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Changes in Organic, Inorganic contents, Carbon Nitrogen ratio in decomposing *Avicennia marina* and *Rhizophora mucronata* leaves on tidal mudflats in Hajambro creek, Indus delta, Pakistan

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ABSTRACT

Leaf decomposition of *Avicennia marina* (Forskal) Vierh in Denkschr and *Rhizophora mucronata* (Poiret) was studied in situ using litterbags in Hajambro creek, Indus delta. A single exponential model was presented, which best described the rate of decomposition for both the species. The rate of decomposition was species specific, *A. marina* leaves decomposed slower than the *R. mucronata* ($p<0.001$). The time in days required for 50% loss of the initial dry mass (t1/2) was 49.55 days for the *A. marina* and 44.43 days in case of *R. mucronata* . The organic content in the leaves was high initially but decresed gradually during decomposition, which is negatively correlated with inorganic contents. This study will help in the management and conservation of mangrove ecosystem of Hajambro creek, Indus delta, Pakistan.

Keywords: : *Mangrove, Decompositiom, Indus delta, Mudflats, Avicennia marina, Rhizophora mucronata, Hajambro creek.*

INTRODUCTION

The productivity of the mangrove forests depends on the litter fall. The fallen mangrove litter on the forest floor is decomposed by the bacterial action and other organisms, as well as acted upon by physical, chemical and biological processes [1-6], and generate a continuous source of nutrients in mangrove ecosystem [7-10]. These nutrients ions (most importantly the ammonium, nitrate, nitrites) are finally available for primary production and this in turn supports a wide variety of consumers [5-6, 11-12]. The process of decomposition of mangrove leaves can be divided in three phases [3]. Substantial loss of carbon and nitrogen occurs within few days during early phase of decomposition, mainly by the microbial breakdown of the organic biomass [14]. Ultimately a considerable turnover of organic and inorganic materials occurs [14-15]. In the second and third phases of leaf litter decomposition, labile organic material and refractory structural components decomposed, all all of which is enhanced by physical and biological breakdown of the litter. The bacteria play the most important role in the oxidation of refractory constituents of the leaves, such as cellulose and lignin [13].

The nutrients released during decomposition are available for the primary productivity [1, 13, 16] and also become available for plant itself and are not lost from the system. There are various factors controlling rate of decomposition and energy release, such as, the degree and frequency of tidal inundation, soil temperature [17] and moisture [18], and the presence or absence of the litter-consuming fauna within mangrove forest [19-21]. Litter decomposition also increases soil fertility [23]. Mangrove swamps usually constitute a shallow ecosystem. The shallow coastal sediments are generally considered as important sites for the remineralization of organic matter [8-10, 23-27].

The main objective of this study was to assess the decomposition rate of mangrove litter and to study variations in the nutrient concentration in the adjacent creeks. A part of this study has been presented in [28, 29]. Further details of the research findings, which has been done for the first time in Hajambro creek, such as C:N ratio,

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organic and inorganic contents in *Avicennia marina* during the decomposition has been described here for the international viewers. The specific objectives are to determine the rate of decompo sition of mangrove foliage in the Indus delta mangrove forests and to determine the differences in decomposition rates of two different mangroves species, namely, *Avicennia marina* and *Rhiophora mucronata*.

MATERIALS AND METHODS

Study area

The study was conducted in the Hajambro Creek, Indus delta. The Indus delta is situated at 24º08'789" and 067º27'187"E (Hajambro channel) of Karachi coast approximately at the distance of about 170 Km from Karachi(Figure 1). The Indus River in Pakistan has the seventh largest delta supplied by eighth largest drainage area in the world [30]. During the summer monsoon seawater inundated both the active and inactive parts of the delta, leaving behind evaporated salt deposition during its retreat [28].

Assessment of leaf-litter decomposition rates

The decomposition of mangroves leaf-litter was studied using the litterbag technique reported by several scientists around the world [31-33]. Mature yellow senescent leaves of *A. marina* and *R. mucronata* were collected from the trees in March 2006 and air-dried. Known weight of leaf samples were than placed in nylon net bags (20cm x 25 cm of 1 mm mesh). Bags were incubated for 125 days in the rhizosphere among mangrove plants and retrieved at different intervals. Residual leaf material was carefully picked from the nylon bags, washed gently with distilled water and then oven dried at 70°C for 48 hours. Difference of initial and final weights gives the weight loss at each time interval. Ash free dry weight (AFDW) was determined by igniting the leaf material at 450°C for 8 hrs [32].

