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DECOMPOSITION AND NUTRIENT RELEASE BY *AVICENNIA MARINA* (FORSK.) VIERH. IN A MANGROVE ISLET AND A BRUSHPILE IN NEGOMBO ESTUARY

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Abstract: Decomposition rates of dry and fresh *Avicennia marina* leaves in a mangrove islet and a brushpile in Negombo Estuary were investigated for 3 months using litter bags. The highest decomposition rate (k) was recorded for fresh leaves in the estuary (k=0.032) and the lowest for dry leaves in the forest (k=0.013). About 9 weeks were required for 50% decomposition of dry leaves in the forest, but only 3 weeks were necessary for fresh leaves in the estuary to reach the same level of decomposition. Within one month, 90% of N, P and K in the fresh leaves were released to the estuary. The nitrogen enrichment was significant in the fresh and dry leaves in the forest after 7 weeks. N and P release were slow but K release was fast.

Key words: *Avicennia marina*, brushpiles, decomposition, litter, mangroves, Negombo estuary, nutrients.

INTRODUCTION

Grazing, decomposition and tidal export are the important processes by which nutrients in the mangrove litter are cycled and transported. The nutrient dynamic process that takes precedence in a specific mangrove habitat is determined by a number of factors of that habitat, which includes the amount of litter, the abundance of grazers and microfauna, soil characteristics, tide and elevation. In the Negombo Estuary where the tidal fluctuation is low and fishermen use mangrove twigs in brushpile fishery, probably decomposition and aquatic grazing food-chains play a major role in nutrient dynamics. Studies on litter decomposition are important to the Negombo Estuary because of this unique method of fishing,[1] and since 80% of estuary's catch is attributed to brushpile fishery.[2] Fishermen use mainly *Avicennia marina* and *Lumnitzera racemosa* twigs to make their brushpiles. Degradation of *Avicennia marina* leaves under laboratory conditions[3] and field conditions has been documented in Australia,[4,5] New Zealand,[6,7] Philippines,[8,9] Thailand[10,11] and South Africa,[12] but no published information is available for mangroves of this region. This study was undertaken to compare the rate of decomposition of mangrove litter in the forest and in the estuary. The study also extends to the patterns of N, P and K release during the decomposition of mangrove leaves in the forest and estuary.

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METHODS AND MATERIALS

This study was conducted in Negombo Estuary, (latitude 7° 11' N and longitude 79° 50' E) in the west coast of Sri Lanka (Fig. 1). The field experiment was carried out in Mandagas-alamba, an islet located in the northern estuary and in a nearby brushpile. The distribution of mangroves in this islet has been mapped out and *Avicennia marina* is reported to be the dominant species, which together with *Ceriops tagal* covers 3.2 ha of the islet.[13] The salinity variation of the estuary during the study period was from 11ppt - 32ppt. Monthly rainfall was comparatively low from 0 to 149 mm. Diurnal water temperature during the sampling time fluctuated from 32°C to 35°C and dissolved oxygen from 8 to 10 mg l^{-1}.

