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DETERMINATION OF CARBON AND NITROGEN IN LITTER FALL OF MANGROVE ECOSYSTEM IN PENINSULAR MALAYSIA

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Abstract

Mangroves in Peninsular Malaysia are typical of tropical forest setting. Nevertheless, the state of the mangrove forests has led to various classifications; natural and degraded mangroves. The study aimed to utilize litter fall (production and standing crop) potential as a means of evaluating the degree of productivity of the mangrove types across seasons, in addition to determining the abundance of carbon and nitrogen in the Peninsular mangrove forest. Leaf litter accounted for more than 70% of the total litter production in both natural and degraded mangroves, and the peak month for such production was December; 82.7% and 82.2%, for Sungai Haji Dorani and Kuala Selangor Nature Park, respectively. The degraded mangrove recorded higher concentration of total N (6.16 mg/g) than the natural mangrove forest (5.60 mg/g) at significant level. However, the organic carbon (CO) content across the litter parts varied with the three seasons. The CO of leaf litter was at the peak during the dry season, however, analysis on the branch and fruit revealed that during the intermediate and wet seasons CO level could be higher than the concentration observed at dry season. Though, the study concluded that both mangrove types in Peninsular Malaysia showed high similarity in the degree of litter production, yet the identified differences suggest that counter measures need to be adopted in order to protect mangroves from degradation and possible productivity loss.

Key words: Mangrove; Carbon; Nitrogen; Litter production; Litter standing crop.

Introduction

Litter fall (production and standing crop) is fundamental to ecosystem process due to its importance in for organic matter production and decomposition cycle. From a global point of view, mangrove is a highly productive ecosystem that is not only known for its primary productivity, but also recognized for export of organic matter and support for variety of aquatic life (Woodroffe, 1982). Litter fall is highly required in energy and nutrients cycle in the woodland ecosystem (Guo *et al.*, 2006). Through tree harvesting, litter fall adds nutrient to the soil, thereby encouraging land use sustainability. In as much as it is technically difficult to obtain direct methods of measuring primary productivity in mangrove forests, Bunt *et al*. (1979) utilized the extrapolation of litter production data for the generation of net primary production.

This is to infer that litter from mangrove swamps potentially represents a significant organic input to the sea, especially where the swamps are extensive, such as on the west coast of the Peninsular Malaysia (Sasekumar & Loi, 1983). Geographical location is found to influence mangrove productivity. This is because litter production and breakdown rate do not only vary with species but also geographically (Guo *et al.*, 2002). In fact in the tropics, mangrove swamps achieve their highest structural and floristic diversity; hence litter production rates in the temperate region are less than in the tropical setting (Woodroffe, 1982). Estimates of litter production have been reported for some mangrove forests around the globe. Leaf litter production in Florida and Central America was 2 g m^{-2} day $^{-1}$ (dry weight), (Lugo & Snedaker, 1974), Heald, 1971 reported a total litter of 2.4 g m^{-2} day $^{-1}$ (Heald, 1971); in Queensland it ranged from 1.04 to 5.26 g m^{-2} day $^{-1}$ (Duke*et al.*, 1981); and Sasekumar & Loi (1983) recorded from 3.5 g m^{-2} day $^{-1}$ to 6.72 g m^{-2} day $^{-1}$ in mangrove forest zones of Peninsular Malaysia. Despite the importance of mangrove forests, much attention has not been given to litter production. Similarly, none of the literature has viewed litter fall from the angle of evaluating both natural and degraded mangroves. Mangrove forests significantly play a key role in the storage of atmospheric carbon mainly by storing organic C in living and dead biomass, thereby reducing effects brought about by greenhouse gases (Khan *et al.,* 2007). However, it is worthy to note that the level of C storage in soil is about two or three times more than that of atmospheric C that is found as CO_2 (Davidson *et al.*, 2000). Similarly,nitrogen uniquely influences mangrove productivity, and it is the major source in below-ground biomass (Alongi *et al.*, 2003). Hence, it is deduced that mangrove forests constitutes efficient sinks for organic C and N, and even essential nutrients that ensure increased rate of plant growth (Holguin *et al.*, 2001). While some mangrove forests are pristine, some have experienced degradation due to anthropogenic activities like building resorts, fishing etc., thereby making them degraded mangrove forests. The study was designed to utilize litter fall (production and standing crop) potential as a means of evaluating the degree of productivity of the mangrove types across seasons, in addition to determining the abundance of carbon and nitrogen in the Peninsular mangrove forests.