Total Nitrogen analysis

The total nitrogen in the decomposed material and the sediments was studies according to the micro-Kjeldhal method.

Total carbon extimation

The total carbon in the decomposed leaves fragment was estimated by the wet oxidation methods.

Total organic and Inorganic matter estimation in the decomposed leaves fragments

The total organic matter was estimated by ignited the known quantity of the decomposed fragments of the *Avicennia marina* leaves from the litterbags, at 550°C in muffle furnace for 4 hours. The difference in the initial weight of the dried residuals detritus material and the ash gave the quantity of the organic and inorganic quantity remains in the detritus mass of *Avicennia marina* decomposing leaves fragments.

Figure 1 Map showing location of Indus delta mangroves where study of decomposition of *Avicennia marina* and *Rhizophora mucronata* was carried out in the mudflatd of Hajambro creek.

Statistical analysis

The relation ship between percent AFDW remaining (Y) and sampling time (x) was determined by simple linear (Y=a+bx) as well as simple negative exponential (Y=aekt) models. The decomposition rate constant (k) was obtained from the regression models and the half life (t1/2)/k was calculated according to the equation t1/2=(ln2)/k.

RESULTS AND DISCUSSION

Decomposition of mangroves leaves

The decomposition pattern of both *A. marina* and *R. mucronata* showed a very rapid early loss of the biomass, followed by a slower and steady decrease for the remaining period of the experiment, (Figure 2 and 3). The early rapid loss appear to correspond with the leaching of soluble organic material from the leaf biomass, as reported earlier in different studies around the world [13, 21, 32, 34, 35].

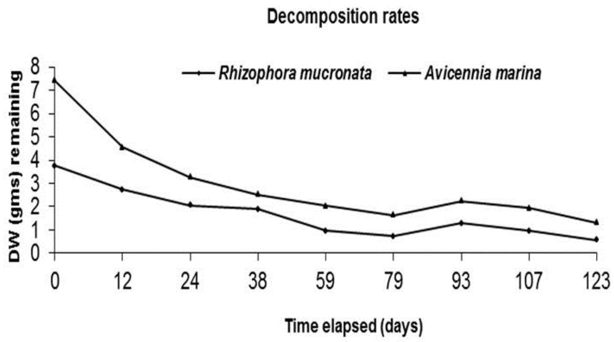

Figure 2 Mean gram dry weight remaining during decomposition of litter biomass of *Avicennia marina* and *Rhizophora mucronata* in Hajambro creek, Indus delta.

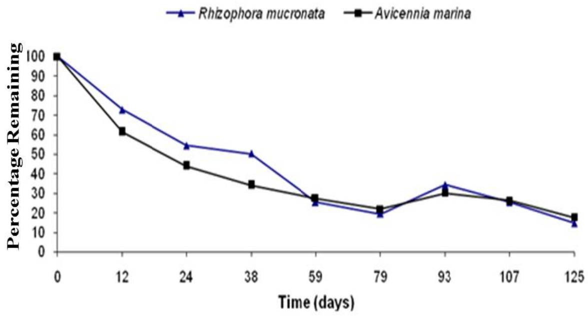

Figure 3 Comparative percent rate of decomposition of *A. marina* and *R. mucronata* leaves [28].

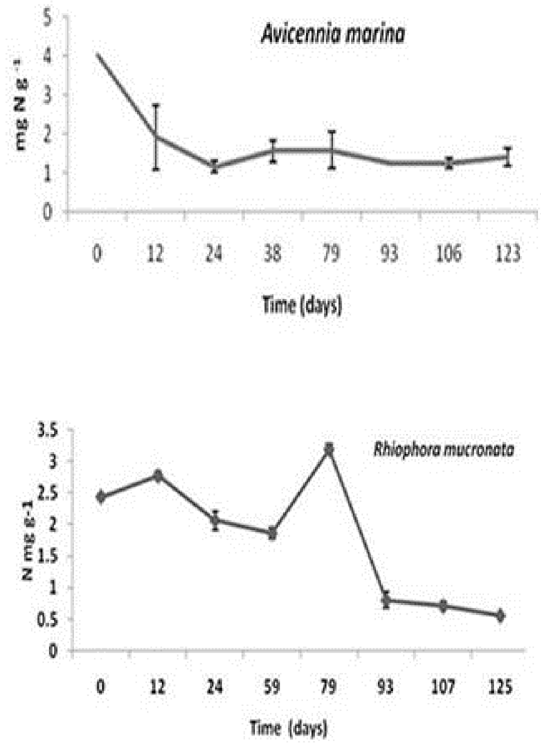

Figure 4 Changes in N concentrations (mg Ng^{-1}) during decomposition leaves of *Avicennia marina* and *R. mucronata*.

