MANGROVES OF KETI-BUNDER, INDUS DELTA: A PRESENT STATUS

Zafar Farooqui
Center of Excellence in Marine Biology, University of Karachi
Government Degree Boys College, KMC-Store, Nishtar Road, Karachi

Abstract

The paper is the part of recent thesis submitted to Institute of Karachi. The topic of thesis is ‘*studies on mangrove ecosystem with respect to biodiversity, productivity and nutrients dynamics”*. *In this paper we present the* present status of Indus delta mangroves with rspect to the present studies done by the author. The present research article constitutes a report of litter production and decomposition rates of Avicennia marina and Rhizophora mucronata leaves from Hajambro creek, Indus delta located near active Indus river mouth and compared. The total litter production was 4.78 tonnes ha^{-1} $year^{-1}$. Extrapolating the data for the whole mangrove covered area in the Indus delta; the figure comes to about 1.2×10^6 tone y^{-1}. The percent contribution of different components of the litter varies, with leaf-litter being the most dominant component (about 50 %) of the total litter biomass. The rate of decomposition was species specific, *A. marina* leaves decomposed faster ($p<0.001$) than the *R. mucronata*. The time in days required for the loss of the initial dry mass (t50) was 49.55 days for the *A. marina* and 44.43 days in case of *R. mucronata*. The initial loss may represent the leaching of dissolved organic matter. The results showed that the breakdown of the leaf litter is species dependent.

Keywords: Mangrove, indus delta, productivity, biodiversity, litter production, decomposition rates, avicennia marina, rhizophora mucronata

Introduction

Research in Pakistan

Mangroves of the Pakistan have received limited attention and studies have been limited to only accessible areas, mostly near Karachi. The preliminary assessment of family *Aviceniacae* was assessed by Jafri (1966). Pakistan had many as eight mangroves species (Saifullah, 1982, Saifullah et al 1994, Siddiqui et al. 2008), but at least four species (*Brugeria conjugata*, *Ceriops roxburghianna and Sonneratia casiolaris*) appear to have been extinct from Pakistan due to changes in the environmental conditions. Today only four species (*Avicennia marina, Aegiceros corniculatum, Rhizophora mucronata*, *Ceriops tagal*) occur naturally, of which the *A. marina* is the most dominant species (Siddiqui *et al.*2008) covering 90% of mangrove-covered forest areas.

Mangroves of Baluchistan are sporadic and confined only in few pockets at Miani Hor, Kalmat Khor, and Jiwani (Gawatar Bay) (Siddiqui et al. 2008). Preliminary survey of the forest structure of Blauchistan (Makran) coast has been reported (Saifullah and Rasool, 1993, Rasool and Saifullah, 1996, WWF Report 1995).

The ecological studies, such as, on the distribution and abundance of mangroves (Mirza, 1983) and litter production and decomposition (Siddiqui and Qasim 1986) was started in 1980s. Mirza (1983) showed using remote sensing data that 2.6 million hectare is covered by mangroves in the Indus delta. Latter on Mirza (1988) also conducted remote sensing studies on mangroves of Indus Delta to give an overall picture of total distribution of mangroves covered areas. Pioneering work on litter production and decomposition in mangroves at Karachi backwaters has been done by Siddiqui (1986), Siddiqui and Qasim (1986 & 1988). Biochemical composition of mangroves foliage (Qasim et al, 1986) and inorganic constituents of mangroves leaves (Ilyas et al, 1989) have been reported. Benthic metabolism and sulphate reduction in mangrove soil in Pakistan has been studied (Ahmed, S.I et al, 1993). In addition, two recent studies (Shafeeq, 2006 and Farooq, 2006) have studied in detail litter production and decomposition, nutrient release in the mangrove environment (Sandspit) and its ecology and also on the biogeochemical processes in the mangrove sediments.

A number of studies are available on the identification and distribution of fauna and flora in mangrove environment in Pakistan. These reports include studies on bacteria and Cyanobacteria (Nuzhat, et al, 1995; Siddiqui et al 2000); algae (Saifullah and Rasool, 1988, Saifullah and Taj, 1995), phytoplankton (Harrison, et al, 1995); zooplankton (Huda and Ahmad, 1988); mollusk, such as telescopium (Barkati and Tirmizi, 1988), clam (); crabs ….; Avifauna (Karim, 1988); fishes of mangroves area (Ahmad, 1988). A report on antibacterial activities of *Avicennia* (Atiq-ur-Rehman, et al. 1995) and mangrove oil (Nuzhat, et al, 1995) showed the importance of mangrove in the pharmaceutical industry.