Materials and Methods

The study areas, Sungai Haji Dorani (SHD) (03° 40′ N and 100°58′ E) and Kuala Selangor (KSNP) (03° 20′ N and 101°14′ E) are both located in the Selangor state of Peninsular Malaysia on 35 ha and 95 ha, respectively (Fig. 1). Both areas are characterized by humid tropical climate with mean annual rainfall of 1701-1710 mm. SHD experiences a semi–diurnal tidal regime whereas KSNP is inundated only during the spring high tides. The study areas show consistent weather pattern defined by three climate seasons: the dry season (April to September), wet season (October to December) and the intermediate season (January to March). At relative humidity average of 77%, the zones experience mean annual temperature of 27.3-27.7ºC under the influence of northeast monsoon and southwest monsoon situations. These areas exhibit a great diversity in tropical vegetation which varies markedly on individual species; SHD the degraded mangrove (*Avicennia marina, Bruguiera cylindrica, Excoecaria agallocha, Xylocarpus mekongensis*and *Sonneratia alba*) and KSNP the natural mangrove (*Avicennia officinalis, Bruguiera parviflora, Rhizophora mucronata* and *Sonneratia alba*) (Hemati *et al.*, 2013).

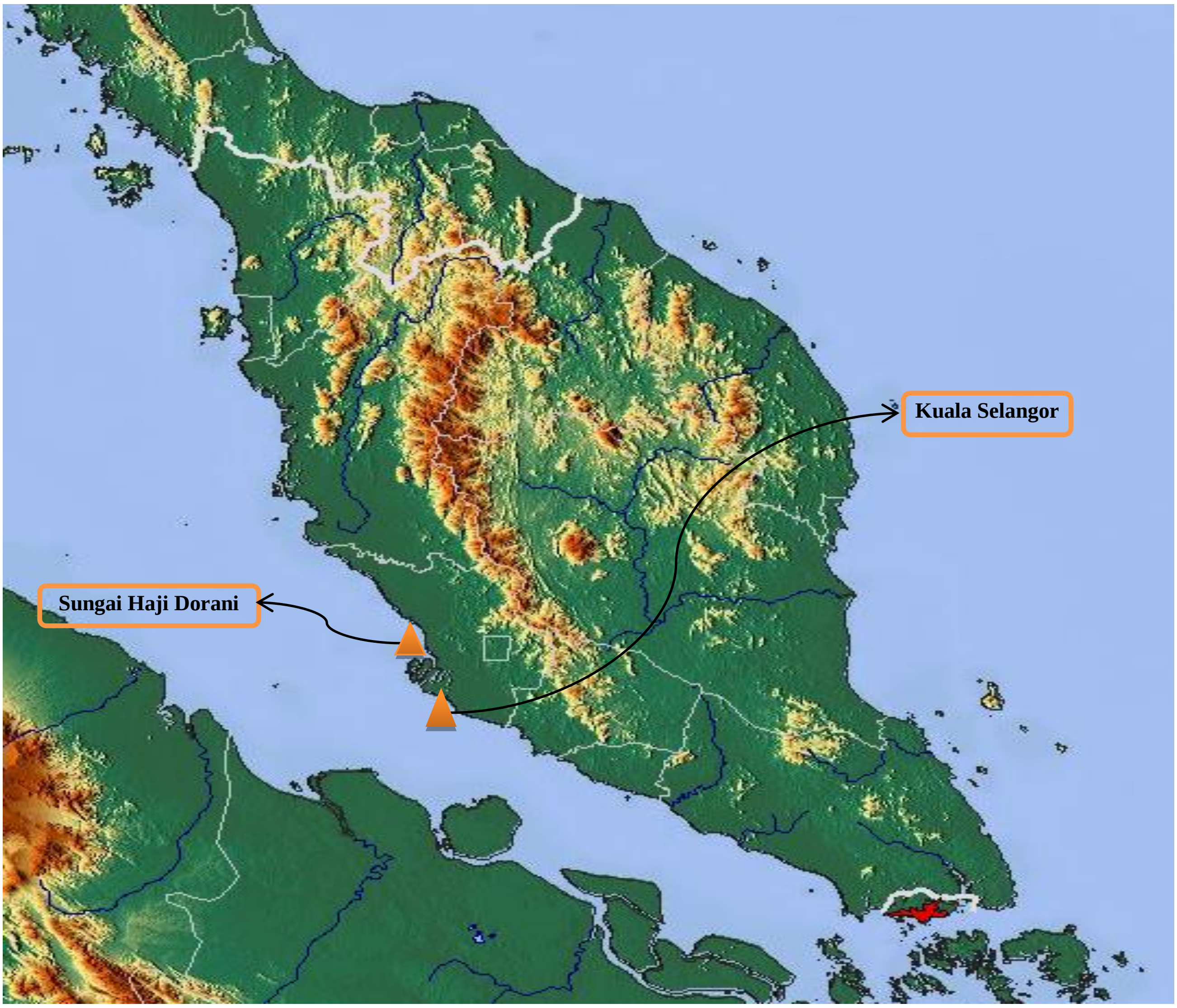

Fig.1. Map of Study areas.

Litter production: The used Quadrants (1m) (the plastic net) were suspended with nylon ropes between trees at 2m heights from the ground level so as to avoid effects from high tides. In each of the mangrove forests, fifteen quadrants were set up randomly. Sampling was undertaken from August, 2012 to the end of July, 2013. A total of twelve collections were made in each station on monthly basis. Collected Litters were oven dried at 65˚C for four days and eventually weighed (Mahmood *et al.*, 2003). It is worthy of note that prior to drying of litter, the total litter was discretely sorted into various litter components. While converting total amounts for each station to daily figures, no correction were made to accommodate leaching or other losses. The ensuring total litter falls for the twelve collections were correlated with the three seasons that characterized Peninsular Malaysia, namely; dry, wet and intermediate seasons. All samples were analyzed for organic carbon using Walkey-Black (1934)method. Total N concentrations were determined with a high sensitivity CHN analyzer. Three replicates were measured for each sample.

