985 in *Albizia* and teak and during August 1985 in eucalypt; the minimum being during June 1986. December 1985 and May 1985 in *Albizia.* teak and eucalypt litters, respectively.

3.2.2. *Laboratory*

In the laboratory, $CO_2$ evolution varied between 44.3 to 129.7μ g/g/h in *Albizia,* 13.9 to 87.4 μ g/g/h in teak and 2.3 to 91.7 μ g/g/h in eucalypt during the same period. The $CO_2$ evolution was maximum during August 1985 and minimum during May 1985 in all the three species.

The microbial activity (in terms of $CO_2$ evolution) was highest in *Albizia* and lowest in eucalypt during most of the months, especially in the initial stages of decomposition. under both the incubation conditions. The $CO_2$ evolution was relatively low during the first month of litter decay in the laboratory. This was true for teak and eucalypt litters in the field also. In all cases, the highest microbial activity was recorded during SW monsoon, both in the laboratory and the field.

Statistical analysis of the results showed that there is significant difference in $CO_2$ evolution between individual litters incubated both in the field and the laboratory ($P < 0.01$). The $CO_2$ evolution was significantly higher under field condition in all cases ($P < 0.01$). There was also significant difference ($P < 0.01$) in microbial activity during different months.

It is evident from the results of this study that the microbial activity in decomposing litters in the field varied significantly from those incubated in the laboratory. These differences in $CO_2$ evolution were expected as the atmospheric conditions (especially atmospheric temperature and relative humidity), soilfremperature and litter moisture content varied between these two conditions (Figs. 1-3). The decomposition rate of litters was also significantly different between field and laboratory conditions. Temperature and moisture are considered to be two major environmental factors governing microbial respiration (Williams and Gray, 1974; Singh and Gupta., 1977).

The $CO_2$ evolution was highest in decomposing *Albizia* litter and lowest in eucalypt especially during the initial stages of decomposition. This variation in microbial activity between litters may be attributed to the differences in physical and chemical characteristics of the litters, which are known to affect decomposition rates (Swift *et a/.,* 1979). Singh (1969a) also observed significant difference in $CO_2$ evolution from litters derived from diverse plant species at Varanasi. According to Olson and Crossley (1963) and Witkamp (1966b) the differences in decomposability between different litter species are most prominerit during the initial stages of decomposition and the species influence decreases with progressing decay and increasing contact with the soil fauna. The low rate of microbial activity in eucalypt litter in comparison

with *Albizia* and teak might be due to the presence of polyphenols in eucalypt leaves. The hard texture of the leaves may have also offered resistance to microbial activity.

Freshly fallen litters, in general, are known to harbour a distinct microbial population, but their activity is stated to be more or less arrested until the onset of favourable climatic conditions (Williams and Gray, 1974). This was probably why the microbial activity was relatively low during the initial stages of decomposition.

The peaks in $CO_2$ evolution were observed when the litter moisture content (Fig. 3) was maximum in *Albizia* and teak in the field and in eucalypt and teak in the laboratory. This high rate reflects the favourable effect of substrate moisture content on microbial activity. The positive influence of litter/soil moisture on the rate of microbial activity was reported by several workers (Singh, 1969a; Edwards, 1975; Singh and Gupta, 1977; Sinha and Dayai, 1983; Das and Ramakrishnan, 1985). Wiant (1967) has shown a curvilinear increase in $CO_2$ production with increasing moisture content under laboratory conditions. The variation in moisture content of litter recorded in this study was brought about by the onset of SW monsoon.

The results of this study show that the physical and chemical characteristics of the litters and the atmospheric conditions are the two major factors governing $CO_2$ evolution from decomposing litters.

Table 5. Organic carbon (%) in soils under *Albizia,* eucalypt and teak litters during different periods of observation.

| | | *Albizia* | | *Eucalyptus* | | Teak | |
|---|---|---|---|---|---|---|---|
| | Months | Control | Treated | Control | Treated | Control | Treated |
| 1 | May 1985 | 1.45 | 1.65 | I.49 | 1.56 | 2.26 | 2.36 |
| 2 | June | 1.41 | 1.53 | 1.52 | 1.57 | 2.20 | 2.35 |
| 3 | July | 1.42 | 1.56 | 1.57 | 1.62 | 2.18 | 2.30 |
| 4 | August | 1.43 | 1.59 | 1.55 | 1.61 | 2.23 | 2.33 |
| 5 | September | 1.42 | 1.62 | 1.52 | 1.60 | 2.22 | 2.40 |
| 6 | October | 1.48 | 1.63 | 1.53 | 1.63 | 2.23 | 2.34 |
| 7 | December | 1.49 | 1.83 | 1.54 | 1.82 | 2.20 | 2.60 |
| 8 | October 1986 | 1.48 | 1.56 | 1.51 | 1.55 | 2.23 | 2.31 |

### 3.3. Organic carbon content of soil

Organic carbon (OC) values of soils under decomposing *Albizia,* eucalypt and teak litters during different periods of observation are provided in Table 5. The OC content of soils ranged between 1.53 to 1.83% for *Albizia,* 1.55 to 1.82% for eucalypt and 2.3 to 2.6% for teak during the study period. The highest values were recorded during December 1985 in all the treatments. The OC values of control soils ranged between 1.41 to 1.49%, 1.49 to 1.57% and 2.18 to 2.26% for *Albizia,* eucalypt and teak litters, respectively. In statistical analysis, significant differences were recorded between OC content of soils holding different litters ($P<0.05$). However, no significant differences were noticed between the OC content of control soils and soils under different litters. There was no significant difference in the addition of organic carbon during different stages of decomposition.

The OC content of soils under the three litters recorded during this study broadly agrees with earlier reports on OC content of soils in *Albizia,* eucalypt and teak plantations in Kerala, (Alexander *et.a/.,* 1981a b; Balagopalan and Jose, 1986). However, the OC content of soils in *Albizia* plantations reported by Balagopalan (1989) is much higher than that reported here. The variations in OC content of soils, under various litters was expected as these soils were collected from plantations of the respective species located in diverse areas.