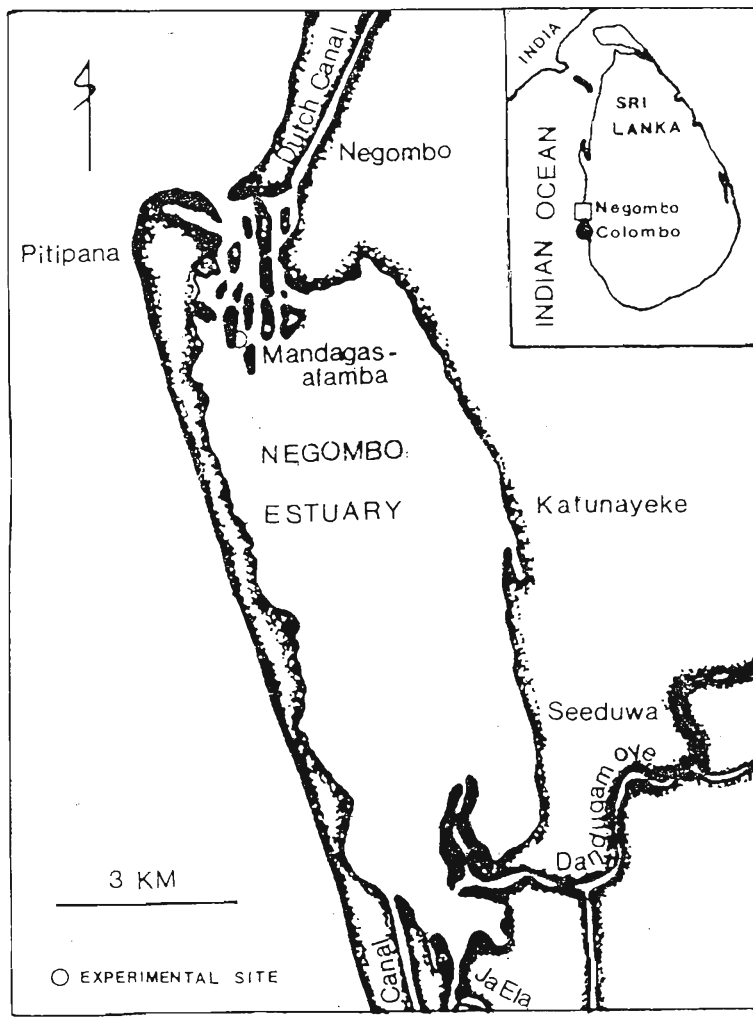

Figure 1: The experimental site in the Negombo Estuary.

This field experiment was designed to compare the terrestrial and aquatic decomposition of fresh and dry mangrove leaves. The litter decomposition was determined using 20 x 30 cm^2 nylon net litter bags of 5 mm mesh size as in other investigations.[14] An earlier study has shown that there is no significant difference in decomposition rates of *Avicennia marina* leaves determined, using 7 mm and 1 mm mesh litter bags.[4] This mesh size, while retaining leaf fragments in water allowed crabs to nibble on litter. Small sesarmid crabs, *Chiromates darwinensis, C. indiarum* and *C. bidens*, with orbital widths 3.5-17.5 mm occur in this mangrove habitat,[15] and their impact on decomposition was not excluded by this mesh size. Juvenile crustaceans and fish could nibble litter in bags in the aquatic habitat, thus their contribution was also included in the decomposition process.

The fresh green leaves for the experiment were plucked from plants. They included young, intermediate and old leaves. Dry leaves were collected from the litter surface. Only the recently fallen, non-fragmented leaves from the upper layers of litter were used in bags. Since a preliminary investigation showed that fresh leaves were 3 times heavier than dry leaves, the weight of the bags with fresh leaves was made 3 times heavier than dry leaves.

Twenty litter bags with 300g of dry leaves and 100g of fresh leaves were deployed in the field as follows:

1. Ten litter bags with fresh leaves in the forest
2. Ten litter bags with dry leaves in the forest
3. Ten litter bags with fresh leaves in the estuary (brushpile)
4. Ten litter bags with dry leaves in the estuary (brushpile)

At first, the bags were removed every two weeks, but later at monthly intervals. This experiment was conducted from March to June 1987. The bags were gently washed to remove silt and the leaves were dried at 70°C to constant weight.

The following equation for litter decomposition[16] was used to compare decomposition rates under 4 different conditons.

$$dX/dt = L - kX$$

dX is a small change in time t, L is the incoming litter, X is the litter present and k is the instantaneous rate of litter decay. Under the current experimental conditions, the equation takes the form,

$$dX/dt = -k/X \quad \text{or} \quad X_t = X_o\, e^{-kt}$$

where X_o is the initial weight of litter and X_t is the weight after a time t.

Potassium content was determined by flame photometer, total N by Micro-Kjeldhal method and P colorimetrically by molybdate method.[17] All analyses were done at the University of Sri Jayewardenepura. Mean unit weights of N, P and K in leaves under different conditions and time were determined from 3 samples at every instance.