Mangroves forests of induc delta

The Indus delta, stretching from Karachi to the south-east to Sir Creek near Indian border, is comprised of 17 major creeks, numerous minor creeks, and extensive areas of mudflats and mangroves forests () is considered as seventh largest delta supplied by eighth largest drainage area in the world (Wells and Coleman, 1984). Indus River has shifted its course from Gharo-Phitti creek system to current location in the Khobar creek. The former have now become abandoned tidal creeks with full strength seawater. Salinity of the active Indus delta (Khobar creek) remains high during most of the dry period when downstream discharge is mostly obstructed by the dams and dikes uphill. Salinity in the delta reduces only in the flood condition (i.e. July – September).

The Indus River delta is ranked fifth largest semi-arid mangrove area in the world (Siddiqui et al 2008, Senadaker). Existing estimates show that 97% mangroves covered (approximately 0.26 million hectare) in Pakistan in the delta region (Mirza et al 1988). Only three species (*Avicennia marina*, *Aegiceros corniculatum*, *Rhizophora mucronata*) are currently present, of which the *A. marina* (salt tolerant species) is the most dominant species. *Rhizophora* species has been extinct and efforts are being made to rehabilitate this species in the Indus delta. *Rhizophora*, however occurs as natural forest in mangrove forests along Balochistan coast.

Mangroves forest along the Sindh coastal areas have been reported to have undergone tremendous stress and destructions owing to the climatic as well as the anthropogenic changes during recent past and hence the mangrove covered area decreased drastically (Farooqui *et al*, 2012).

As mentioned above, Indus delta mangroves have been ignored largely due to inaccessibility, despite the fact that these forests have undergone extensive deforestation. Grazing by the camels and significant reduction of the downstream discharge of freshwater appeared to be the major factors in this regard. Following the restrictions imposed by the Sindh Forest Department on camel grazing, in the pat few years, in the areas around Ket-Bunder emergence of new natural forests along with the planted species of mangroves (*A. marina* and *R. mucronata*) are quite evident (Siddiqui et al. 2008). If the deforestation, both grazing and cutting of trees, can be controlled and reduced sufficiently, a very drastic natural regeneration of mangroves can be achieved (Siddiqui et al. 2008).

Reduction in freshwater has been considered as the factor impacting mangroves. Runoff from Indus River has been reduced over past few decades and now only during flood seasons (summer) some water in the Indus delta finds it way down the Kotri-Barrage into the creeks near Ket-Bunder (Penatt J.C 1993), at this time salinity in creeks which usually remains between 40 and 42 pot, reduced to 15 ppt in Hajambro creek near Ket-Bunder, or even lower (7-9ppt) in creeks near Khobar, the main drainage site of the Indus (Siddiqui *et al* 2008). Similarly the suspended loads in the creeks also enhanced, as expected, during this period. It ranged between 100-1250mg l^{-1} in Hajambro Creek and Channels around that area (Siddiqui *et al.* 2008). Much lower values (100-180 mg L^{-1}) have been recorded earlier from Isaro Creek during non-flood period (Harrison et al 1997). Indus River Indus is needed to flow into the coastal areas not only for freshwater but most importantly for sediment flux to replace sediments withered during SW monsoon.

Main objective of the study

The main objective of the study was to understand the ecology and plant response in the fifth largest mangrove forests in the Indus delta. The current research had its specific focus on the assessment of productivity (litter production), litter decomposition.

Material and method

Area discription

Sandspit is located between Manora Island and Hawksbay at 24 ^{o} 50’ N and 66 ^{o} 56’E while the Hjambro creek is situated at 24^{o}08’789” N and 067^{o}27’187”E of Karachi coast. The Indus River in Pakistan has the seventh largest delta supplied by eighth largest drainage area in the world (Wells & Coleman, 1984). During the summer monsoon seawater inundated both the active and inactive parts of the delta, leaving behind evaporate salt deposition during its retreat.

Climatic data

Climatic data, such as, temperature, humidity, and wind speed, were obtained from Meteorological Department, Government of Pakistan for the study period and used to assess the impact of climatic factors on the rate of litter production.

Litter production

The litter production study was carried out in two areas along Indus delta from April 1999 to March 2000 (Sandspit backwater) and during April 2005 to March 2006 (Hajambro creek). The traps made up of PVC pipe frame (25 x 25 cm) and fitted with conical nylon bags (1 mm^2 mesh), were used for the collection of mangrove litter. Three sets containing three traps each were fixed randomly and secured under mangrove trees in such a way that traps remain vertically upright and bags suspend above the high tidal water mark. The litter collected in the traps was recovered bimonthly over a period of one year. The content of each trap was carefully removed and placed in separate polythene bags and brought to the laboratory where it was sorted into different component (i.e., leaves, twigs, flower, fruits and other miscellaneous). All components were dried at 70^{0}C for 48 hours and weighed. The weight of the total litter and of each component produced in nine traps was averaged and calculated as tones per hector per year.