The OC content of treated soils was always higher than the controls. The increase ranged between 0.08 to 0.34% for *Albizia,* 0.04 to *0* 28% for eucalypt and 0.08 to 0.4% For teak during different periods of observation. Though these differences were not significant statistically, it may be noted that the addition of OC to soil from eucalypt litter was relatively lower than that from the other two litters.

### 3.4. Microflora of leaf litters

3.4.1. *Quantitative features*

The number of various microorganisms per g of different litters recorded during the study period is presented in Figs. 8-10.

a. *Field*

*i. Fungi*

The number of fungi/g of litter ranged between 1.4 to 88 2 x $10^5$, 0.6 to 27.1 x $10^5$ and 1.7 to 116.3 x $10^5$, respectively in *Albizia,* eucalypt and teak during different periods of observation (Fig. 8). The fungal population was highest during July 1985 and lowest during June 1986 in *Albizia* and teak. In eucalypt, the highest counts were recorded during August 1985 and lowest

during December 1985. There was a slgnificant reduction in the number of fungi during June 1985.

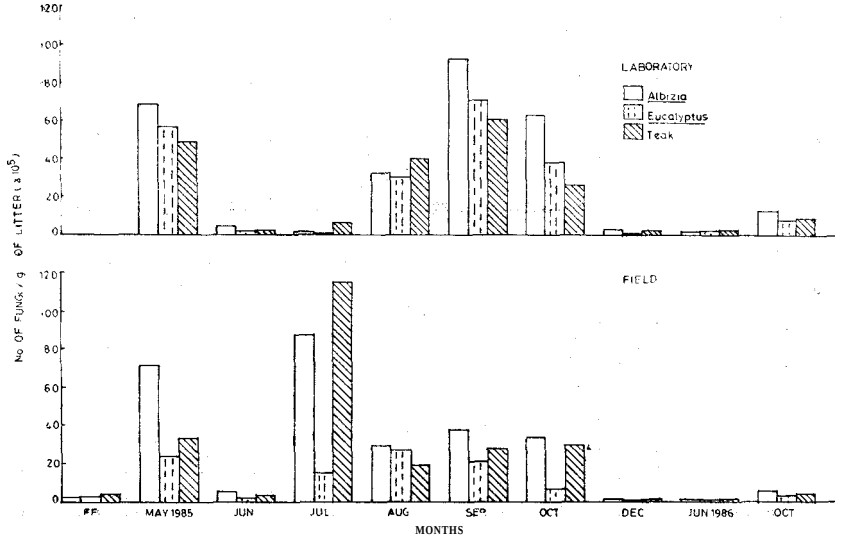


Fig. 8. Variation in population of fungi on leaf litters under field and laboratory conditions during different months.

*ii. Bacteria*

The count of bacteria varied between 2 8 to 66.8 x $10^7$ in *Albizia,* 0.6 to 12.8 x $10^7$ in eucatypt and 3.6 to 93.2 x $10^7$ in teak litters during the study period (Fig 9). The bacterial population was highest during June 1985 in all the litters. The lowest population was noticed during June 1986, October 1986 and September 1985 in *Albizia,* teak and eucalypt, respectively,

*iii. Actinomycetes*

The number of actinomycetes/g of litter ranged between 0.3 to 46x$10^6$, 0.2 to 6.9 x $10^6$, and 0 4 to 76.2 x $10^6$ in *Albizia,* eucalypt and teak (Fig. 10). The peak in actinomycete population was recorded during September 1985 in all the three litters. The counts were minimum during October 1986 in *Albizia* and teak and during July 1985 in eucalypt. The number of actinomycetes showed a sudden decrease after attaining a peak. The population of actino-rnycetes was comparatively low throughout the period of decomposition except in May and September 1985.

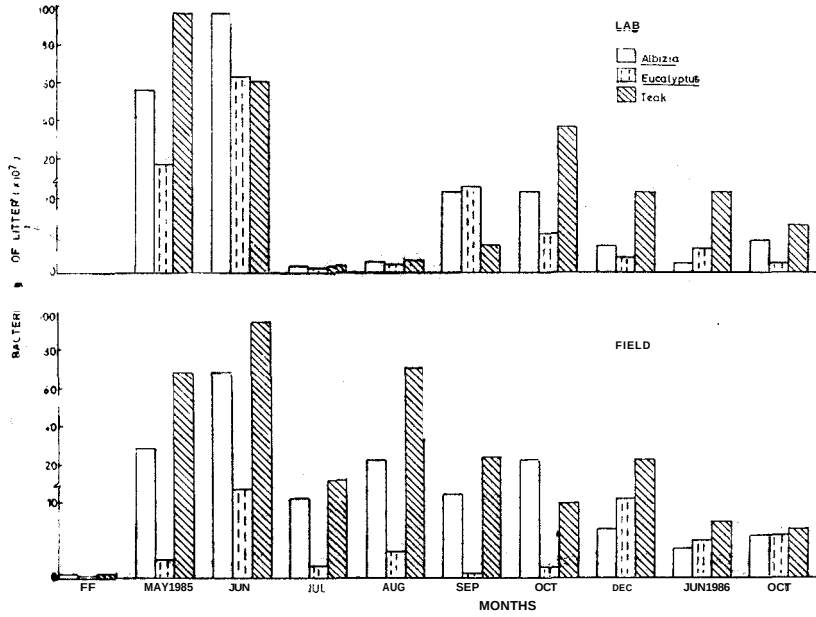


Fig. 9. Variation in population of bacteria on leaf litters under field and laboratory conditions during differeht months.

***b. Laboratory***

***i. Fungi***

The number of fungi/g of litter varied between 1.7 to 93.2 x $10^5$ in *Albizia,* 0.8 to 68.8 x $10^5$ in eucalypt and 1.9 to 98.7 x $10^5$ in teak (Fig. 8). The count was maximum during September 1985 in all the cases; the minimum being during July 1985 in *Albizia* and eucalypt and during December 1985 in teak.

***ii. Bacteria***

The bacterial population ranged between 0.7 to 96.3 x $10^7$ in *Albizia,* 0.3 to 61.8 x $10^7$ in eucalypt and 0.2 to 59.8 x $10^7$ in teak (Fig. 9). The number of bacteria was highest during June 1985 in *Albizia* and eucalypt and during May 1985 in teak. The counts were lowest in July 1985 in all the litters.