RESULTS

Decomposition: The percentage weight loss of dry and fresh leaves of *Avicennia marina* in the estuary and in the forest, during the study period is shown in Fig. 2. This figure also gives the decay constants (k) for the decomposition of dry and fresh leaves in the two habitats. Accordingly, the highest decomposition was observed for fresh leaves in the estuary (k=0.032) and lowest for dry leaves in the forest (k=0.013). In general, decomposition was highest in the estuary than in the forest and in fresh leaves than in dry leaves. However, analysis of variance (ANOVA) indicated that there was no significant difference (df= 3, F= 3.86; $p>0.05$) between the treatments.

Nutrients: N, P and K per unit weight of dry and fresh leaves in the forest and estuary at different times of sampling are given in Table 1. From these values the weights of N, P and K in litter bags were computed. The unit weight of K decreased with time, but the unit weight of N and P in dry leaves in the forest floor decreased initially and then increased after 23 days.

Figure 3 shows the percentages of the remaining N, P and K in the litter bags. According to this figure the nutrient release is rapid in the estuary but slow in the forest. The release of K is faster than the release of N and P. In 3 weeks 90% of K was released from the leaves kept in the estuary, whereas for N and P it has taken 7 weeks for the release of the same percentage.

DISCUSSION

Ecosystem processes: There is a conflict of opinion on the major process that governs the transfer of nutrients from mangrove plants to the environment. While grazing food chains dominate the process in some mangroves,[18,19] detritus food chains are important in others.[20] As tidal influence decreases, as it is the case in Negombo Estuary, the litter decomposition and accumulation become more important[21] and detritus food chains take precedence over grazing food chains. The use of mangroves in brushpile fishery, further contributes to the decomposition of litter in brushpiles. Probably leaf fragments settle close to brushpiles and decompose there, since they are constructed in areas of low tidal energy.