Litter standing crop: For the collection of litter standing crop at individual site, a total of fifteen plots, each 1m × 1m were taken randomly by quadrate sampling method on the forest floor through the seasons; the dry (August 2012), wet (November 2012), and intermediate (April 2013) seasons. From each individual sample plot, all litter standing cropcompositions(leaves, small branches and fruit) were collected. Collected litter standing crop samples were washed to remove dirt and sediment parts. Samples were oven dried at 65° C for four days to get the oven-dry weight. The oven-dried litter standing crops were then separated into different parts (leaves, small branches, flower, seeds, and fruit) and the corresponding weights were recorded. After measuring such weights, the means of sample plots were calculated for individual sites at each season. Some sub-samples (200g or 500g) were taken from all the components of litter standing crop**.** These sub-samples were crushed and pulverized, before being sieved through 2 mm mesh for the determination of carbon in the samples.

Results and Discussion

Production of litter at both mangrove forests was observed throughout the year (Table 1). Though there was high proximity in pattern of distribution across the months, distinct seasonal variation in litter production was observed in the mangrove stands at both study areas. This is in agreement with reports from various parts of the world for Pakistan (Zafar *et al.*, 2012), India (Wafar *et al.*, 1997; Dehairs*et al.*, 2000), Malaysia (Steinke & Ward, 1988), America (Pool *et al.*, 1975), Australia (Woodroffe *et al.*, 1988, Goulter & Allaway, 1979), Kenya (Gwada & Kairo, 2001) and Vietnam (Nga *et al.*, 2005).

Leaves and branches accounted for the largest part of the litter produced throughout the year which is typical of previous studies (Sasekumar & Loi, 1983). Similarly with more than 70% of the total litter being leaf, it can be attributed to the type of tree distribution in the mangrove area which includes leafy trees like distribution as observed during the dry season (averaged 61.39%). 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 (Clough *et al*., 2000; 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. High proximity in distribution was found between wet season and intermediate season as their average values were 78.53% and 72.97%, respectively in KSNP. However evaluating the leaf litter distribution across individual months of the year, December was found to be the peak period for both mangrove forests; 81.63% and 85.29%, for SHD and KSNP, respectively. However, when the natural and degraded mangrove were compared in term of leaf litter production, least value 34.76% was collected in the natural mangrove (KSNP) while about 35.9% was found in the same month (July) at SHD which is a degraded mangrove forest. In SHD, the trend of leaf litter fall showed a continuous increase from September until December but reduced from February to May.