***iii. Actinomycetes***

The count of actinomycetes varied between 0.7 to 80.5 x $10^6$. 0.4 to 93.3 x $10^6$ and 0.2 to 105.4 x 106, respectively in *Albizia,* eucalypt and teak

litters (Fig. 10). The highest numbers were recorded during September 1985 and the lowest during July 1985 in all the three litters.

There was a rapid increase in the number of various microorganisms on litters during the first month of decay (May 1985) when compared with that on freshly fallen titters. This increase was however, not very pronounced on eucalypt litter. Peaks in the population of fungi and bacteria on litters in the field were noticed during SW monsoon. The numbers were lowest either during the NE monsoon or during the advanced stages of decomposition.

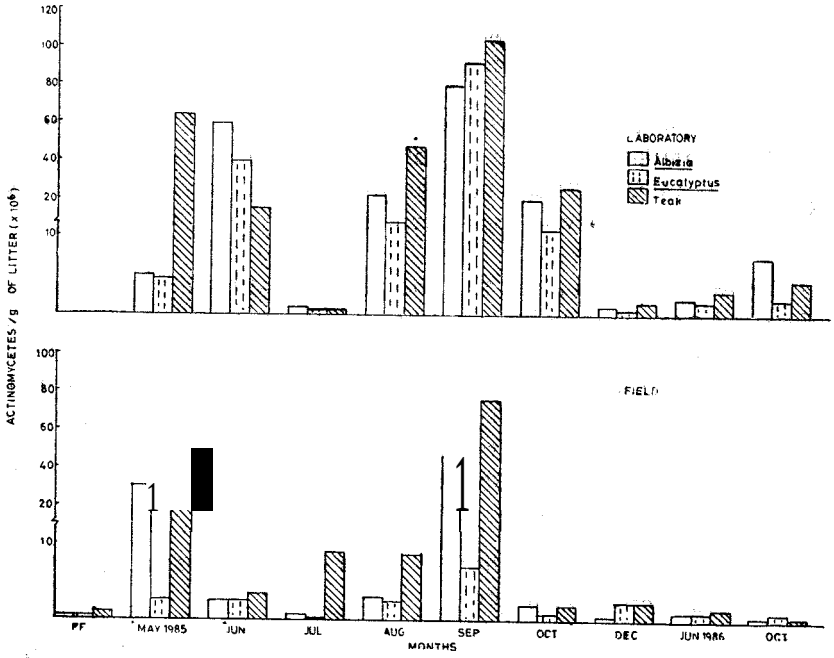


Fig. 10. Variation in population of actinomycetes on leaf litters under field and laboratory conditions during different months.

The statistical analysis *of* the data showed significant differences in the number of fungi/g of *Albizia* and eucalypt litters irrespective of rnonths or incubation conditions. ($P < 0.05$). The number of fungi also varied significantly between months irrespective of incubation conditions ($F=l4.61$ ,$P<0.01$). No significant differences in population of fungi could be observed between *Albizia* and teak, teak and eucalypt and also between laboratory and field conditions.

In the case of bacterial population, the differences in counts were significant between *Albizia* and eucalypt ($P<0.05$). and teak and eucalypt litters

($P < 0.05$) irrespective of months or incubation conditions (Table 6). The number of bacteria/g of teak and *Albizia* litters did not vary significantly. Significant difference was also noticed in the number of bacteria colonizing litters during different months, irrespective of incubation conditions ($F=l3.83$, $P < 0.01$). However, the population of bacteria on various litters showed no significant variation between incubation conditions.

With regard to the number of actinomycetes, the differences were significant between teak and eucalypt litters ($P < 0.05$). irrespective of the months or incubation conditions. The number of actinomycetes varied significantly between months ($F=20.29$, $P < 0.01$) and incubation conditions ($F=20.25$, $P<0.01$). No significant differences were recorded in the number of actinomycetes between *Albizia* and eucalypt, and teak and *Albizia* litters.

In correlation analysis positive correlation was noticed between $CO_2$ evolution and population of fungi colonizing *Albizia* ($r=0.78$; $P<0.05$) and teak ($r=0.87$, $P < 0.05$) litters in the field. However, the population of bacteria and actinomycets was not positively correlated with $CO_2$ evolution.

It is now well established that the decomposition of plant litter on the soil surface is brought about by a variety of microorganisms including bacteria, fungi and actinomycetes (Jensen, 1974; Swift *et a/.,* 1979). Among these microbes, fungi are recognised to be the chief colonizers and decomposers (Hudson, 1968; Hayes, 1979). The bacteria are known to act only as secondary decomposers and the role of actinomycetes is described to be limited (Gyllenberg and Eklund, 1974; Goodfellow and Cross, 1974).

Table 6. Mean value of population of microorganisms isolated from *Albizia* eucalypt and teak litters.

| S. No. | Species | No. of microorganisms/g of litter | | |
|---|---|---|---|---|
| | | Fungi | Bacteria | Actinomycetes |
| 1 | *Albizia falcataria* | $314.89^{a*}$ | $204.38^{a}$ | $160.24^{ab}$ |
| 2 | *Eucalyptus rereticornis* | $174.73^{b}$ | $83.06^{b}$ | $105\ 70^{a}$ |
| 3 | *Tectona grandis* | $242.07^{ab}$ | $303.98^{a}$ | $242.61^{b}$ |

* Figures superscribed by the same letter are not significantly different at 5% level.

The results of the present study showed that the population of bacteria. fungi and actinomycetes colonizing decomposing litters vary significantly between the litter species. Eucalypt litter harboured lesser number of bacteria when compared with the other two. The number of fungi on eucalypt was lower than that on *Albizia* and actinomycetes lower than that on teak. The absolute and relative differences in the counts of microorganisms of the various litter species reflected the predominant influence of substrate composition on the microflora (Witkamp, 1963).

Witkamp (1963, 1966a) who compared the number of bacteria in leaf litter from different tree species observed that the dominant factor controlling the bacterial density was tree species; more easily decomposable litter species with low C:N ratios harboured higher number of bacteria than did more resistant species especially in freshly fallen litter. The results of the present study are in agreement with these findings.