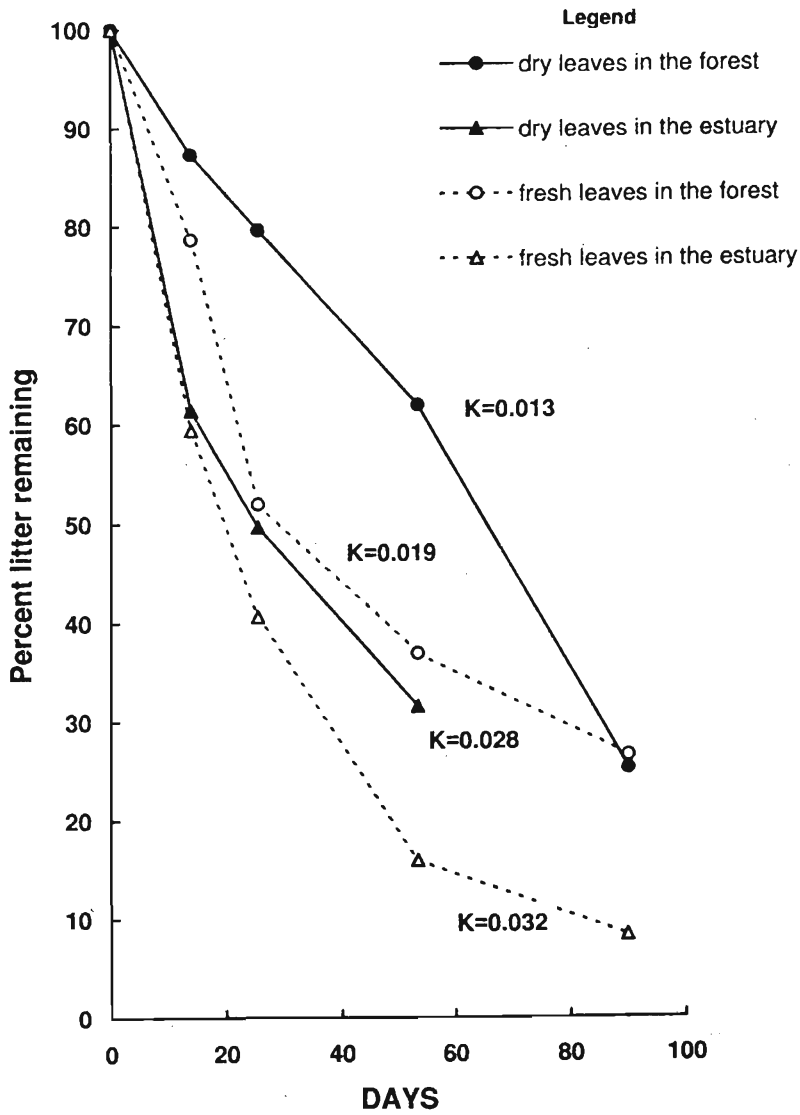

Figure 2: **The mean percentage weight loss in litter bags containing dry and fresh leaves in the mangrove forest and brushpiles.**

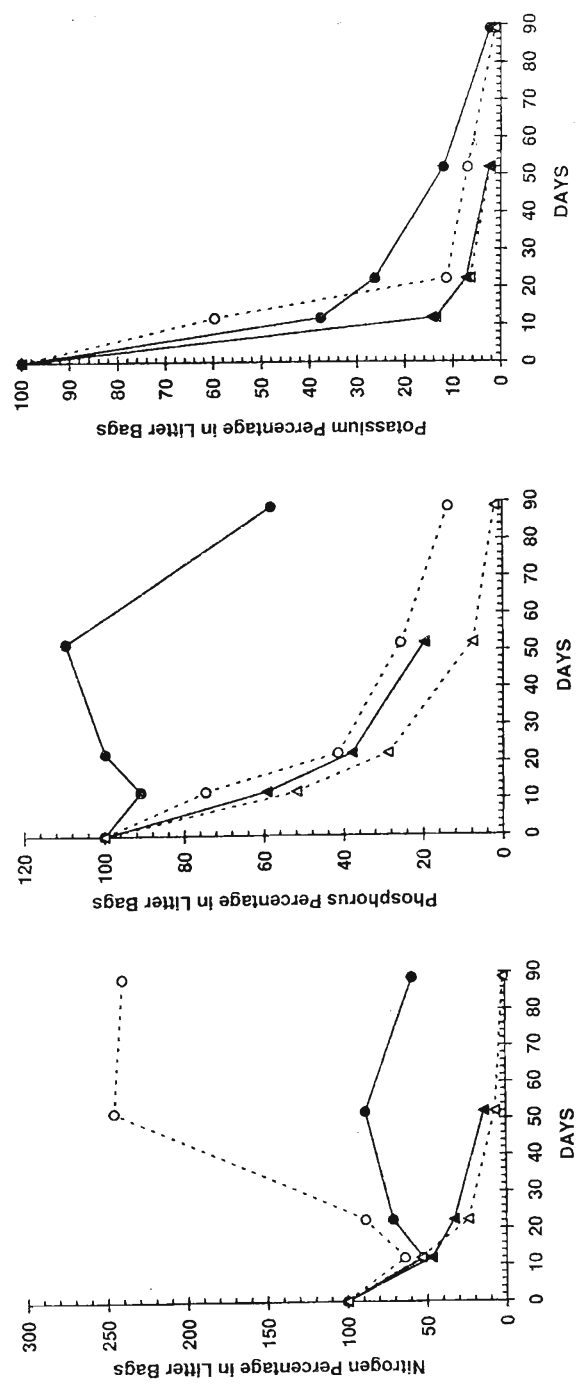

Figure 3: Percentage of remaining nitrogen, phosphorus and potassium in litter bags as decompositon proceeded. (●——● Dry leaves in the forest; o ------- o Fresh leaves in the forest; ▲——▲ Dry leaves in the estuary; Δ ------- Δ Fresh leaves in the estuary).

Table 1: Percentage of N, P and K in decomposing *Avicennia marina* leaves.