Statistical analysis

Pearson correlation coefficient was used to evaluate the differences in total litter fall rate with reference to physic-chemical parameters. Statistical analysis was performed using the Minitab 14 software.

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 (Siddiqui & Qasim, 1988; Tam, *et al.* 1990; Shafique, 2006). 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 ^{o}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 (Tam, *et al.* 1990). The total nitrogen in the decomposed material and the sediments was studies according to the micro-Kjeldhal method.

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 ($Y=ae^{kt}$) models. The decomposition rate constant (k) was obtained from the regression models and the half life ($t_{1/2}$)/k was calculated according to the equation $t_{1/2}$=(ln2)/k.

Results

Assessment of litter production in indus delta

Litter production (leaf, fruits flowers and twigs) in the mangrove forests at Hajambro creek was observed throughout a year. A distinct seasonal pattern in total litter fall was observed at both sites (Fig. 1) with a lowest value in January and peaks in July . The average total litter production in the region would be 4.57 tonnes h^{-1} y^{-1} (4.35 tonnes h^{-1} y^{-1}; SB and 4.8 tonnes h^{-1} y^{-1} HC).(Fig 1 and 2).

The production of various litter components, such as, leaves, twigs, flowers, fruits and miscellaneous, also vary seasonally at both stations. The percentage contribution of different components of the litter contributes highest portion 60 % (HC)) of the total litter biomass. However, low values were observed form from May to June., due to high production of fruit and flowers. It is interesting to note that two peaks were recorded (in August to September and February to March) (Fig. 1, 2 and 3). On the other hand, twigs, flowers, fruits and Miscellaneous components contribute respectively about 12%, 28%, 5%, and 4.438% . Flowering season appear to showing highest flower-litter in June h 5.53 gm day^{-1} (Fig 1,2 and 3).

Similarly, maximum fruits litter was collected in August (1.39 gm day^{-1}). (Fig. 1, 2 and 3). Twigs fall was maximum in Jun, with 1.17 gm produced per day. The miscellaneous unidentified components appear to vary greatly through the year with maximum in May (0.54 gm day^{-1}) .

Climatic data obtained from Meteorological Department shows seasonal variations in wind speed, air temperature and % humidity. Only wind speed appear to have a significant positive correlation (r^2= 0.7) with total litter production.

The seasonal pattern of the litter production (the main part of this thesis, has been expressed in Fig 3, and the pie-chart is shown in Fig 4 representing percentage of various components of litter.

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, (Fig 5). 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 (Steinke *et al*. 1983, Valiela, *et al.*, 1985; Robertson, 1988; Tam *et al*. 1990; Steinke *et al*. 1993b). Later on, the decomposition rate slows down due to the more resistant materials, such as cellulose and lignin, in the remaining leaf litter (Valiela, *et al.* 1985; Robertson, 1988). 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* ($p<0.001$). About 90% of the AFDW of the leaf litter of *R. mucronata* was lost from litterbags after 6 wk of decomposition (Fig 5). 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 Steinke *et al.* (1983). The decay constants of the *A. marina* and *R. mucronata* were found to be 0.097 and 0.109 Wk^{-1}, respectively (Table I).

Discussion

Litter production

In the present study, leaf litter contributed 50-60 % in the total litter fall, which agrees with the data reported by Steink & Ward (1988). The present study at SB and an earlier study conducted at the same site (Siddiqui & Qasim, 1990) show differences in the production rate indicating variation in litter production in different years. This could be due to variation in different environmental parameters, such as growth condition, height of the tree, salinity, temperature, evaporation, wind speed and nutrient input, etc., which regulate the production rate (Lugo & Snedaker, 1974; Leach & Burgin, 1985; Woodruff, 1982; Pinto, 1992; Slim *et al*. 1996; Shanula and Whittick, 1999; Ake-Castillo *et al.* 2006). Generally, litter production values for mangrove forests worldwide range from 2 to 16 t ha^{-1} per year (Twilley & Day, 1999). Tree height (growth condition) has been particularly considered as one of the major controlling factors in litter production by Woodroffe *et al.* (1988) who categorized the production rate and tree height relationship. For example, tree height exceeded 10 m produces litter upto 8 $t.h^{-1}.y^{-1}$ and lower litter production (3 $t.h^{-1}.\ y^{-1}$) has been attributed to a dwarf mangrove stands (Woodroffe *et al.* 1988). Comparing this data with the present study where tree height, for example, is between 10-15 m at SB, the rate of litter fall (4.35 $t.h^{-1}.y^{-1}$) appeared to be lower than expected considering the tree height. On the contrary, height of the trees at HC corresponds to dwarf type mangroves but the total litter production (4.8 $t.h^{-1}.y^{-1}$) reported here is slightly higher than what is suggested for dwarf mangrove (Woodroffe *et al*. 1988). This suggests that there ought to be some other factors than tree height which influence the litter fall, such as wind speed, fresh water input and climatic conditions, etc. Our result also shows a significant positive correlation between litter production and wind speed (r^2= 0.7). Therefore, it may be suggested that wind speed is more dominant factor than tree height in controlling the litter production in this area.