The population of bacteria showed a rapid increase during the initial stage of decomposition both in the field and the laboratory. This was also true in the case of population of fungi on litters in the field. The number of these organisms decreased after the peak, when the process of decomposition progressed. The initial rapid increase in number of bacteria and fungi on decomposing litters was reported by several workers (Gray *et a/.,* 1974, Jensen, 1974; Rai and Srivastava. 1982). This is evidently due to the availability of large amount of nutrients from fresh litters. The less favourable climatic conditions and a gradual depletion in nutrients in the decomposing litters might have caused the decrease in microbial population during the NE monsoon and during the advanced stages of decomposition.

The variation in number of microorganisms during different months may be attributed to the differences in atmospheric conditions and litter moisture content. The increase in number of bacteria and fungi on litters in the field during SW monsoon is probably due to the congenial atmospheric and soil conditions, and the increased moisture content of leaf litters during this season (Witkamp, 1963; Rai and Srivastava, 1982; Sinha and Dayal. 1983). The bacterial and fungal population is known to respond to improved moisture conditions on litters (Jensen, 1974; Alexander, 1977). The sharp reduction in the number of fungi during June 1985 under field and laboratory conditions rnay be due to the high competition for substrate by bacteria which showed a peak in population during this month under both the incubation conditions.

With regard to actinomycetes, the maximum population was observed during September 1985 both in the field and the laboratory. The low population of actinomycetes during the other months may be due to their feeble competitive ability. They are known to become prominent on decomposing

organic matter only when the nutrients become limiting and the pressure of the more effective competitors like bacteria and fungi diminishes (Alexander.1977).

The number of fungi and bacteria per g of field and laboratory incubated litters did not differ significantly, in this study. This shows that favourable conditions for the proliferation of these organisms existed under both the situations and that they can adapt well to such major variations in climatic conditions.

The maximum evolution of $CO_2$ corresponded with an increase in number of fungi/g of *Albizia* and teak litter under field conditions. This shows that the higher microbial activity recorded during this period was due to the increased activity of fungi on litter. Dwivedi and Shukla (1977), Rai and Srivastava (1981, 1982) and Dhkar and Mishra (1987) have also reported the positive correlation between the number of fungi/g of soil/litter and microbial activity in soil/litters.

3.4.2. *Qualitative features*

A total of 44 genera of fungi were isolated from the decomposing leaf litters, which included 6 genera of Zygomycetes, 3 of Ascomycetes and 35 (79.57") belonging to fungi imperfecti. Two genera of basidiomycetes were also identified. Among the rest of the isolates, a few were unidentified and others sterile forms. Eighteen genera (41%) were common to all the three litters. The relative abundance (%) of various fungi isolated from the litters is given in Tables 7-9.

i) Fungal flora of *Albizia* litter (Table 7)

The fungi isolated from *Albizia* litter belonged to 26 genera. Of these, the fungi imperfecti were represented by 20 genera (77%); Zygomycetes by 5 (19%) and Ascomycetes by one genus. A basidiomycete, which produced fruiting bodies on the litter during July and October 1985 was identified as *Collybia leucophaea* (Berk. & Br.) Sacc.

The dominant primary colonizers of the litter were *Penicillium* spp.. *Aspergillus* spp., *Robillarda sessilis* and *Doliomyces mysorensis. Aspergillus niger,* which could be isolated on all the occasions of sampling. except from the freshly fallen litter, was the most frequent and dominant fungus. The relative abundance or *A. niger* was highest during SW monsoon. *Penicillium* was the most predominant fungus on freshly fallen litter. The population of Penicillia decreased during the course of decomposition. *Aspergillus flavus, Aspergillus* spp.. *Curvularia lunata. Doliomyces mysorensis. Fusarium* spp., *Robillarda* spp. and *Trichoderma viride* were the most frequent and dominant secondary colonizers. The members of the Zygomycetes mostly appeared at the advanced stages of decomposition.

Table 7. Relative abundance (%) of fungi isolated from the leaf litter of *Albizia falcataria* during different months (field).

| Sl. No. | Fungi | ff* | May '85 | June | July | Aug. | Sept. | Oct. | Dec. | June '86 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *Absidia cylindrospora* Hagem | 0.5 | | | | | | | 0.1 | |
| 2 | *Acremonium* sp. | | | | 0.4 | 0.8 | | | | |
| 3 | *Alternaria* sp. | | | 0.6 | 2.2 | | | | | |
| 4 | *Aspergillus flavus* Link | | 1.0 | 0.4 | 0.9 | 1.6 | 3.6 | 0.7 | 0.3 | |
| 5 | *A. niger Van Tieghem* | | 6.4 | 51.5 | 29.4 | 35.5 | 19.4 | 4.8 | 1.3 | 28.7 |
| 6 | *Aspergillus* spp. | 1.5 | 16.2 | 8.8 | 2.2 | | 0.8 | 13.3 | 37.3 | 25.0 |
| 7 | *Bartalinia robillardoides* Tassi | | | | | | | | 56.7 | |
| 8 | *Bipolaris spicifera* (Bainier) Subram. | | | | | | | | | 0.6 |
| 9 | *Chaetomella raphigera* Swift | | | | | | | | | 3.5 |
| 10 | *Chaetomium globosum* Kunze ex Steud | 0.8 | | | | | | | | |
| 11 | *Cladosporium cladosporioides* (Fresen) de Vries | | 0.3 | | 2.6 | | | | | |
| 12 | C. *oxysporum* Berk. & Curt. | | | | 1.7 | | | | | |
| 13 | *Cunninghamella bertholletiae* Stadel | | | | | | | | | 0.2 |
| 14 | *Curvularia eragrostidis* (P. Henn) JA Meyer | | | | | | | | | 0.4 |
| 15 | *C. lunata* (Wakker) Boedijn | | 0.1 | 1.4 | 0.4 | | 0.6 | 0.1 | 0.1 | 0.8 |
| 16 | C. *senegalensis* (Speg.) Subram. | | | | 0.4 | | | | | |
| 17 | *Doliomycs mysorensis* Nagraj & Kendrick | 7.9 | 56.1 | | 23.4 | | | 20.8 | | 0.4 |
| 18 | *Fusarium oxysporum* Schlecht. | | | | *0.8* | | | | | |

