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ASSESSMENT OF LITTER PRODUCTION IN SEMI-ARID MANGROVES FORESTS NEAR ACTIVE INDUS RIVER MOUTH (HAJAMBRO CREEK) AND KARACHI BACKWATERS, PAKISTAN

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Abstract

Litter produced in mangrove forest includes vegetative and reproductive part of the plants, which forms a primary source of organic biomass available as food to a wide variety of commercially important detritus feeding organisms inhabiting the mangrove forests. Litter production studies in Pakistan have previously been carried only at Sandspit backwaters. The present study constitutes a report of litter production from Hajambro creek (HC), Indus delta located near active Indus river mouth and Sandspit backwaters (SB), Karachi coast. A distinct seasonal pattern in total litter fall was observed at both locations. The total litter production was 4.57 tones $ha^{-1}y^{-1}$. Extrapolating the data for the whole mangrove covered area in the Indus delta, the figure comes to about 1.2 x 10^6 tones y^{-1}. The lowest value was observed in January (HC) and February (SB), being the driest season, while the maximum value for litter fall was observed in June (HC) and September (SB), southwest monsoon season. The percent contribution of different components of the litter varies, with leaf-litter being the most dominant component (57% at SB and 50 % at HC) of the total litter biomass. Low values of leaf-litter were observed during flowering and fruiting seasons (from July to September at SB and from May to June at HC). The twigs, flowers, fruits and other unidentified components contribute about 12.1%, 28 %, 5% and 4% (HC) and 9%, 3%, 18% and 12% (SB), respectively. Wind speed appear to have a significant positive correlation (r^2= 0.7) with total litter production.

Introduction

Mangrove swamps are one of the most productive ecosystems of the world with regards to gross primary productivity and litter production (Lu *et al.,* 1988; Kalio, 1992; Harrison *et al.,* 1994; Day *et al.,* 1996). It is ranked second only to highly productive coral reef ecosystem in terms of productivity and tertiary yield in tropics (Christensen, 1978; Qasim & Wafar, 1990). Litter produced in mangrove forest includes vegetative and reproductive part of the plants, which forms a primary source of organic biomass available as food to a wide variety of commercially important detritus feeding organisms inhabiting the mangrove forests (Odum & Heald, 1975; Duke, 1988; Slim *et al*., 1996; Betoulle *et al.,* 2001). The litter biomass remineralizes and provides energy and nutrient to organisms in the mangrove ecosystem tropically supported by a complex food chain (Odum *et al.,* 1973; Aksornkose and Khemnar, 1980; Ake-Castillo *et al*.., 2006). Measurement of true primary productivity is difficult. However, litter fall has been widely used as an indicator **(**Mall *et al.,* 1991; Chale 1996; Tam *et al.*, 1998; Arreola-Lazarrga *et al.,* 2004).

Litter production in mangrove ecosystem appears to be a continuous process that occurs during both dry and wet seasons, showing considerable seasonal variations (Siddiqui & Qasim, 1990; Mall *et al.*, 1991; Wafar *et al.,* 1997; Clough *et al.,* 2000). Rate of litter production is generally affected by geographical location, type of forest and sediments, water stress during hot and dry periods, high winds and storms and fresh water drainage (Golley *et al.,* 1962; Gill & Tomlinson, 1971; Lugo & Snedaker, 1974; Goulter & Allaway, 1979; Cox & Allen, 1999). These factors contribute to variable litter productivity among forests consisting of different species and among same species located at different geographical locations. This can be clearly seen in Table 1 where litter production in mangrove forests of the world is compared.

In Pakistan largest mangrove covered area of 86,727 ha is located in the Indus delta, South west of Karachi (Anon., 2005). Pakistan has fewer mangrove species. Karachi backwaters form a wide belt behind the sandy beach of Sandspit stretching from Hawksbay to Manora channel. Backwaters consists of monospecific (*Avicennia marina*) mangrove forest with tall trees having thick canopies. Balochistan coast that extends from Karachi (CapeMonze) towards the west has only sparse mangrove vegetation exhibiting mix population of *A. marina, Rhizophora mucronata* and *Ceriops tegal* with *A. marina* being most abundant species (Saifullah & Rasool, 1995; Saifullah, 1993).

Litter production studies in Pakistan have previously been carried only at Sandspit backwaters (Siddiqui & Qasim, 1990; Siddiqui & Shafique 2000). Litter production from Indus delta has not been reported. Therefore, the present study constitutes a first report of litter production from Indus delta (Hajambro creek) located near active Indus river mouth. Here we compare litter production in Indus delta with production in mangroves at Karachi coast studied in 1988 and 2000. Seasonal pattern of productivity was correlated with climatic factors prevailing in the area (Table 2).

Material and Methods

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.

Table 1. Rates of litter production in mangrove forest inhabiting by different mangrove species from various part of the world.

