

A Comparative Study of Leaf Litter Decomposition Rates in a Hill Forest and a Forest Plantation in Peninsular Malaysia

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ABSTRAK

Suatu perbandingan dibuat di antara kadar pereputan daun seraya (*Shorea curtisii* Dyer ex. King) dengan daun pain (*Pinus caribaea* var. *Hondurensis*) selama 16 minggu di suatu hutan bukit Dipterokarp (HDF) dan di suatu ladang pokok pain (PP). Di kedua-dua tempat, daun seraya telah reput dengan kadar yang lebih cepat daripada daun pain. Kehilangan berat daun seraya selepas 16 minggu adalah di antara 19.5% (PP) hingga 39.0% (HDF) manakala daun pain menunjukkan kehilangan berat di antara 10.3% (PP) hingga 13.6% (HDF). Mikroartropoda tanah disyaki memainkan peranan yang lebih penting dalam pereputan daun seraya di HDF dari di PP. Kepentingan keputusan ini ke atas pengurusan hutan dibincangkan.

ABSTRACT

A comparison of seraya (*Shorea curtisii* Dyer ex. King) and pine (*Pinus caribaea* var. *Hondurensis*) leaf litter was made over a period of 16 weeks in a Hill Dipterocarp Forest (HDF) and in a pine plantation (PP). At both sites, seraya leaves decomposed at a faster rate than pine needles. Weight losses after 16 weeks from seraya leaves varied from 19.5% (PP) to 39.0% (HDF) while pine needles showed weight losses varying from 10.3% (PP) to 13.6% (HDF). Soil microarthopods were suspected to play a more important role in seraya leaf litter decomposition in the HDF than in the PP. The significance of these findings on forest management is discussed.

INTRODUCTION

It is generally accepted that soils in the tropical zone are highly leached and deprived of nutrients and that the bulk of the nutrients are in the plant litter. Litter decomposition ensures the release of these elements which are important in forest tree nutrition. Thus the speed of recycling of mineral nutrients depends largely on the rate at which plant litter, especially leaf litter, decompose on the forest floor.

Although various aspects of lowland rainforests in Southeast Asia have been researched on for decades, Anderson and his co-workers (1983) found little information available on the two important aspects of litter decomposition and nutrient cycling. Among some of the studies of these processes which have been reported in Malaysia are those of Bullock and Khoo (1969), Bullock (1978), Lim (1975, 1978), Ogawa (1978), Yoneda *et al.* (1978), Gong (1982), Anderson *et al.* (1983), Anderson and Swift

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(1983), Baillie and Ashton (1983) and Gong and Ong (1983).

The lowland rainforests in Peninsular Malaysia have been largely depleted and logging activities are currently concentrated in the Hill Dipterocarp Forests between elevations of approximately 300–760 m a.s.l. To supplement the forecasted shortage of timber supply at the end of the 20th century (Musa Hitam, 1980; Myers, 1980), the Malaysian government has recently launched the Compensatory Plantation Programme to plant fast-growing, short rotation exotics such as *Acacia mangium* and *Gmelina arborea*. However, there is little information available regarding the ecology and management of hill forest and even less is known about plantations of exotics.

The future of Malaysian forestry depends on the productivity of these hill forests and plantations. The rate of litter decomposition and nutrient cycling will largely determine the productivity of these forests. The aim of this paper is to provide some information on the rates of litter decomposition in a hill forest and in a forest plantation.

MATERIALS AND METHODS

Site

This study was conducted over a period of 16 weeks in the two following sites.

Site 1: Primary Hill Dipterocarp Forest (HDF) in Ulu Gombak Virgin Jungle Reserve, Selangor (3° 21'N, 101° 45'E), at an altitude of 460 m above sea level. The study plot of 30 m × 30 m was situated on a well drained eastward sloping (20°) spur.

Site 2: A fourteen-year-old *Pinus caribaea* var. *Hondurensis* plantation (PP) in Bukit Tinggi Forest Reserve, Pahang (3° 19'N, 101° 49'E) at an altitude of 480 m above sea level. The study plot (30 m × 30 m) was situated on a well drained north facing slope (26°).