Table I. Simple Negative exponential regression equations (Y=aekx or Y=ln+Kx) on % of the litter mass and its nitrogen remaining in the litter bags (Y) against time (X) during decomposition of *A. marina* (Am) and *R .mucronata* (Rm)

Parameters	Plant species	Regression Equation	k (d^{-1})	$t_{1/2}$(d)
%AFDW remaining	*Am*	lnY=4.605-0.013988X	0.014	49.55
	Rm	lnY=4.605-0.0156X	0.016	44.43
%N remaining	*Am*	lnY=4.605-0.00629X	0.006	110.2
	Rm	lnY=4.605-0.0025X	0.003	81.55

(reproduced from [29] with permission).

Later on, the decomposition rate slows down due to the more resistant materials, such as cellulose and lignin, in the remaining leaf litter [13, 21]. Such decay patterns were better described by the simple negative exponential equations (Table I) rather than simple linear regression equations. The summary of the regression equations for both the species (A. marina and R. mucronata) were given in (Table I). Although R. *mucronata* and *A. marina* had significantly different regression slopes ($p<0.01$), patterns of decomposition were not different from each other. Analysis of the variance showed that there were highly significant differences in the percentage dry mass remaining between two species ($p<0.001$). Despite the similarity in litter decomposition pattern of the two species, the leaves of R. *mucronata* decomposed faster with a more rapid release of nutrients (nitrogen) than that of A. marina ($p<0.001$).

Table II Decay constant of Mangrove leaf litters of different species, from the research done around the world, for comparison with our recent study in Indus delta.

Geographical Location (season)	Mangrove species	Decay constant (per day)	Half-life (t_{50}) days	References
Shenzhen, China (summer)	*Aegiceros corniculatum*	0.0146	48	Tam *et al.* 1990
Shenzhen, China (summer)	*Kandelia candel*	0.0516	13	Tam *et al.*, 1990
Sai Keng Hong Kong (Winter)	*Aegiceros corniculatum*	0.0065	107	Lu and Lin., 1990
Fujian, China (Summer)	*Avicennia marina*	0.1155	6	Lu and Lin., 1990
Fujian, China (Summer	*Kandelia candel*	0.0385	18	Lu and Lin., 1990
Fujian, China (Winter)	*Avicennia marina*	0.0277	25	Lu and Lin., 1990
Fujian, China (Winter)	*Kandelia candel*	0.0124	56	Lu and Lin., 1990
Queensland, Australia	*Rhizophora stylosa*	0.0178	39	Robertson, 1988
Queensland, Australia	*Ceriops tagal*	0.0257	27	Robertson, 1988
St. Lucia Estuary, South Africa (Warm)	*Brugeria gymnorrhiza*	0.0123	56	Steinke & Ward, 1987
St. Lucia	*Brugeria gymnorrhiza*	0.0077	90	Steinke & Ward, 1987
St. Lucia	*Avicennia marina*	0.0120	58	Steinke & Ward, 1987
Victoria, Australia	*Avicennia marina*	0.0087	80	Van der Valk & Attiwill, 1984
Sydney, Australia	*Avicennia marina*	0.0124	56	Goulter and Allaway, 1979
Kunduchi, Tanzania	*Avicennia marina*	0.0045	154	Chale, 1993
Phuke Island Thailand	*Rhizophora apculata*	0.0173	40	Boonruang, 1978
New Zealand	*Avicennia marina*	0.0347	20	Boonruang, 1978
Florida, USA	*Rhizophora mangle*	0.0128	54	Fell *et al.*, 1975

About 90 % of the AFDW of the leaf litter of *R. mucronata* was lost from litterbags after 6 wk of decomposition (Figure 3 & 4). At the end of 6 wk of incubation, leaf materials of *R. mucronata* were difficult to identify and the residual material of homogenous texture remained inside the bags. Similar observations were also recorded by [34]. The decay constants of the *A. marina* and *R. mucronata* were found to be 0.097 and 0.109 Wk-1, respectively (Table I). Since leaves of both species were exposed to the same environmental conditions, so the differences in the decompo sition rates are probably due to the differences in the leaf morphology, texture and chemical composition. Differences in leaf quantity are known to affect decomposition rates [5, 21, 36]. Different decay constant had been recorded for different mangroves species in different geographical location and in different regions (Table II), probably due to the differences in the nitrogen and tannin contents [6, 13, 35, 37]. Plant material with a higher lignin contents or a higher C:N ratio are more refractory, and thus decompose more slowly than plant materials with relatively low lignin contents or a relatively low initial C:N ratio [13, 21, 35].