	Location	Litter production tones h^{-1} y^{-1}	Resource
	Genus: Avicennia		
A. marina	Pakistan	3.71	Siddiqui & Qasim (1990)
	Australia	2	Goulter & Allaway (1979)
	Tanzania	12	Shunula & Whittick (1999)
A. germinata	Terminos	1.15-3.03	Day *et al.*, (1996)
	Guyana	17.71	Chale (1996)
A. nitida	South Florida	0.8-12.7	Pool *et al.*, (1975)
A. nitida	Puerto Rico	4.9	Lugo & Snedaker (1974)
A. officinalis	Dona Paula	9.05	Wafar *et al*., (1997)
Avicennia sp.	Sydney	4.58	Goulter & Allaway (1979)
	Kenya	8.58	Gwada & Kalro, 2001
	Kenya	6.2	Ochieng & Erftemeijer 2002
	Australia	2.3	Woodroffe *et al*., (1988)
	India	10.2	Wafar *et al*., (1997)
	India	6.53	Dehairs *et al*., (2000)
	Australia	9.22	Mackey & Smail (1996)
	Mexico	1.75	Arreola-Lizarraga *et al*., (2004)
	Florida	4.8	Lugo & Snedaker (1974)

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.

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^oC for 48 hours and weighed. The weight of the total litter and of each component produced in nine traps was averaged and calculated as g m^{-2} d^{-1} and then converted into tons per hectare per year.

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

Table 2. Litter production at Sandspit back waters and Hajmbro Creek in *Avicennia marina*.

Litter components	Sandspit backwaters litter production (tons.$h^{-2}Y^{-1}$)	Sandspit backwaters litter production (tones. $h^{-2}Y^{-1}$)	Hajmbro creek Litter production (tones. h^{-1} Y^{-1})
	Year 1990**	**Year 1999-2000*****	**Year 2005-2006**
Total leaves	2.73	2.28	2.91
Total twigs	-	0.18	0.57
Total flower	-	0.73	0.77
Total fruits	.95*	0.82	0.23
Other/miscellaneous	-	0.34	0.29
Total litter fall	3.71	4.35	4.78

* Shows that Miscellaneous includes the twigs, flowers and fruits
** Siddiqui & Qasim (1990)
*** Siddiqui & shafique (2000)

Results

Litter production of leaf, fruits flowers and twigs in the mangrove forests at Hajambro creek (HC) and Sandspit backwaters (SB) 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 (HC) and February (SB) and peaks in June (HC) and in September (SB).

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).

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 (50% (SB) and 60 % (HC)) of the total litter biomass. However, low values were observed from July to September at SB and from May to June at HC, respectively, due to high production of fruit and flowers. It is interesting to note that only one peak of total leaf fall (in October) was observed at SB, where as two peaks were recorded at HC (in August to September and February to March) (Fig. 1). On the other hand, twigs, flowers, fruits and Miscellaneous components contribute respectively about 12%, 28%, 5%, and 4.438% at HC and 5.7%, 9%, 4%, 18% and 12% at SB. Flowering season appear to differ slightly at the two study sites showing highest flower-litter in June (HC) and August (SB) with 5.53 gm day^{-1} and 0.41 gm day^{-1}, respectively. Similarly, maximum fruits litter was collected in August at HC (1.39 gm day^{-1}), and in September at SB (1.42 gm day^{-1}) (Fig. 1). Twigs fall was maximum in June at both the stations with 1.17 gm (HC) and 0.29 gm (SB) produced per day. The miscellaneous unidentified components appear to vary greatly through the year with maximum in May at HC (0.54 gm day^{-1}) and in September at SB (0.72 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 (Tables 3 & 4)