Litter bags

Shorea curtisii Dyer ex. King known locally as seraya, which is an important commercial species in hill forests and *Pinus caribaea* var. *Hondurensis*, a fast-growing plantation species, were chosen for this study.

Litter bags measuring 20 cm × 20 cm were constructed from mesh of two different sizes. Medium-mesh bags were constructed from aluminium screening material with a 2.0 mm mesh while fine-mesh bags were constructed from stainless steel sieving material with an approximately 0.5 mm mesh.

Litter bags of the two mesh sizes were each filled with 5.0 g air-dried seraya leaves or pine needles. Sub-samples of the leaves and needles were oven-dried at 80°C to determine the initial oven-dry weights in the litter bags.

Each study plot in both site 1 and site 2 was divided into nine subplots measuring 10 m × 10 m, of which six were randomly chosen for this study. In each of the six subplots in both site 1 and site 2, four medium-mesh and four fine-mesh bags containing seraya leaves and a similar set of bags containing pine needles were laid out on 29 August, 1983. Each litter bag was placed with one face in contact with the soil which had been cleared of litter before the experiment to ensure homogeneity. The two mesh sizes were considered as two treatments. At intervals of four weeks, litter bags were collected, four (one medium-mesh bag and one fine-mesh bag each of seraya leaves and pine needles) from each subplot at each site, up to a period of 16 weeks from commencement of the study.

The leaves/needles were removed from the mesh bags, brushed free of foreign material and oven-dried to constant weight at 80°C in paper envelopes. The percentage dry weight remaining (D_r) was calculated using the following equation:—

$$D_r(\%) = \frac{\bar{W}_t}{W_i} \times 100$$

where \bar{W}_t = mean oven-dry weight at time t
 W_i = initial oven-dry weight

Statistics

The data was transformed using the arcsine transformation as most of the values lay above 70% (Sokal and Rohlf, 1969). The F-test for homogeneity of variances between each set of transformed and untransformed data was found to be significant in all cases. The transformed data was therefore used for the computation of confidence limits and for the comparison of means by t-tests.

From the original data, regression analyses were carried out on weight losses from the leaf litter using the decay function $\ln W_t = \ln W_0 - kt$ (from $W_t = W_0 e^{-kt}$) where W_t is the weight of litter (percentage of original weight) remaining at time t , $\ln W_0$ is the intercept (W_0 being the initial percentage weight) and k the slope of the regression line.

RESULTS

Dry weight losses from seraya leaves and pine needles in the HDF and PP are shown in Fig. 1. Regressions were fitted to the data to calculate a weighted mean value for the litter in the bags at 16 weeks to avoid bias in the estimates of the weight of litter remaining in the bags at the end of the study. An extrapolated value was obtained for 52 weeks. The negative exponential decay function showed a good fit in all cases ($r \geq 0.91$, $p < 0.05$). Observed and calculated values for 16 weeks and 52 weeks are shown in Table 1. A χ^2 comparison for homogeneity between observed and expected values showed that the observed final weight of litter in the mesh bags did not differ significantly from the expected values. Thus comparisons between litter types and sites have been made using the data obtained from the final set of samples.