* freshly fallen Litter

| Sl. No. | Fungi | ff* | May '85 | June | July | Aug. | Sept. | Oct. | Dec. | June '86 |
|---|---|---|---|---|---|---|---|---|---|---|
| 19 | *F. solani* (Mart.) Sacc. | 0.7 | | | | | 12.5 | 1.3 | | |
| 20 | *Fusarium* spp. | | 5.4 | 0.4 | 7.8 | 22.0 | | 0.7 | 2.5 | 16.2 |
| 21 | *Monodictys levis* (Wiltshire) Hughes | | | | | 0.4 | | | | |
| 22 | *Mucor* spp. | | | 0.6 | | | | | | |
| 23 | *Myrothecium cinctum* (Corda) Sacc. | | | | | | | **0.4** | | |
| 24 | *Myrothecium* spp. | 0.2 | | | | | | | | |
| 25 | *Penicillium* spp. | 61.4 | 6.1 | 14.1 | | , 0.8 | 1.1 | | 0.1 | 2.3 |
| 26 | *Pestalotiopsis* sp. | | | | 1.7 | | | | | |
| 27 | *Phoma* sp. | | | | | | | 0.1 | | 0.4 |
| 28 | *Pyrenochaeta* sp. | | 0.1 | | | | | | | |
| 29 | *Rhizopus oryzae* Went & Geerligs | | | | | | 1.9 | | 0.1 | |
| 30 | *Rhizopus* sp. | | 0.2 | | | | | | | 0.4 |
| 31 | *Robillarda sessilis* (Sacc.) Sacc. | 10.7 | | | | | 35.9 | | | |
| 32 | *Robillarda* sp. | | 7.4 | 17.3 | 19.0 | | | 57.4 | | 1.0 |
| 33 | *Scytalidium lignicola* Pesante | *0.2* | | | | | | | | |
| 34 | *Syncephalastrum racemosum* Cohn ex Schrot. | 0.2 | | 1 | | | | | | |
| 35 | *Trichoderrna viride* Pers. ex Gray | 0.5 | 0.5 | 2.8 | 6.5 | 21.6 | 9.7 | | | 0.2 |
| 36 | *Trichoderma* spp. | | | | | | 8.0 | | | |
| 37 | *Ulocladium atrum* (Preuss) Sacc. | | | | | | | | | 0.6 |
| 38 | Unidentified fungi | 2.1 | | 0.4 | | | 0.3 | 0.1 | 1.0 | 1.0 |
| 39 | Sterile dark mycelium | 0.2 | 0.1 | | 0.9 | 4.5 | 0.6 | 0.1 | | 8.4 |
| 40 | Sterile white mycelium | 0.2 | 0.6 | | | | 1.7 | | | 6.4 |

II) Fungal flora of eucalypt litter (Table 8)

Thirty-four genera of fungi were isolated from eucalypt leaf litter. Among these, 27 (79%) genera belonged to fungi imperfecti, 4 (12%) to Zygomycetes and one genus to Ascomycetes. *Marasmius* sp. was the only basidiomycete observed. This agaric produced fruiting bodies on the litter in July 1986.

The dominant primary colonizers were Penicillia, Aspergilli, *Tritirachium* sp.. *Chaetomella circinoseta, C. raphigera* and *Curvularia lunata. Penicillium* was identified as the most frequent and dominant genus on the litter throughout the study. This was followed by *Aspergillus niger.* The relative density of Penicillia showed ups and downs during the course of decomposition; the lowest numbers were recorded during the advanced stages of decomposition. Along with Penicillia and Aspergilli, *Curvularia lunata* was also isolated throughout the sampling period. Among the secondary colonizers of litter, *Aspergi/lus flavus. A. niger. Chetomella circinoseta. Curvularia lunata. Fusarium* spp., *Phoma* spp. (including *P. nebulosa), Robillarda* spp., (including *R. sessilis), Trichoderma viride* and *Mucor spp.* were more frequent (over 50% frequency of occurrence) and dominant. A foliar pathogen of eucalypt, viz., *Coniella castaenicola* was isolated from the litter during June, September and December 1985. The members of Zygomycetes were prevalent during the advanced stages of decomposition.

Table 8. Relative abundance (%) of fungi isolated from the leaf litter of *Eucalyptus tereticornis* during different months (field).

| Sl. No. | Fungi | ff* | May '85 | June | July | Aug. | Sept. | Oct. | Dec. | June '86 | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *Acremonium* sp. | | | | | | 0.2 | | | | |
| 2 | *Acrophialophora fusispora* Saksena (M.B. Ellis)' | | | | 6.1 | | 1.9 | | | | |
| 3 | *Alternaria alternata* (fr.) Keissler | | | *0.3* | | | | | | 9.4 | |
| 4 | *Alternaria* sp. | | | 1.5 | | | | | 0.3 | | |
| 5 | *Aspergillus flavus* | | 0.4 | | 1.2 | 0.6 | 0.7 | 1.6 | | | 13.2 |
| 6 | *A. niger* | | 1.4 | 3.6 | 3.1 | 14.0 | 14.5 | 13.0 | 14.1 | 11.2 | 26.0 |