Flower litter was not a significant part of the total litter production for both mangroves from June to December and this is attributed to the non- flowering period of the mangrove trees. However, they became part of the total litter from January and increased until April and May. Therefore, the presence of flower litter is highly limited to intermediate season in mangrove forests of Peninsular Malaysia regardless of natural or degraded status of the mangrove. Sequel to flowering period is seed production in trees; hence the absence of propagule in the litter from October until March is accounted for by the plant cycle.

Therefore, dry season is the peak of propagule litter production in both mangrove forest; 55.13% and 56.04 % for SHD and KSNP respectively, in the July. Bracts which were the very small leaves attached to the trees, were also parts of the litter production through the year. Peaks for bracts litter were found at the early wet season and mid intermediate season but the least distribution was found in dry season especially in July wherein 4.22 % and 4.31 % were obtained in SHD and KSNP, respectively.

Table 1. Litter production in both study areas (2012-2013).

Year	Month	Leaves (%)		Branches (%)		Flowers (%)		Bracts (%)		Propagule (%)	
		SHD	KSNP	SHD	KSNP	SHD	KSNP	SHD	KSNP	SHD	KSNP
2012	Aug	50.2	55.2	13.1	8.1	0.0	0.0	4.9	3.9	36.7	32.9
	Sep	63.0	66.1	18.7	19.3	0.0	0.0	14.8	8.9	3.4	5.5
	Oct	72.4	72.7	14.8	12.5	0.0	0.0	12.6	14.7	0.0	0.0
	Nov	78.5	77.5	12.4	11.3	0.0	0.0	9.0	11.3	0.0	0.0
	Dec	**81.6**	**85.2**	12.4	5.2	0.0	0.0	5.9	9.4	0.0	0.0
2013	Jan	79.1	79.2	11.5	2.2	1.5	7.9	8.1	10.5	0.0	0.0
	Feb	74.8	69.1	11.4	12.0	3.1	3.8	10.5	14.9	0.0	0.0
	Mar	70.8	70.5	13.0	13.3	5.0	5.4	11.1	10.9	0.0	0.0
	Apr	70.8	72.5	13.2	11.4	6.0	5.3	7.7	8.8	2.8	1.8
	May	67.4	72.3	9.9	9.1	5.8	5.2	7.9	8.2	8.8	5.0
	Jun	64.6	67.5	10.5	10.3	0.0	0.0	10.2	10.6	14.6	11.5
	Jul	35.9	34.7	4.7	4.8	0.0	0.0	**4.2**	**4.3**	**55.1**	**56.0**

Furthermore, the results of the litter production rate showed that the individual litter rate ranged from 0.08 to 6.59 g m^{-2} $day^{-1}$and 0.09 to 8.82 g m^{-2} $day^{-1}$for SHD and KSNP, respectively. Discrete analysis revealed that the leaf production rate for the degraded mangrove was 6.59 g m^{-2} day $^{-1}$in March (Fig. 2) as against 5.29 g m^{-2} day^{-1}recorded in November for the natural mangrove (Fig. 3). The result from natural mangrove is similar to Sasekumar & Lio (1983) indicating that Malaysian mangroves are comparable to those of Queensland where 5.36 g m2 day can be obtained (Duke *et al.*, 1981). However, the higher value found in SHD may be attributed to the interferences in its existence brought about by the anthropogenic activities (resort, fishing etc.) around it. From the foregoing, it also showed that the rate of daily leaf litter production varied between the wet and intermediate seasons for both mangrove forests. Therefore it is worthy to note that mangrove productivity may vary considerably due to nutrient conditions of the soil (Cerón-Bretón *et al*., 2011).