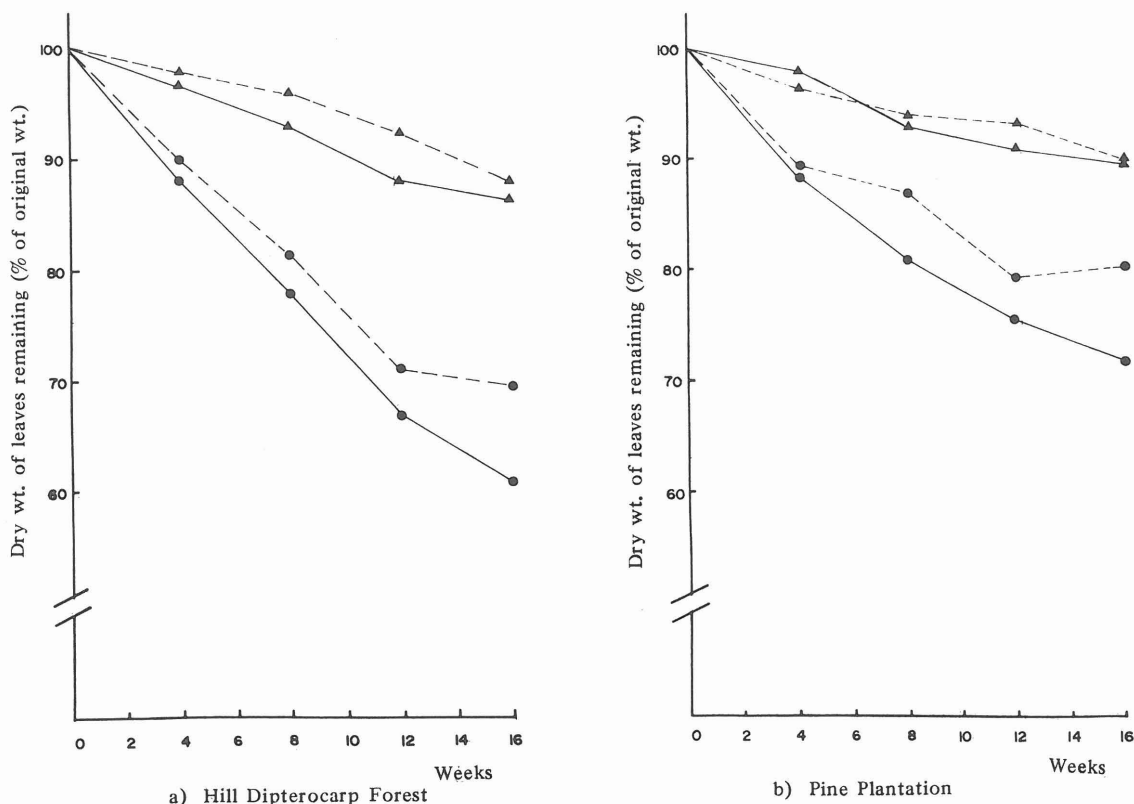


Fig. 1. Dry weight of leaves remaining in (—) medium- and (---) fine-mesh litter bags containing (●) seraya leaves and (▲) pine needles in two forest types of Peninsular Malaysia: (a) Hill Dipterocarp Forest, (b) Pine Plantation.

TABLE 1
 Dry weight losses of leaves in litter bags in a natural hill forest and pine plantation.
 Parameters and correlation for the regression $\ln W_t = \ln W_0 - kt$

Site	Hill Dipterocarp Forest				Pine Plantation			
	Seraya		Pine		Seraya		Pine	
	0.5 mm	2.0 mm	0.5 mm	2.0 mm	0.5 mm	2.0 mm	0.5 mm	2.0 mm
Observed % weight loss after 16 weeks (mean \pm 95% confidence limits)	30.5 \pm 4.5	39.0 \pm 4.4	11.9 \pm 2.8	13.6 \pm 4.2	19.5 \pm 10.7	28.0 \pm 11.5	10.3 \pm 3.0	10.4 \pm 2.1
Predicted % weight loss after 16 weeks	32.2	39.3	11.3	14.2	21.4	28.6	9.7	10.8
Predicted % weight loss after 52 weeks	70.1	80.1	33.9	39.3	45.9	61.3	25.8	32.0
Regression slope (k)	-0.02	-0.03	-0.01	-0.01	-0.01	-0.02	-0.01	-0.01
Intercept ($\ln W_0$)	4.58	4.60	4.62	4.61	4.53	4.54	4.59	4.61
Correlation coefficient	0.97	0.99	0.97	0.98	0.95	0.99	0.95	0.97

Weight losses from seraya leaves in medium-mesh after 16 weeks were 39.0% in the HDF and 28.0% in the PP (Table 1). A student's t-test revealed these weight losses to be significantly different ($t = 2.44$; $n = 10$; $P < 0.05$). Similarly, weight losses of seraya leaves in fine-mesh after 16 weeks were significantly higher in the HDF (30.5%) than in the PP (19.5%) ($t = 2.47$; $n = 12$; $p < 0.05$).