Type of leaves/ habitat	Decomposing time (days)	N	P	K
Dry	0	0.54	0.024	3.00
leaves	12	0.43	0.022	0.72
in the	23	0.37	0.019	0.44
estuary	52	0.22	0.016	0.22
Dry	0	0.54	0.024	3.00
leaves	12	0.32	0.021	1.30
in the	23	0.48	0.029	1.00
forest	52	0.77	0.042	0.50
	89	1.29	0.054	0.28
Fresh	0	0.26	0.072	2.22
leaves	12	0.23	0.063	0.56
in the	23	0.16	0.048	0.38
estuary	52	0.12	0.032	0.35
	89	0.05	0.018	0.30
Fresh	0	0.26	0.072	2.22
leaves	12	0.21	0.067	1.70
in the	23	0.44	0.052	0.50
forest	52	1.7	0.049	0.44
	89	2.41	0.036	0.11

Decomposition: It has been observed that litter decomposition rates exhibit habitat-specific and species-specific differences.[22] In this study, the decomposition of mangrove leaves in the estuary was higher than that on land similar to *Avicennia alba* and *Scyphiphora heterophyllacea* in the Philippines.[8,9] Dry mangrove leaves decay at a slower rate than fresh leaves as in other aquatic plants.[23]

The decay constant k can be used to compare decay rates, higher k-values being an indication of higher decomposition rates. Leaves are reported to have a higher k value than twigs and branches of the same species.[24] Besides environmental factors and leaf structure, k values may be influenced by the mesh size of the litter bags and the duration of the experiment. Some studies have utilised litter bags of mesh size, 1 mm,[24] 2 mm[25], 3 mm[26] and 7 mm.[4] While

the small mesh sizes reduce the role of crabs in decomposition, large mesh sizes enhance the leaching of leaf fragments in late decomposition. Size, morphology and texture of leaves are important in selecting the mesh size. Previous studies on *Avicennia marina* leaves have indicated that 1 to 7 mm mesh size is suitable for this species. In this experiment, the deviation from exponential decay equation, observed for the dry leaves in the forest is probably due to the late rapid leaching or the influence of some environmental factors. Decomposition is rapid during the first few months and more than 70% decomposition was completed within the first 90 days .

The k-values recorded for mangroves in this study are comparable with those recorded for macrophytes in Hudson Estuary, which ranged from 0.0024 in *Typha angustifolia* to 0.0133 in *Potamogeton* sp.[24] In spite of the less amenable leaf chemistry of mangroves for decomposition, compared to these macrophytes, the slightly higher k-values recorded for mangroves could be due to high ambient temperature in the mangrove habitat. Sedges and willows are reported to have high k values (k=0.261 to 0.316).[25] The k values recorded for rain forests of Sri Lanka are higher than those recorded for mangroves in the current study.[26] The reference to k-values in this study is indicative rather than conclusive, due to the small number of samples.

It takes only 3 weeks for 50% decomposition to occur in fresh leaves in Negombo Estuary, whereas for dry leaves in the forest it takes 9 weeks, indicating that, brushpile fishery enhanced litter decomposition. Both in Sri Lanka and in Thailand about 3 weeks were required for 50% decomposition of *Avicennia marina* leaves in water.[10] However, in the Philippines more than 8 weeks were required for 50% decomposition in dry *Avicennia alba* leaves.[9] For 50% decomposition in dry *Avicennia marina* it has taken 8 weeks in Sydney Harbour[4] and 6-8 weeks in New Zealand.[7]

Nutrients: N, P and K are essential elements for plants and are described as macronutrients. N and K percentages in *Avicennia marina* leaves recorded in this study are in the middle range of percentages recorded for terrestrial plants and P value towards the lower limit of the range.[27] *A. marina* leaves in the current study recorded lower percentages of N and P compared to those of *A. alba* in the Philippines[28] and *A. marina* in Australia,[29] but the K percentage was higher than that in the Philippines and Australia. Seedlings of *A. marina* are reported to uptake potassium preferentially over a wide range of external sodium concentrations.[30] Further, the same report stated that *A. marina* like *A. officinalis* is an obligate halophyte with optimum growth at salinity range of 58-290 mM chloride (50-250 mM sodium). From *A. marina* seedlings grown in culture solutions it was found that, potassium had an intermediate level of accumulation between the high sodium accumulation and the low calcium and magnesium accumulation.[31] Potassium accumulation was highest in 75% sea

water but low in 100%, 50%, 25% and 0% sea water. While physiological processes accumulated nutrients in different parts of the plant, the overall nutrient level in the entire plant may indicate the nutrient composition of soil and water. The knowledge of such information is useful to evaluate whether the relatively small size of mangrove plants in Sri Lanka is due to soil chemistry or other factors, such as low tidal fluctuation and paucity in tidal forest management.