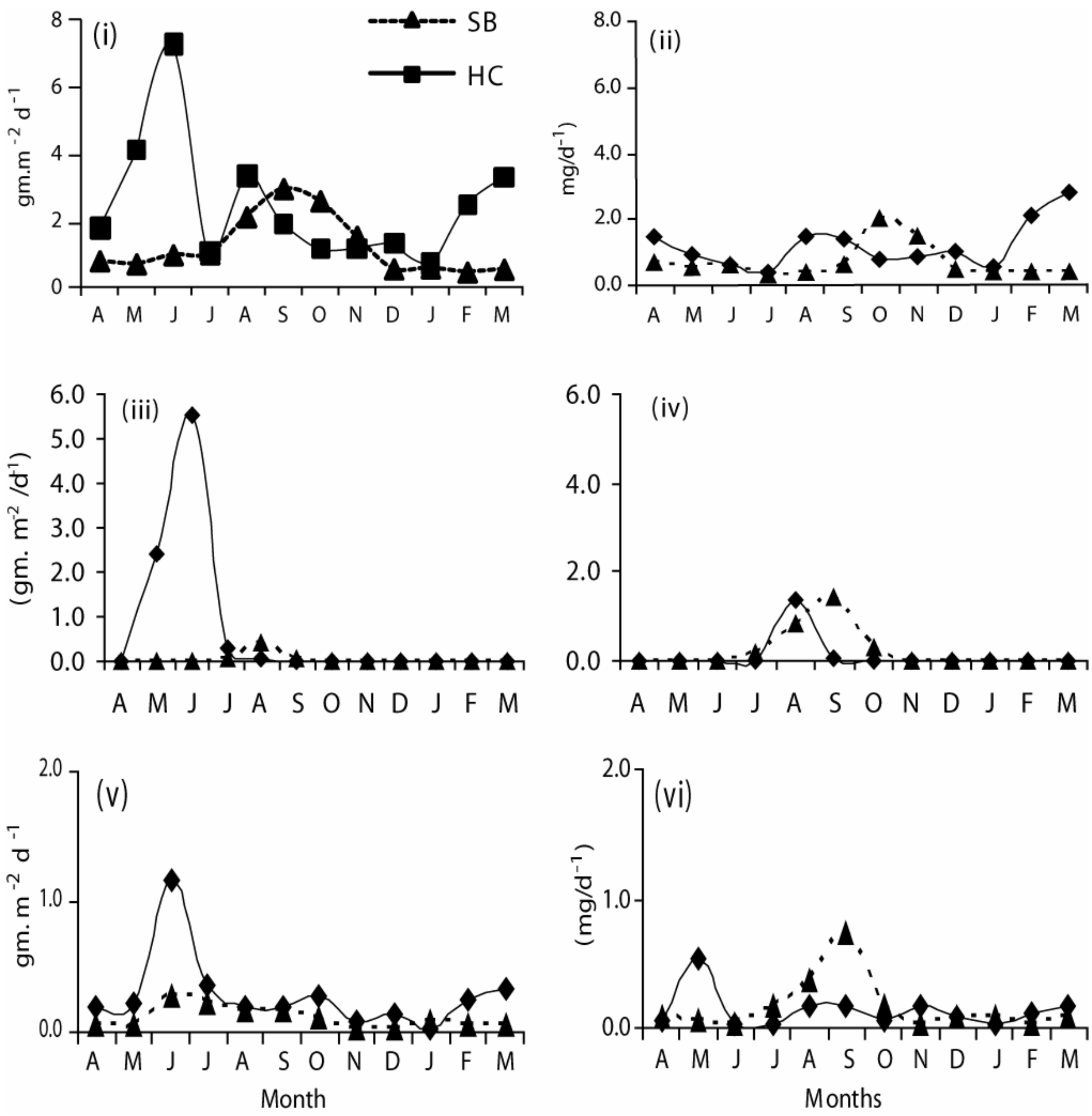

Fig. 1. Comparative studies of the litter production and its different component (i) total litter fall (ii) total leaves fall, (iii) total flower fall, (iv) total fruits fall, (v) total twigs fall and (vi) other miscellaneous at Hajambro creek (HC) and Sandspit backwaters (SB) areas along Sindh coast of Pakistan.

Table 3. Pearson correlation coefficient matrix showing relationship between total litter fall and environmental parameter at Hajmbro backwater.

	Total litter fall	Temperature	Humidity
Temperature	0.495		
Humidity	0.161	0.097	
Wind speed	0.721*	0.571	0.396

*=Significant at probability 0.05

Table 4. Pearson correlation coefficient matrix showing relationship between total litter fall and environmental parameter at Sandspit backwater.

	Total litter fall	Temperature	Humidity
Temperature	-0.181		
Humidity	0.483	-0.583	
Wind speed	0.682*	-0.232	0.578

*= Significant at probability 0.05

Discussion

In the present study a distinct seasonal pattern in litter production was observed in the mangrove stands at both sites of HC and SB. This is in agreement with reports from various parts of the world for India (Wafar *et al.,* 1997; Deharis *et al.,* 2000), Malaysia (Steinke & Ward, 1988), America (Pool *et al.,* 1975), Australia (Woodroffe *et al.,* 1988, Goulter & Allaway, 1979), Kenya (Gawada & Kairo 2001) and Vietnam (Nga *et al.,* 2005). A major peak observed in September (highest fall) at SB appears to be a cumulative effect of highest leaf and fruit fall, whereas at HC the highest value for litter production in June corresponds to high flower production. A minor peak in April (SB) and May (HC) for total litter fall is in good agreement with Siddiqui & Qasim (1990). On the basis of present data an estimated total of 1.13 X 10^6 tonnes of mangrove litter is produce annually in the Indus delta. The total mangrove covered are in the Indus delta was taken as 86,727 ha (Anon., 2005).

In the present study, leaf litter contributed 50-60 % in the total litter fall which agrees with the data reported by Steinke & 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 (Heald, 1971; Lugo & Snedaker; 1974; Leach & Burgin, 1985; Juman, 2005). Generally litter production values for mangroves 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 10-15m at SB, the rate of litter fall (4.0 $t.h^{-1}.y^{-1}$) 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 (4.7 $t.h^{-1}.y^{-1}$) 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 liter 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.

This is the first study reporting litter production in the mangrove forests of Indus Delta. Two sites are compared in this study showing 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 differs at both stations. Leaves constitute the major component of the total litter production. The flower and fruits production confined only specific period of the year but contribute significantly to the observed peak in that period.

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