* freshly fallen litter

| Sl. No. | Fungi | ff* | May 85 | June | July | Aug. | Sept. | Oct. | Dec. | June '86 | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | *Aspergillus* spp. | 8 7 | 5.4 | 3.6 | 5.5 | 2.2 | 4.7 | 5.9 | 16.1 | 19.7 | 17.7 |
| 8 | *Aureobasidium pullulans* DeBary (Arnaud) | | | | | 2.8 | | | | | |
| 9 | *Chaetomella circinoseta* Stolk | *0.8* | 12.0 | 15.8 | 0.6 | | 0.9 | 0.3 | 1.3 | | |
| 10 | *C. raphigera* | 0.6 | | | | | | 0.7 | 0.8 | | |
| 11 | *Chaetomella* sp. | | | 1.8 | | | | | | | |
| 12 | *Chaetomium funicola* Cooke | | 0.3 | | | | | | | | |
| 13 | *Chaetomium* sp. | | | 0.3 | | | | | 0.3 | | |
| 14 | *Cladosporium cladosporioides* | | | | 0.6 | 2.2 | | | | | |
| 15 | *C. oxysporum* | | | | | 1.7 | | | | | |
| 16 | *Coniella castaneicola* (Ell. & Ev.) Sutton | | 9.4 | | | | 2.6' | | 0.8 | | |
| 17 | *Coniella* sp. | 0.3 | | | | | | | | | |
| 18 | *Curvularia eragrostidis* | | | | | | 0.2 | | | 0.4 | |
| 19 | C. *lunata* | 0.6 | 4.0 | 4.6 | 9.8 | 2.8 | 0.2 | 4.6 | 2.0 | 5.2 | 3.3 |
| 20 | *C. pallescens* Boedijn | | | | | | 0.2 | | | | |
| 21 | *C. sengalensis* | | | | | | 0.9 | | | | |
| 22 | *Doliomycs mysorensis* | | 0.4 | | | | | | | | |
| 23 | *Fusarium oxysporurn* | | | | | | 1.4 | 0.7 | | | |
| 24 | *F. solani* | | | | | | 3.5 | 1.4 | | | |
| 25 | *Fusarium* spp. | | 0.4 | | 5.5 | 6.7 | 4.7 | 7.8 | 0.3 | 19.7 | 0.3 |
| 26 | *Geotrichum candidum* Link | | | | | | | | 0.3 | | |
| 27 | *Gliocladium roseum* Bainier | | | | | 2.8 | | | | | |
| 28 | *Graphium sp.* | | | | | 1.7 | | | | | |

| Sl. No. | Fungi | ff | May '85 | June | July | Aug | Sept. | Oct. | Dec. | June '86 | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 | *Humicola fuscoatra* Traaen | | | | | | | | | | *0.5* |
| 30 | *Monodictys levis* | | | | | | 0.4 | | | | |
| 31 | *Monodictys* sp. | | | | 0.6 | | | | | | |
| 32 | *Mucor* spp. | | | | | | 0.9 | 0.7 | 0.3 | 10.0 | 5.4 |
| 33 | *Myrothecium* sp. | | | | | 2.8 | 1.1 | | | | |
| 34 | *Neocosmospora vasinfecta* E.F.Sm. | | | | | | | | | | 0.3 |
| 35 | *Penicillium* spp. | 75.2 | 51.4 | 14.6 | 9.2 | 28.5 | 32.3 | 26.4 | 65.3 | 1.6 | 1.8 |
| 36 | *Pestalotiopsis* sp. | | | | | | 0.2 | 1.0 | 0.3 | | |
| 37 | *Phoma nebulosa* (Pers. Fr) Berk. | | | 10.6 | | | | | | | |
| 38 | *Phoma* sp. | | 4.0 | | 26.4 | 8.9 | 3.3 | 0.3 | 0.3 | 13.7 | |
| 39 | *Pithomyces sacchari* (Speg.) MB. Ellis | | | | | | | | 0.3 | | |
| 40 | *Robillarda sessilis* | | | 25.8 | | | 16.2 | 11.5 | | | |
| 41 | *Robillarda sp.* | | 4.0 | | 6.7 | | | 1.5 | 3.2 | 2.7 | |
| 42 | *Rhizopus* sp. | | | | | | 0.7 | | 0.5 | 1.2 | |
| 43 | *Stemphylium* sp. | | | 0.8 | | | | | | | |
| 44 | *Syncephalastrum racemosum* | | | | | | | 1 | | 3.2 | |
| 45 | *Thielavia* sp. | | | | | | | | | | 0.3 |
| 46 | *Torula* sp. | | | | | | | | | 1.6 | |
| 47 | *Trichoderma viride* | | | 3.6 | 1.8 | | 0.7 | 10.1 | | 0.8 | 1.5 |
| 48 | *Trichoderma* sp. | | | | | | 1.2 | | | | |
| 49 | *Tritirachium* sp. | 3.9 | | | | | | | | | |
| 50 | *Ulocladium atrurn* | | | 3.0 | | | | | 0.3 | 0.4 | |
| 51 | *Zygorhynchus sp.* | | | | | | | | | 0.3 | |
| 52 | Unidentified fungi | 7.3 | 5.4 | 4.0 | | 2.2 | | 1.6 | 5.4 | 1.6 | 0.6 |
| 53 | Sterile dark mycelium | 0.3 | 0.7 | 3.0 | 2.5 | 15.6 | 3.5 | 1.6 | 0.5 | 4.8 | |
| 54 | Sterile white mycelium | | 1.1 | 0.6 | 20.2 | 2.6 | 1.6 | 10.1 | | | 16.2 |

iii) Fungal flora of teak litter (Table 9)

The fungi isolated from teak litter belonged to 32 genera. Of these, fungi imperfecti were represented by 28 genera (87.5%) Zygomycetes by three (9.4%) and Ascomycetes by one genus. *Marasmius* was found colonizing the litter during October 1985.

Aspergilli,Penicillia, *Tritirachium* sp., *Coniella granati, Myrothecium verrucaria and Chaetomella circinoseta* were the dominant primary colonizers. The most frequent and dominant colonizers of the litter during the entire period of study were species of *Aspergillus. Penicillium* and *Phoma.* Among the secondary saprophytic fungi, *Aspergillus flavus. A. niger, Curvularia lunata* and species of *Fusarium, Alternaria* and *Myrothecium* showed comparatively higher frequency of occurrence and dominance than other fungi. *Mucor* and *Rhizopus* were isolated during the advanced stages of decomposition. The relative abundance of *Penicillium* decreased during the course of decomposition. *Trichoderma viride* was frequent at the later stages of decay.