The total Carbon contents oin the decomposing *Avicennia marina* leaves showed high carbon contents initially, which gradually dereased towards the end of the experiment (Figure 5 & 6). *A. marina* leaves were reported to have comparatively lower initial C:N ratio (high nitrogen content) than *R. mucronata* [6, 38] and would be expected to decompose faster [39].

Later on, the decomposition rate slows down due to the more resistant materials, such as cellulose and lignin, in the remaining leaf litter [13, 21]. Such decay patterns were better described by the simple negative exponential equations (Table I) rather than simple linear regression equations. The summary of the regression equations for both the species (*A. marina* and *R. mucronata*) were given in (Table I). Although *R. mucronata* and *A. marina* had significantly different regression slopes ($p<0.01$), but patterns of decomposition were not different from each other. Analysis of the variance showed that there were highly significant differences in the percentage dry mass remaining between two species ($p<0.001$). Despite the similarity in litter decomposition pattern of the two species, the leaves of *R. mucronata* decomposed faster with a more rapid release of nutrients (nitrogen) than that of *A. marina* ($p<0.001$).

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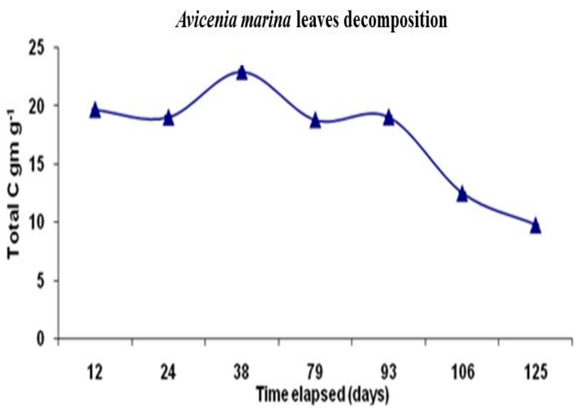

Figure 5 Change in concentration of C mg g-1 during decomposition of leaves of A. marina on tidal mudflats in Hajambro creek, Indus delta.

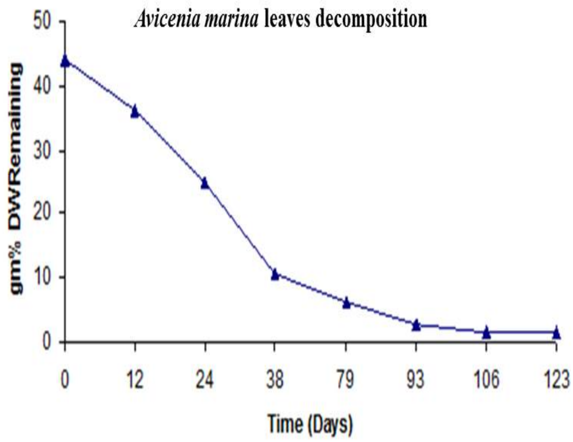

Figure 6 Percentage gram weight of organic carbon remaining during the decomposition in *Avicennia marina* leaves.

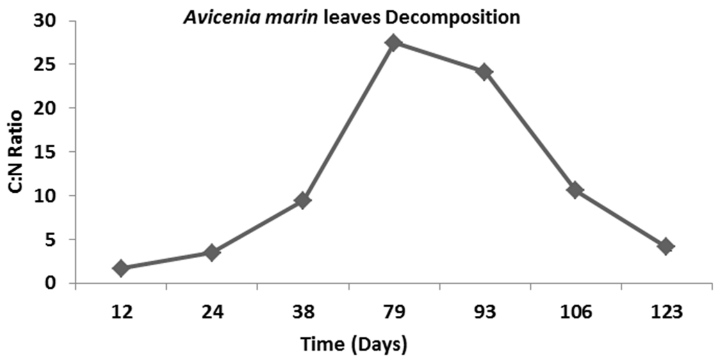

Figure 7 C:N ration the decomposing leaves fragment of *Avicennia marina*.