The present study constitutes first report on litter production in the mangrove forests of Indus Delta. Two sites that are compared in this study show seasonal variations in the total litter production with highest fall in autumn (September/October). The total litter fall at both the stations is more or less the same, but the flowering season appears to differ at both stations. Leaf litter constitute the major component of the total litter production throughout the year. On the other hand, flower and fruit production remain confined only to a specific period, but contribute significantly to the observed peak in that period.

Mangroves leaves decomposition

Since leaves of both species were exposed to the same environmental conditions, so the differences in the decomposition 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 (Robertson, 1988; Basuguren and Puzo, 1994; Twilley *et al.* 1997). Different decay constant had been recorded for different mangroves species in different geographical location and in different regions, probably due to the differences in the nitrogen and tannin contents (Van der Valk & Attiwill 1984; Valiela, *et al*. 1985; Steinke, *et al*. 1993b; Wafar, *et al*. 1997). 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 (Valiela, *et al.* 1985; Robertson, 1988; Steinke, *et al*. 1993b). *A. marina* leaves were reported to have comparatively lower initial C:N ratio (high nitrogen content) than *R. mucronata* (Rao, *et al.* 1994; Wafer, *et al.* 1997) and would be expected to decompose faster (Wieder and Lang, 1982). The initial N content of leaves recorded in the present study for both species was similar. Therefore our result that *R. mucronata* decomposes 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* (Valiela, *et al.* 1985; Robertson, 1988; Steinke *et al.* 1993) 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 (Tam *et al.* 1990). Initial N content of both species was low and showed increases probably due to microbial colonization (Fig 6).

The litterbag method may underestimate actual decomposition but will reflect trends and allow comparison among species and sites (Wieder and Lang, 1982). 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 (Steinke *et al.* 1993a,b), are excluded. The role the large macro-invertebrates in breakdown of mangrove leaf was investigated by Ashton (1999) through leaf tethering experiments. There are many other factors that also contribute to the rate of decomposition of detritus, such as salinity and aerobic/ anaerobic conditions (Mall, *et al*. 1991), soil redox potential (Alongi, *et al.* 1998), total organic nitrogen concentrations related to heterotrophic activity (Valiela, *et al.* 1985; Robertson, 1988; Steinke *et al.* 1993b), exposure to the sun (air & soil temperature) (Mackey and Snail, 1996) and desiccation (tidal inundation) (Robertson, 1988). During decomposition significant amount of nutrients (Steinke *et al*. 1993b) and organic matter (Lu & Lin, 1990) release from leaf detritus, which support forest productivity and food web.

Acknowledgement

The first author (Zafar Farooqui) greatly acknowledges the support of Higher Education Commission Pakistan for providing the Indigenous PhD Scholarship (300 Scholars programme; PIN NO IKB 0349090). The people of center of Excellence in Marine Biology, University of Karachi are also acknowledged for their hospitality and logistic support during the study. The Metrological department was highly acknowledged for providing the metrological data of the area.