Weight losses from pine needles were significantly less than from seraya leaves in both the HDF and the PP for both mesh sizes. In the PP, seraya leaves in medium-mesh recorded a 28.0% weight loss after 16 weeks as compared to 10.4% for pine needles in medium-mesh over the same period of time ($t = 5.25$; $n = 10$, $p < 0.01$). In the HDF, seraya leaves in medium-mesh showed 39.0% weight loss after 16 weeks whereas pine needles under the same conditions showed only a 13.6% weight loss ($t = 6.54$; $n = 11$; $p < 0.01$).

Overall the pine needles showed weight losses varying from 10.3% in fine-mesh in the PP to 13.6% in medium-mesh in the HDF (Table

1). There were no significant differences in weight losses of pine needles between sites or due to differences in mesh size.

A different result was obtained for seraya leaves in the two sites. Seraya leaves confined in medium-mesh showed significantly higher weight losses (39.0%) than those contained in fine-mesh in the HDF (30.5%) ($t = 3.46$; $n = 11$; $p < 0.01$); after 16 weeks. There were however no significant differences in weight losses from seraya leaves contained in medium-mesh (28.0%) and fine-mesh (19.5%) in the PP.

DISCUSSION

A short-term study such as this cannot possibly give us a clear picture of the complex and long-term processes involved in decomposition and nutrient cycling. However these results do provide a basis for comparison of decomposition processes in different forest types and provide some understanding of their operation at the ecosystem level of organization (Anderson *et al.*, 1983).

A number of authors have criticized the use of litter bags for studying decomposition (see Weider and Lang, 1982) but it is still a widely used technique. This technique has its limitations but in the absence of a practical alternative, Will *et al.*, (1983) consider it a valuable technique particularly in comparative studies covering the early stages of decomposition.

Most litter bag studies reported in the literature have been carried out over different periods of time varying from a few months to more than a year. Thus in this discussion loss rates have been calculated as percentage loss per year based on the exponential decay curve obtained from extrapolation of data gathered over sixteen weeks. However this comparison of leaf weight losses from litter bags can be made only in general terms since this study did not include investigations of resource quality, soil and soil litter microclimate and soil fauna populations.

Weight losses of seraya leaves vary from 46% year⁻¹ in the PP (the slowest of the fine-mesh) to 80% year⁻¹ in the HDF (the fastest of the medium-mesh). Anderson *et al.* (1983) working in Gunung Mulu National Park, Sarawak, obtained weight loss rates varying from 50% year⁻¹ to 63% year⁻¹ for mixed, freshly fallen leaves; 65–97% year⁻¹ for *Ficus* leaves and 62–96% year⁻¹ for *Parashorea* leaves. Their lower weight losses were obtained from the 40 μ m mesh while the higher weight losses were obtained from the 7 mm \times 20 mm mesh. In Jamaican montane rainforests, Tanner (1981) using 2 mm mesh bags obtained a mean value of 47% year⁻¹ for fifteen leaf species while Edwards (1977) obtained a range of 26–95% year⁻¹ (average 40% year⁻¹) for six species of leaves in 8 mm mesh bags in the montane rain forests of New Guinea (2400–2500 m a.s.l.). These rates are, however, low when compared to those obtained by other workers in the Lowland Dipterocarp Forest of Peninsular Malaysia. Lim (1975) working in Pasoh Forest Reserve in Negeri Sembilan found that tethered *Dipterocarpus crinitus* leaves showed 80% weight loss after 8 months while *Dipterocarpus sublamellatus* leaves had a 33% weight loss after 4 months. Gong (1982) working in the same area found

that unconfined leaves had a 98.5% weight loss after five weeks. The higher rates of decomposition in the lowland forest are possibly due to the abundance of termites in such forests (Matsumoto, 1978). In contrast, very few termites or their nests and mounds were observed in the hill forest and in the pine plantation.

In Sarawak, Anderson *et al.* (1983) found that decomposition rates of leaves in the Mulu forests were similar to those in lower montane forests and some lowland forests in the Central Amazon but were generally slower than in West African forests. They also came to the conclusion that the decomposition rates of the three litter types investigated were equal to or slower than those of several tree species in temperate deciduous forests. In this experiment, the regression slopes of weight loss against time (Table 1) from the mesh bags are 0.01–0.03 for seraya as compared to the range of 0.05–0.28 obtained by Anderson *et al.* (1983) in Sarawak. This result suggests that the decomposition rates of seraya leaves in the HDF are generally lower than those obtained for several other species in Sarawak.