In all the litters, the sterile forms (mostly ,basidiomycetous mycelium) showed highest relative density during the advanced stages of decomposition. Fungi exclusive to *Albizia* litter were *Absidia cylindrospora. Cunninghamella bertholletiae, Bartalinia robillardoides* and *Collybia leucophaea. Acrophialophora fusispora. Aureobasidium pullulans. Gliocladium roseum, Neocosmospora vasinfecta. Pithomyces sacchari. Stemphylium* sp.. and *Zygorhynchus* sp. were restricted to eucalypt and *Botryodiplodia theobromae, Paecilomyces* sp and *Scolecobasidium variabile* to teak litter.

The concept of fungal succession on plants and other substrates has now become well established (Hudson, 1968; Hayes, 1979). The sequence of this succession upon a natural substratum reflects a complex interaction of nutritional relationships between each fungus and the substratum together with competition between individual fungi (Macauley and Thrower, 1966).

Fungi belonging to different taxonomic groups have been recorded from the leaf litters of diverse plant species. There are several published works in this line (Hering, 1967; Eicker, 1973; Jensen, 1974; Visser and Parkinson, 1975).

The results of the present study on fungal succession on leaf litters indicated that a good number of fungi are common to all the three litters. but a few others are restricted to one or the other litter. This may be due to the occurrence of species specific fungi (Macauley and Thrower, 1966). But, the possibility of a chance occurrence of certain species of fungi on a particular litter cannot be overruled. However, in spite of these differences a general pattern of development of the litter mycoflora appears more or less dearly in this investigation.

Table 9. Relative abundance (%) of fungi isolated from the leaf litter of *Tectona grandis* during different rnonths (fiel d).

| Sl. No. | Fungi | ff* | May '85 | June | July | Aug. | Sept. | Oct. | Dec. | June '86 | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *Alternaria alternata* | | | 8.9 | | | 0.4 | | 0.4 | | |
| 2 | *Alternaria* sp. | | 0.8 | | 0.6 | 0.4 | | | | | |
| 3 | *Aspergillus flavus* | | 4.2 | 1.0 | 1.7 | 5.0 | 1 9 | 2.4 | | 0.7 | 0.6 |
| 4 | *A. niger* | | 6.3 | 20.3 | 35.4 | 18.5 | 8.1 | 4.8 | 16.5 | 11.3 | 36.1 |
| 5 | *Aspergillus* spp. | 46.5 | 11.8 | 32.9 | 1.1 | | 8.5 | 25.2 | 46.4 | 18.7 | 14.6 |
| 6 | *Beltrania rhombica* O. Penzig | 0.2 | | | | | | | | | |
| 7 | *Botryodiplodia theobromae* Pat | | | | | | | 0.8 | | | |
| 8 | *Bipolaris spicifera* | | | | 0.6 | | | | | | |
| 9 | *Chaetomella circinoseta* | 0.6 | | | | | | | | | |
| 10 | *Cladosporium cladosporioides* | | 0.8 | | | | | | | | |
| 11 | *C. oxysporum* | | 0.8 | | 1.1 | 1.2 | | | | | |
| 12 | *Coniella granati* (Sacc.) Petrak& Sydow | 1.3 | | | | 0.4 | | | | | |
| 13 | *Curvularia brachyspora* Boedijn | | | 0.2 | | | | | | | |
| 14 | C. *eragrostidis* | 0.2 | | | 1.1 | | | | | | |
| 15 | C. *lunata* | 0.2 | 1.3 | 1.2 | 6.3 | 1.2 | 6 6 | | | 3.5 | 6.1 |
| 16 | *C. pallescens* | | | | | | | | | 1.1 | *0.3* |
| 17 | *C. senegalensis* | | | | | | 1.2 | | | | |
| 18 | *C. verruciformis* Agarwal & Sahni | | | | | | | | 0.4 | | |
| 19 | *Doliomyces mysorensis* | | 11.3 | | | 5.4 | | | | | |
| 20 | *Fusarium solani* | | | | | | 12.0 | | | 0.4 | 1.8 |
| 21 | *Fusarium* spp. | | 0.4 | | | 9.5 | 4.2 | 4.5 | | 9.2 | 0.3 |
| 22 | *Geotrichum candidum* | | | 0.2 | | | | | | | |

* freshly fallen litter

| Sl. No. | Fungi | ff | May '85 | June | July | Aug. | Sept. | Oct. | Dec. | June '86 | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | *Graphium* sp. | | | | | 1.7 | | | | | |
| 24 | *Humicola fuscoatra* | | | | | | | | 0.4 | | 0.6 |
| 25 | *H. grisea* Traaen | | | | 0.6 | | 0.4 | | | | |
| 26, | *Monodictys* sp. | | | | | 1.2 | 1.2 | 2.0 | | | 1.2 |
| 27 | *Mucorsp.* | | | | | | | 0.4 | | 5.3 | |
| 28 | *Myrothecium roridum* Tode ex Steudel | 0.2 | 4.6 | | | | | 3.7 | 0.4 | | |
| 29 | *M. verrucaria* (Alb. & Sch.) Ditm ex Steudel | 0.8 | | | | | | | | | 1.2 |
| 30 | *Myrothecium* sp. | | | 0.2 | | | 4.6 | | 0.4 | 0.7 | |
| 31 | *Paecilomyces* sp. | | | | | 1.2 | | | | | |
| 32 | *Penicillium* spp. | 40.9 | 12.2 | 17.3 | 17.7 | 2.1 | | 4.5 | 3.0 | 1.1 | 2.8 |
| 33 | *Pestalotiopsis* sp. | | | | 2.9 | | 1.5 | 0.4 | 0.4 | | |
| 34 | *Phoma* spp. | | 22.3 | | 7.4 | 19.8 | 22.0 | 4.1 | 2.2 | 20.4 | 0.3 |
| 35 | *Pyrenochaeta* sp | 0.2 | | | 6.3 | | 3.5 | 2.0 | | | |
| 36 | *Rhizopus sp* | | | | | | | | | 0.7 | |
| 37 | *Robillarda sessilis* | | | | | | | | | | 2.4 |
| 38 | *Robillarda* sp. | | 15.5 | | 11.0 | 5.8 | 5.0 | 19.0 | | 2.5 | |
| 39 | *Scolecobasidium variabile* Barron & Busch | 0.2 | | | | | | | | 0.4 | |
| 40 | *Scytalidium lignicola* | | 0.4 | | | | 2.7 | 0.4 | 0.4 | | |
| 41 | *Syncephalastrum racemosum* | | 1.3 | 1.5 | | 0.8 | 0.8 | | 0.4 | | 0.6 |
| 42 | *Thielavia sp.* | | | | | | | | | | 0.6 |
| 43 | *Torula* sp. | | | | | | | | | 0.7 | |
| 44 | *Trichoderma viride* | | | | 1.7 | | 6.9 | 9.3 | 2.3 | 1.4 | 2.4 |
| 45 | *Trichoderma* sp. | | | | | | | | 7.5 | 1.8 | |
| 46 | *Tritirachium* sp. | 2.5 | | | | | | | | | |
| 47 | *Ulocladium atrum* | | | 11.6 | 0.6 | 0.8 | | | 13.1 | 0.4 | |
| 48 | *U. botrytis* Preuss | | | | | 2.5 | | | | | |
| 49 | Unidentified fungi | 3.3 | | 0.2 | 1.1 | 3.7 | 4.2 | 2.5 | 4.1 | 1.8 | 1.2 |
| 50 | Sterile dark mycelium | 0.8 | 0.8 | 1.2 | 2.3 | 5.8 | 3.4 | 12.6 | 0.4 | 8.8 | 0.3 |
| 51 | Sterile white mycelium | 1.0 | 2.1 | 0.2 | 0.6 | 7.0 | 0.8 | 0.4 | 0.7 | 7.7 | 23.8 |