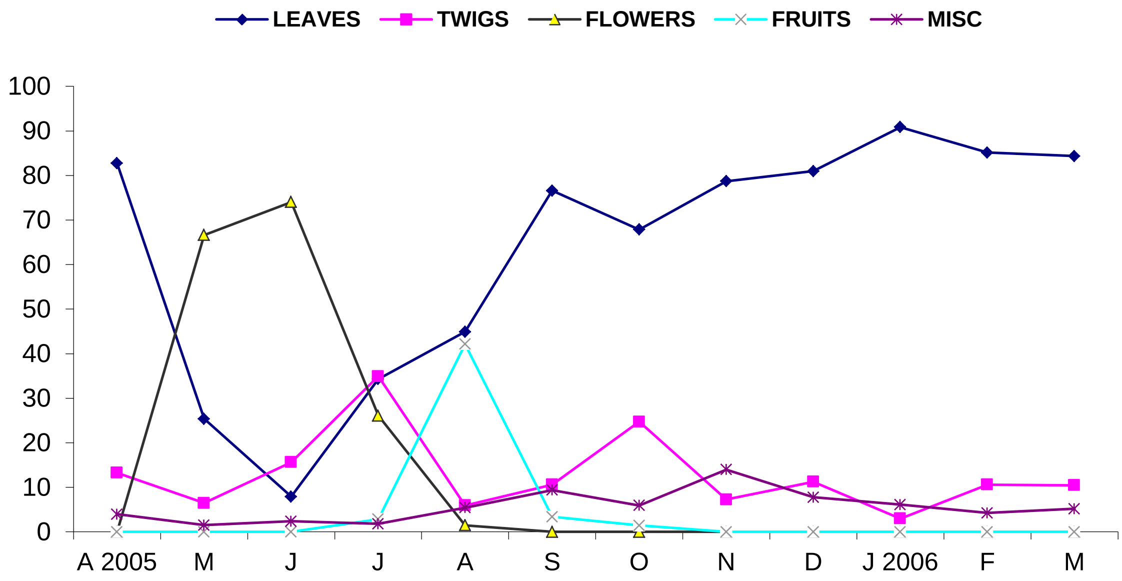
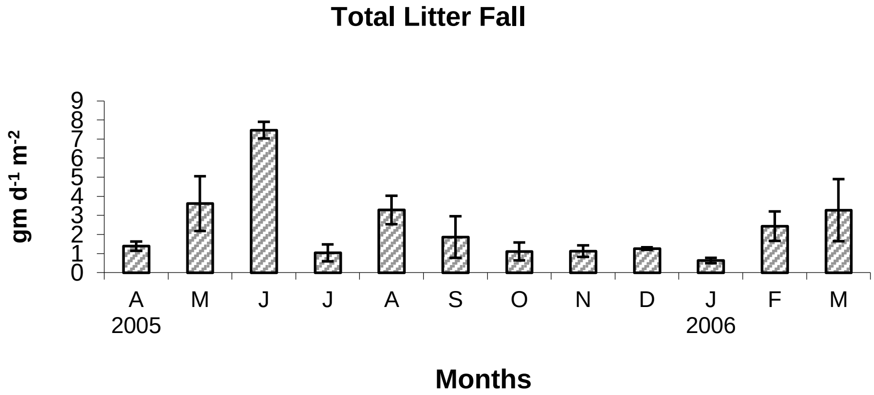
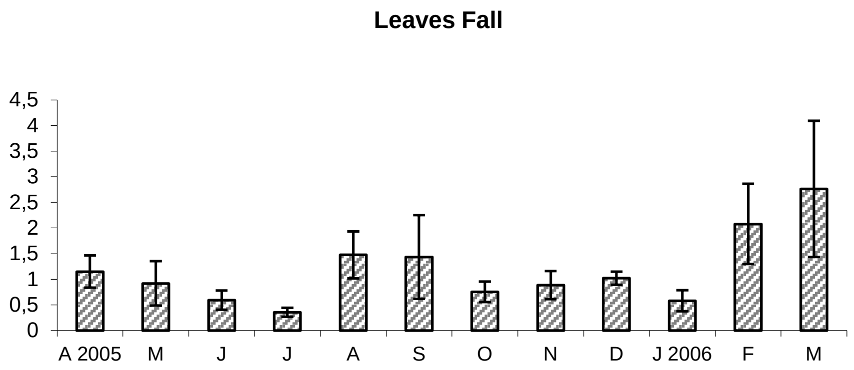


Fig 1. Changes in the contributions of various litter components to total litter Production throughout 2005-2006 in active Indus deltaic area, Pakistan.