Weight losses of pine needles vary from 26% year⁻¹ in the PP (the slowest of the fine-mesh) to 39% year⁻¹ in the HDF (the fastest of the medium-mesh). Although work on pine litter decomposition has been widely conducted in the temperate zone, few or no similar studies have been conducted in the tropics (George, 1982). In Australia, Will (1967) found that *Pinus radiata* litter decomposed at the rate of 25% year⁻¹. In Europe, Mikola (1960) found that the rate of decomposition of pine litter varied from 13.5% year⁻¹ in northern Finland (mean temperature of 8.5°C) to 21% in southern Finland (mean temperature of 13.5°C). It appears that the rates of pine litter decomposition obtained in this study are similar to those in Australia but generally higher than those in temperate forests.

The use of different sized mesh-bags revealed that soil microarthropods play a significant role in the degradation of seraya leaves in the HDF. It was observed that seraya leaves contained in medium-mesh bags placed in the HDF had clear evidence of grazing activities which was

absent in the other samples. Unfortunately, no quantification of the invertebrate population was made. Weight loss caused by losses of large leaf fragments is negligible due to the size of the mesh used. The absence of differences in weight losses for seraya leaves in the two meshes in the PP could indicate lower feeding activity or a lower incidence of invertebrate saprotrophs in the PP as compared to the HDF, probably because of differences in microclimate of the two sites.

The generally more open and the single layer stratification of the PP allows more sunlight to penetrate to the forest floor, creating a drier environment, consequently decreasing the amount of microarthropods present (Madge, 1965). The PP had also previously been cleared of undergrowth and it is known that cleared areas provide a much harsher environment for decomposer organisms (Ewel, 1976). Another factor could be the lack of substrate diversity, there being only pine needle litter (monospecies) in the PP resulting in reduced fauna diversity.

On the other hand, despite evidence of higher microfauna activity on seraya leaf litter in the HDF, pine needles did not decompose any faster in the HDF when compared to the PP. This could have been due to their hard texture and the presence of astringent substances such as polyphenols and gallic acids which render them less favourable to attack by the soil microfauna (Heath and King, 1964; Heath and Arnold, 1966). The difference in the rates of decomposition of seraya and pine needles could also be due to the nutritive values of the leaves (Hayes, 1979). The mycoflora population isolated from seraya leaves in another part of this study was twice that of the pine needles (Yong, 1983), perhaps indicating that seraya leaves are a more favourable substrate.

It has long been believed that the rate of decomposition and nutrient turnover are generally rapid in the tropical rain forests. However the study of Anderson *et al.* (1983) has shown that litter decay rates in the tropics can be slow and similar to those in some temperate deciduous

forests and the results of this study also support their findings.

Studies elsewhere have shown that litter residence time plays a critical role in the rate at which mineral nutrients are released. For example, Florence and Lamb (cited in Hayes, 1979) found that excessive amounts of nutrients became immobilized in the litter layers and that second rotation crops of *Pinus radiata* frequently produced a decline in growth, probably due to the inability of the low rate of nutrient cycling within the planted stands to support the early high level of wood production. Where decomposition rates were high, 35% to 97% year⁻¹, such as in indigenous stands of *Eucalytus delegatensis*, Wood (cited in Hayes, 1979) found no such declines in growth.

The more rapid rate of decomposition of seraya leaves in the hill forest than in the pine plantation seems to indicate that the more complex, diverse and heterogenous hill forest ecosystem offers a better environment for decomposition processes as compared to the relatively simpler and homogenous pine plantation.

The importance of soil microfauna in litter decomposition coupled with the observation of lower microfauna activity in the plantation as compared to the hill forest, implies that any conversion of natural forest to pine plantation forest could probably result in lower and slower rates of decomposition and nutrient turnover due to changes in the microenvironment. Low nutrient turnover rates could reduce the productivity and consequently lengthen the rotation age of the planted pine crop from the expected fifteen years to a longer period. This would have serious implications on the future of plantation forest management.

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