The preponderance of fungi mperfecti on decomposing leaf litters has been reported by several workers (Shukla *et a/..* 1978; Macauley, 1979). The members of fungi imperfecti appears to be strong colonizers of litters showing better adaptability and higher percentage distribution. Members of Zygornycetes and Ascomycetes are found to be weak colonizers. In all the cases, the primary colonizers of litters were members of Coelomycetes and Moniliales and most of these initial colonizers showed their dominance throughout the decomposition period. Aspergilli and Penicillia were recorded as the most dominant Colonizers of *Albizia,* teak and eucalypt litters. The initial colonizers also included *Curvularia, Cladosporium* and *Alternaria.*

The secondary saprophytes of litters comprised several genera of fungi imperfecti and a few genera of Ascomycetes. Basidiomycetes appeared along with these fungi or later. The members of Zygomycetes were mostly isolated during the advanced stages of decomposition. These observations suggest that the succession of fungi on leaf litters reported here agrees well with .the general scheme of fungal succession on litter proposed by Hudson (1968). However, in this study, species of *Pencillium* were found to colonize litters during all the stages of decay. The relative density of Penicillia were highest on the freshly fallen litter. This observation is at variance with Hudson's (1968) hypothesis where he postulated that various soil inhabitants including species of Mucorales and Pencillia appear only during the final stages of decomposition.

The predominance of fungi imperfecti on leaf litters may be related to their high sporulating ability and fast growth. Majority of the genera belonging to this group are recognised as very active cellulose decomposers (Domsch *et a/.,* 1980). The abundance of Aspergilli and Penicillia can be attributed to their ubiquitous nature and their ability to grow over a wide range of temperatures, pH, moisture content and a range of substrates (Pugh, 1974). The dominance of Aspergilli and Penicillia on decaying leaf litters of teak and eucalypt was also reported by Soni (1985).

The low frequency and abundance of Ascomycetes may be due to their slow growth and weak parasitic nature. As the basidiomycetes are seldom encountered in dilution plates, their activity could not be fully assessed. However, most of the sterile forms recovered during the isolations were recognized to have basidiomycetous mycelium. In agreement to Hudson's (1968) hypothesis, these basidiomycetes were prominent at the advanced stages of decomposition.

Several workers (Pugh, 1958; Macauley and Thrower, 1966) have reported that Zygomycetes are isolated most frequently at the advanced stages of decomposition of litters. The results of this study is in agreement with these findings. Hudson (1968) had reported that Zygomycetes, which appear at the

final stages of decomposition, are in the role of secondary sugar fungi growing in association with cellulose and lignin decomposing forms.

The fungal flora of eucalypt litter reported here is in close agreement with the litter mycoflora of *Eucalyptus* sp. recorded by Soni (1985). Apart from the similarity in successional patterns of major groups, most of the individual species are common in both the studies. The results of this study are also comparable to the fungal flora of *Eucalyptus maculata* (Eicker, 1973) and *E. pauciflora* (Macauley, 1979) leaf litters reported from South Africa and Australia, respectively. Similarities are noticed in the pattern of succession of flora and also a good number of fungi isolated from these litters are common with the mycoflora of *E. tereticornis* litter.

The leaf litter mycoflora of teak is broadly consistent with reports on litter fungi of teak by Sinha and Dayal (1983) from Varanasi and Soni (1985) from Jabalpur. Regarding the composition of the flora, the results are more in agreement with those of Soni (1985). The successional patterns of major groups of fungi on litter were similar in all the three studies.

It is evident from the results of this study and similar studies (Kjoller and Struwe, 1982) that irrespective of the area of the study and the variations in climatic and soil factors, the fungal flora of litters from the same/related tree species showed a close similarity in species composition. This indicates that the major factor influencing the composition of the fungal flora is the substrate quality. To what degree soil and climatic factors determine the composition of the mycoflora still remains to be ascertained.

## 4. CONCLUSIONS

The following conclusions can be drawn from the results of this study.

1 The rate of decomposition of eucalypt leaf litter is slower than that of teak and *Albizia* litters. The decay rate is higher under the field conditions than under the laboratory conditions in the case of all the three species.

2 Litter moisture content is crucial for the decomposition of leaf litters under tropical warm humid climate.

3 The litter decay is rapid and the microbial activity higher during south-west monsoon in the study area. The microbial activity is higher in the field than in the laboratory.

4 The succession of fungi on decaying leaf litters of teak, eucalypt and *Albizia* is in agreement with the general scheme of fungal succession on plant litters proposed by Hudson.

5 Substrate quality is the major factor which determines the rate of leaf litter decomposition, $CO_2$ evolution, the density of microorganisms associated with the litters and also composition of their mycofloras.

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