Figures of litter production





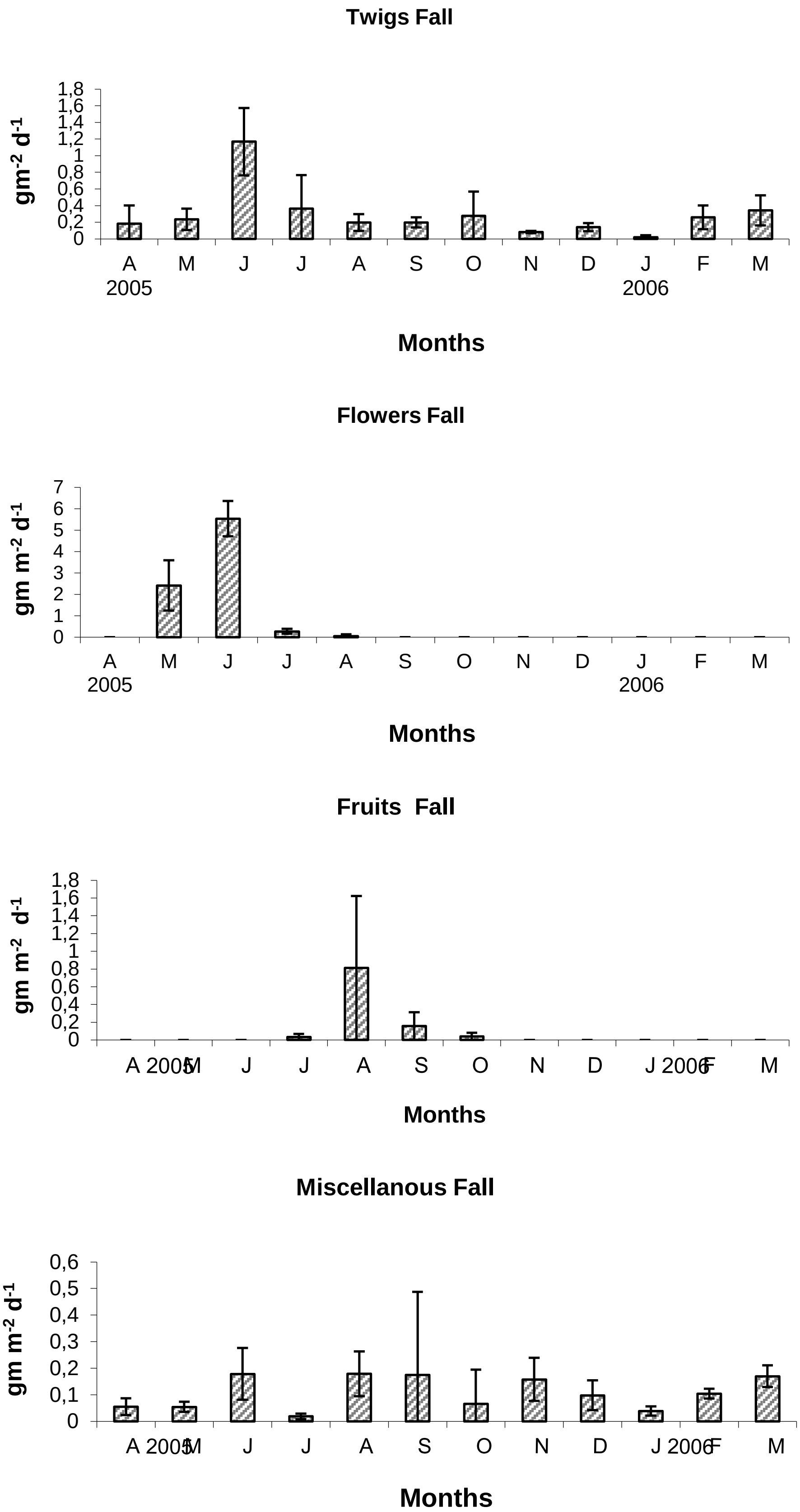


Fig 2 Monthly variation in the daily fall rate of various components of litter in the active Indus deltaic Area, Pakistan. (Values are mean (±SD)).