Similarly, the higher rate of propagules (fruit) litter (8.82 g m^{-2} day $^{-1}$) found in KSNP than in SHD (4.36 g m^{-2} day $^{-1}$) might be an evidence of an enriched nature of natural mangrove, hence seed production became associated to the degree of mangrove productivity as well as the mangrove species composition. In overall, the non- leaf litter accounted for less than 30% of total litter production in both mangrove forests.

As regards litter production in KSNP, the concentration of total N across the plant parts showed that 7.40 mg/g was found in the fruit part more than the 3.34 mg/g and 6.07 mg/g recorded in the branch and leaf, respectively (Fig. 4). Similar values were found in SHD. However, the order of increase in total N was branch < leaf< fruit. The result revealed that abundant total N was recorded in the wet season for both study areas; 5.80 mg/g and 6.44 mg/g for KSNP and SHD, respectively (Fig. 5). This might be attributed to humidity variation across seasons. Yet regardless of the trend similarities shared by both sites, SHD recorded a higher mean value for total N (6.16 mg/g) as against 5.60 mg/g found in KSNP, and was statistically different($p<0.05$).

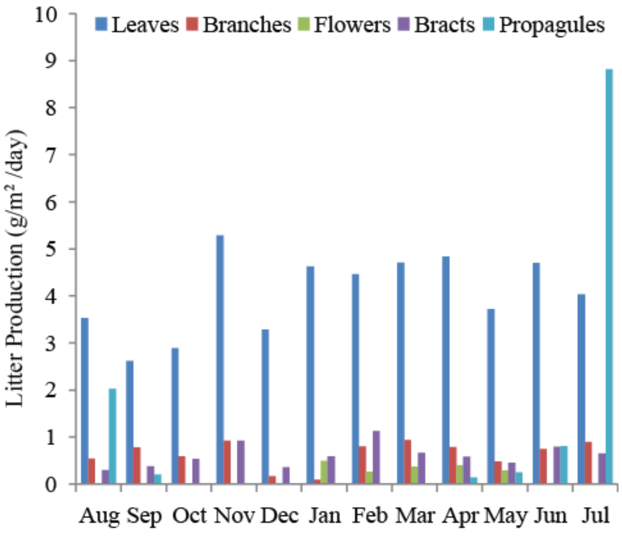

Fig. 2. Litter Production in SHD Mangrove Forest (2012-2013).

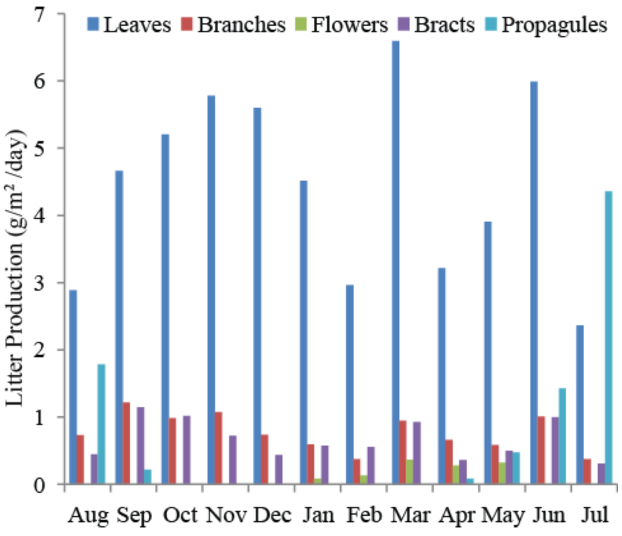

Fig. 3. Litter production in KSNP mangrove forest (2012-2013).

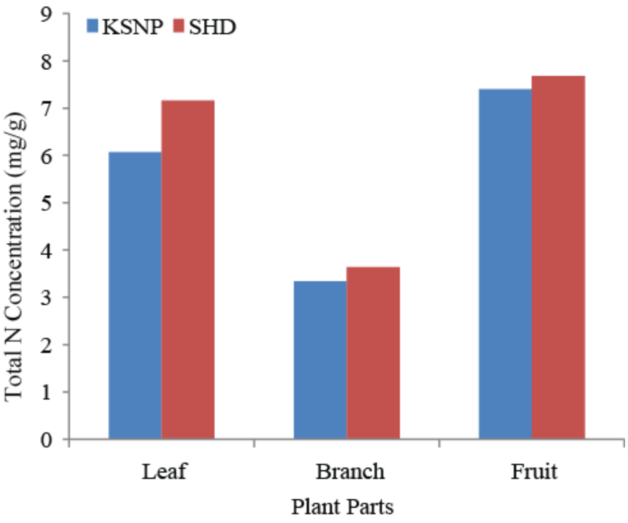

Fig. 4. Total nitrogen concentration in litter production at plant parts in both study areas.