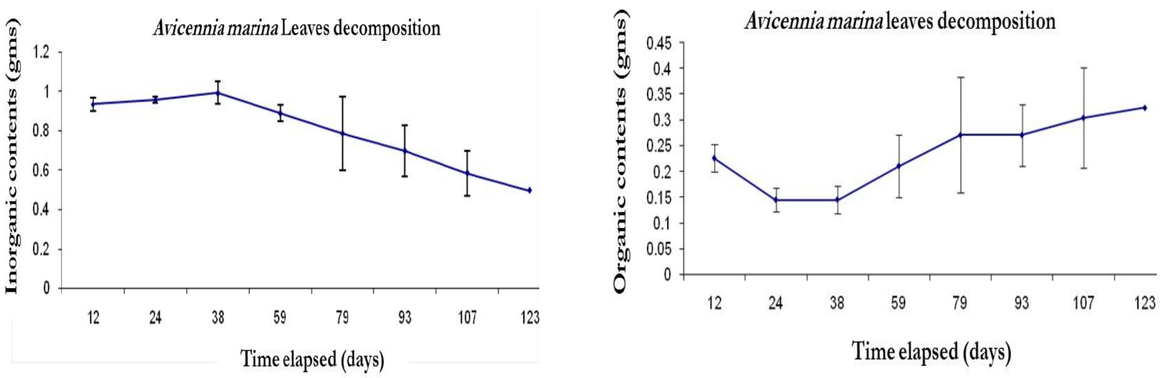

Figure 8 Relative change inorganic contents, from original biomass, in decaying mangroves leaves of *Avicennia marina*.

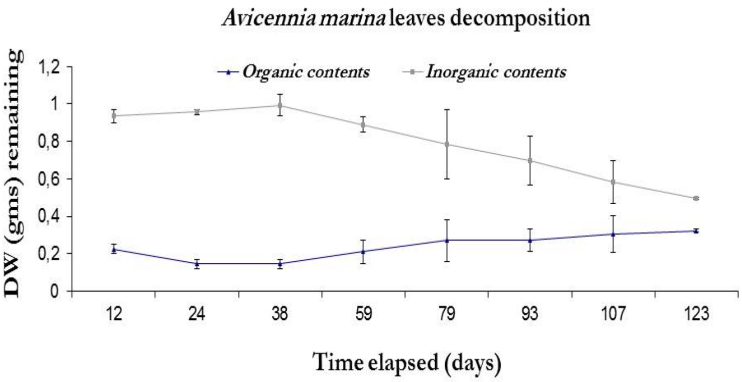

Figure 9 Comparsion of relative change in inorganic and in organic contents, from original biomass, in decaying mangroves leaves of *Avicennia marina*.

The C:N ratio in the decomposing Avicennia amrina has shown the similar results (Figure 7). The initial N content of leaves recorded in the present study for both species was similar. Therefore our result that R. *mucronata* decompo-ses faster as oppose to previous studies may be due to the lignin content in leaves of the two species. Moreover, leaves of *A. marina* have more conspicuous and well-developed fibers and sclereids than those of R. *mucronata* [13, 21, 34] and therefore reduce the decomposition rate as observed in the present study.

The relatively thicker leaves with a cuticle of *A. marina* and R. *mucronata* would offer resistance to degrading organisms, thus reduce the decay rate [32]. Initial N content of both species was low and showed increases probably due to microbial colonization (Figure 4).

The litterbag method may underestimate actual decomposition but will reflect trends and allow comparison among species and sites [39]. The mesh size of the bags allows small invertebrates, fungi and bacteria to access to decaying leaves, but the large invertebrates, such as, crabs which are a major competitor in leaf degradation [34, 35], are excluded. The role the large macro-invertebrates in breakdown of mangrove leaf was investigated by [2] through leaf tethering experiments. There are many other factors that also contribute to the rate of decompo sition of detritus, such as salinity and aerobic/anaerobic conditions [40], soil redox potential [41], total organic nitrogen concen trations related to heterotrophic activity [13, 21, 35], exposure to the sun (air & soil temperature) [17] and desiccation (tidal inun-dation) [21]. During decomposition significant amount of nutrients [35] and organic matter [42] release from leaf detritus, which support forest productivity and food web.

C:N ration in decomposing leaves of Avicinnia marina

The relative C:N ratio was low initially and than increased during the phase of decomposition and than again lowered down (Figure 7).

Relative change in Organic and Inorganic matter

The organic matter was low initially but gradually increased during decomposition of *Avicinnia marina* leaved (Figure 8 & 9), while the inorganic contents in the decomposing leaves was high and gradually decreased towards the end of the experiment (Figure 8 and 9).

CONCLUSION

In summary, the present study suggests that *R. mucronata* leaves decomposes at a faster rates compared to *A. marina*. Niitrogen values of the detritus increases due to microbial colonization. Dissolved and particulate matter released from decomposing leaf material.

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