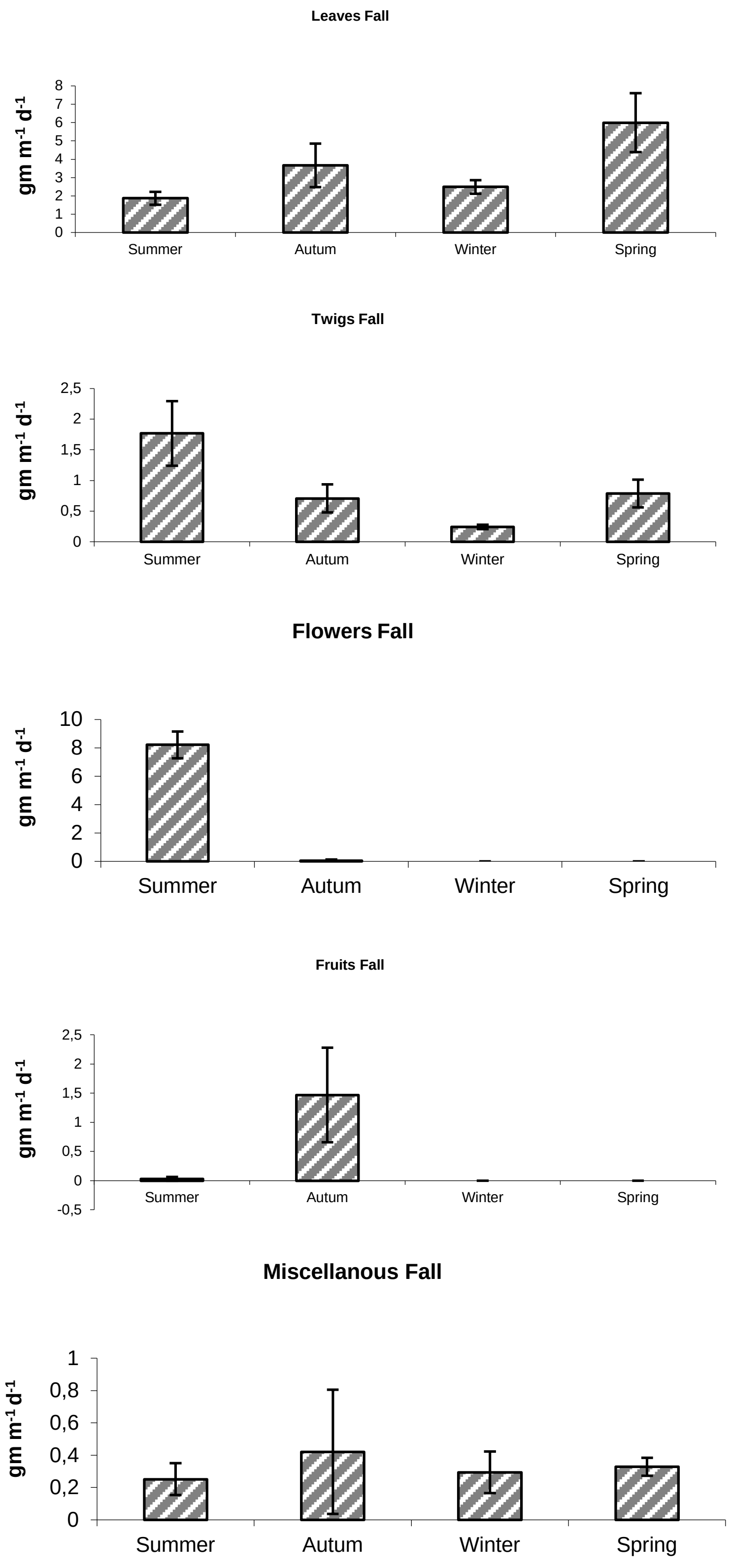


Fig 3. Seasonal variation of total litterfall and its different components.

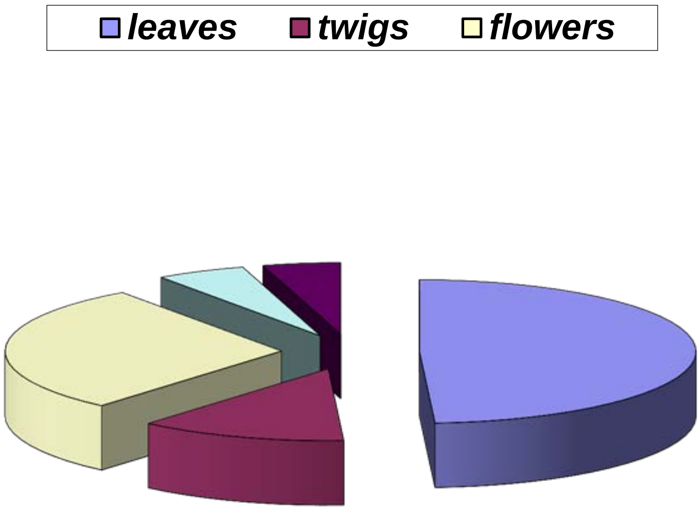


Fig 5. Pie chart representing percentage compositions of different components of litter for Year 2005-2006, studied in Keti-Bunder area at active Indus delta, Pakistan