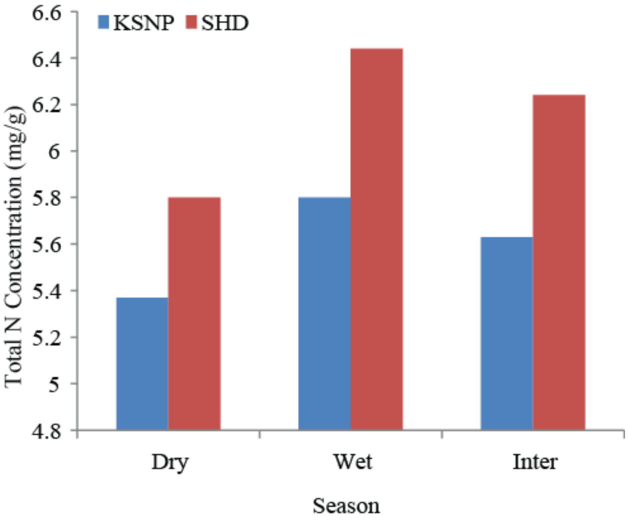

Fig. 5. Total nitrogen concentration in litter production in both study areas.

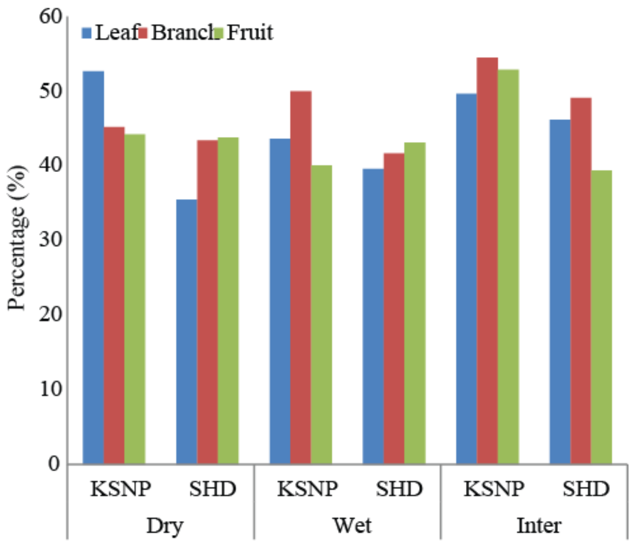

Fig. 6. Organic carbon in litter production for both study areas.

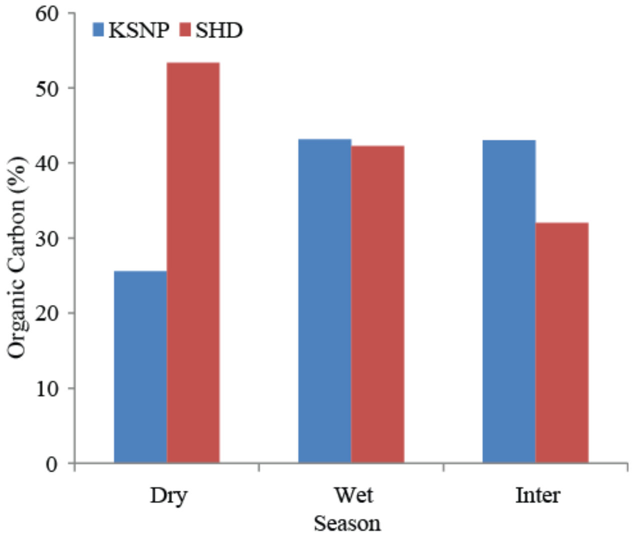

Fig. 7. Organic carbon in litter standing crop at plant parts for both study areas.