In 7 Australian mangrove species namely, *Aegiceras corniculatum, Avicennia marina, Ceriops tagal, Excoecaria agallocha, Osbornia octodonta, Rhizophora stylosa* and *Xylocarpus australasicus*, nitrogen percentage ranged from 0.78 to 1.85, phosphorus percentage from 0.09 to 0.21 and potassium percentage from 0.48 to 1.79.[29] In the Philippines the percentage of nitrogen in leaves of *Avicennia alba, Ceriops decandra, Scyphiphora hydrophyllaceae, Excoecaria agallocha* and *Lumnitzera littorea* ranged from 0.52 to 1.03, phosphorus from 0.05 to 0.11 and potassium from 0.27 to 0.74. Percentages of N and P in the leaves of *Rhizophora apiculta* from Malaysian mangroves were comparable with those in the current study.[32] But the percentage of potassium in the leaves of *A. marina* from Sri Lanka, was higher than that of *R. apiculata* from Malaysia. The differences in the leaf nutrient percentages may be due to soil conditions, age, species and the leaf chemistry. For the analysis of Australian mangrove leaves, mature but not senescent leaves from North Queensland were taken.[29] In the Philippines, samples were collected from monthly litter accumulated in baskets.[28] In the current study, the dry leaves were picked from the forest floor, and the fresh leaves were plucked from trees. A decrease in leaf nitrogen during senescence and an increase in the absolute nitrogen of leaf litter during decomposition has been observed in the mangroves of Florida.[21]

Initial concentrations of elements in plant tissue vary from species to species. However, rate of leaching of a particular element from different species of plants generally remains the same, because of the way specific elements are incorporated in organic matter. As in previous studies with wetland species, potassium leached out of mangrove leaves rapidly.[25,33] Since potassium is not a structural part of plant tissues, rapid leaching of K is to be expected.

Similar to previous studies[10,14] nitrogen enrichment with decomposition, was observed for leaves in the forest after 7 weeks. Nitrogen and phosphorus enrichment is probably due to microbial activity while its initial drop could be due to the release of tannins that makes the colonisation difficult.[34] Nitrogen thus accumulated in the mangrove forest floor are reported to be flushed after rains, making about a 10-fold increase in estuarine nitrogen in Malaysia[35] but slight increase in estuarine nitrogen in Australia.[36]

Fresh leaves in the estuary released all the elements investigated at the fastest rate. Within one month, more than 90% of each element present in litter bags were released. Since the duration of a brushpile is also about a month, it is possible that the nutrients released during this period are utilised by phytoplankton and epiphytic algae in the brushpiles, which further attract fish. Juvenile fish that directly feed on mangrove material are few in this estuary as in the Philippines,[37] and restricted to a few families such as Syngnathidae.[38] But in the American mangroves, direct mangrove feeders including mullets have been reported.[39]

Probably a succession of fish and crustacean taxocenes occur with decomposition of mangrove leaves in the brushpile. This is evident from the fact that the dominant fish species in brushpiles after a month,[2] are different from those captured from areas where fresh mangrove leaf litter has accumulated, after tree felling in this estuary.[40]

Brushpile fishery also deprives the estuary of the benefits of N and P enrichment that occur, when leaves decompose in the forest. Some fishermen have the habit of leaving *Lumnitzera racemosa* twigs on land for sometime, so that plants shed their leaves, before using them in the brushpile. In such a situation, leaf decomposition takes place on land and twig decomposition takes place in water. Since mangroves are heavily exploited in the Negombo Estuary for brushpile fishery, studies are necessary to estimate the biomass of mangroves available, their growth and replacement rates and the current brushpile requirement. Alternatively, *Avicennia marina* and *Lumnitzera racemosa* can be planted in plots around the estuary, set aside for extracting twigs for brushpile fishery.

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