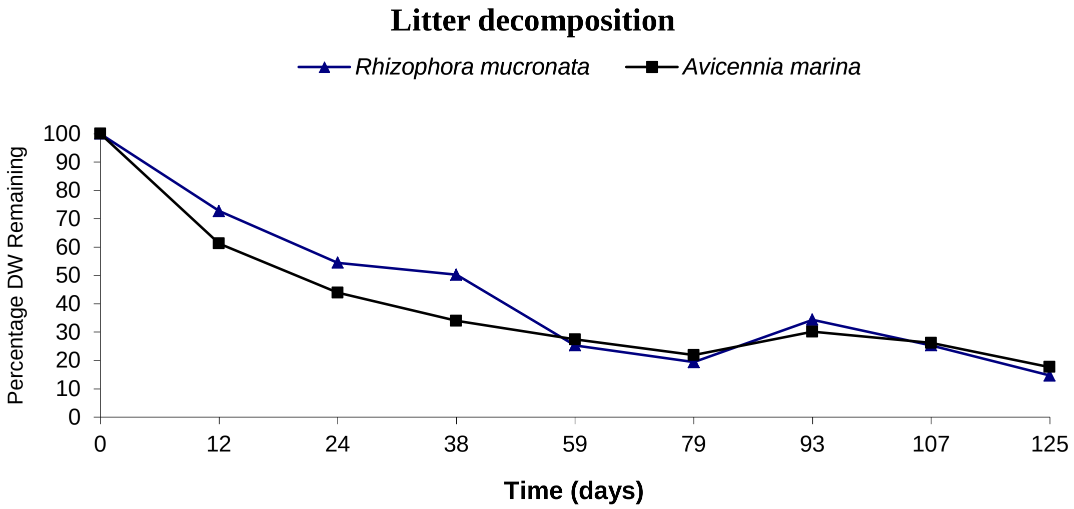
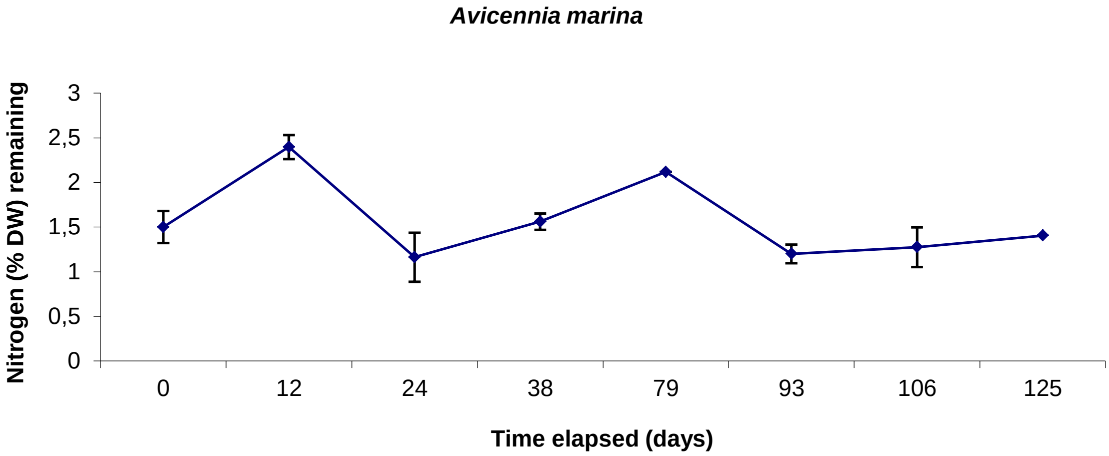


Fig 5. Comparative percent rate of decomposition of *A. marina* and *R. mucronata* leaves.



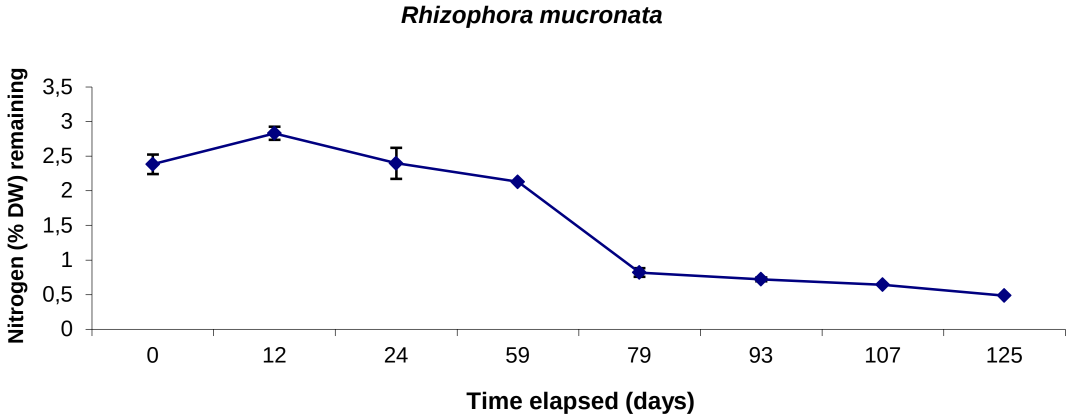


Figure 6. Total nitrogen (%DW) remaining in the residual leaf in the bags, during the process of decomposition

Tables

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