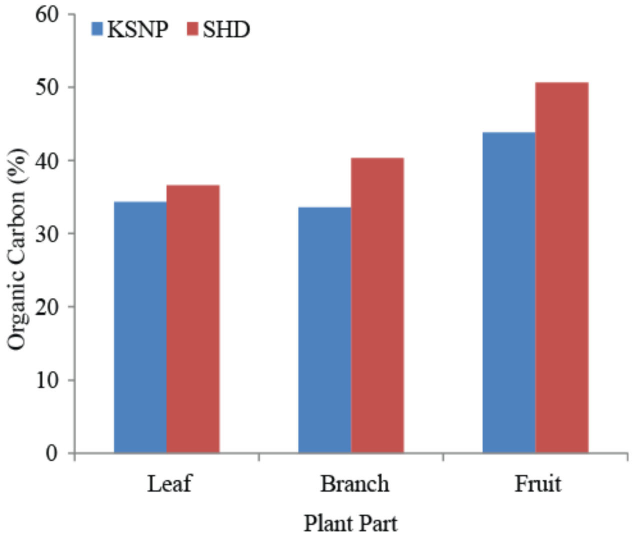

Fig. 8. Organic carbon in litter standing crop according to season for both study areas.

Figure 6 presents the result of the organic carbon from litter production (CO). About 52% CO was found in the leaf litter of KSNP in dry season to mark the highest concentration of CO within the studied area and seasons as against approximately 49% and 43% obtained in the intermediate and wet seasons. However, the trend in branch and fruit was slightly different. The highest CO was found in the intermediate season, than the values recorded during the wet and dry season, respectively. Expectedly dry season often show that soil contains more CO than in the wet season because dry season is characterized with evapotranspiration that allows for vertical transport of organic carbon (Davidson *et al.*, 2000). However, the high degree of organic carbon in the branches and fruits for the intermediate and wet seasons may be as a result of the ability of such plant parts to retain and store nutrients than in leaf where exposure to sunlight and increased surface area may be limiting factors. Organic carbon content in all the tree parts (leaf, branch and fruit) revealed that KSNP showed higher concentrations than what was found in SHD. This might be a reflection of the degraded nature of SHD unlike KSNP that is natural and has almost undisturbed vegetation; hence nutrient conservation is expectedly higher.

Similarly, organic carbon content of litter standing crop was observed across the three seasons and the plant parts (leaf, branch and fruit) as shown in Figures 7 and 8. Carbon storage was more prevalent in the fruit part within both study areas; 43.83% and 50.63% for KSNP and SHD, respectively. In fact both sites showed similar order of carbon increase in the plant parts; leaf< branch< fruit. The reason might be based on the biochemical activities that took place on the identified plant parts. Considering the potential degree of carbon loss brought about by photosynthesis and exposure of the leaf and branch, respectively, it is possible to find higher carbon content in the fruit part.

The statistical evaluation of the results indicated that there were significant positive relationships between organic carbon in leaf, branch and overall. The exception was the relationship between organic carbon in fruit which was not statistically significant; $r=-0.043$. Also, the results of the One-Way ANOVA test indicated that there were significant differences between the group of months toward the overall organic carbon; statistic = 10.791, p-value = 0.000.

Seasonal assessment of the carbon content on the litter standing crop revealed that lowest concentration (25.58%) was recorded in dry season for KSNP, yet the highest yield for SHD (53.33%) was also obtained in the same season. The reason may be attributed to the degree of variation in plant species within each study area; some trees respond differently to seasons, and the most abundant species can influence the litter generated in the season. However, both study areas showed high similarity in C during the wet season. Yet, the mean carbon content deduction showed that 42.53% was recorded in SHD as against 37.24% in KSNP, and difference was statistically significant ($p < 0.05$).

Conclusion

The degree of litter production in the mangrove may project them among the most productive forest types in Peninsular Malaysia. Regardless of different seasons, leaf litter fall is pronounced year round and such may reflect the productive nature of the mangrove forest. However, significant differences exist between total litter production in the natural mangrove and the degraded one. SHD, the degraded mangrove had demonstrated a high potential for C and N sinks despite the anthropogenic activities that affected its natural state. The abundance of litter standing crop on both study areas reflects the degradation potentials of the mangrove forest which can effectively enhance carbon sequestration and nutrient recycling. Hence it becomes imperative to institute protective mechanisms that will shield existing mangrove forests from anthropogenic influences.

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