Bangladesh J. Bot. **39**(1): 61-69, 2010 (June)

CHEMICAL COMPOSITION OF LEAVES OF A MANGROVE TREE (*SONNERATIA APETALA* BUCH.-HAM.) AND THEIR CORRELATION WITH SOME SOIL VARIABLES

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Key words: Coastal zone, tidal inundation, elemental concentration, *Sonneratia apetala*

Abstract

Chemical composition of leaves of *Sonneratia apetala* Buch.-Ham. collected from three islands (chars) representing three hydrological regimes in a segment of the coastal zone of Bangladesh was studied. Their relations to some soil chemical and physical variables have also been investigated. The results showed that concentrations of B, C, Fe, Ga, Li, Mg, Mn, N, Na, P, Zn and Sr in leaves of *S. apetala* grown in different islands differed significantly. It was also revealed that some heavy metals, *viz.* Mn, Fe, Al, Sr and Ti showed wide range of concentrations. The leaves from one of the locations in Motherbunia island were characterized by exceptional high concentrations of heavy metals such as Al, As, Cu, Fe, Li, Ni, Pb that may be due to local contamination. Leaves sampled in the most seaward locations of the same island had highest concentrations of Ba, Ca, Cu, Mn and Na. High Mn concentration was found in the leaves of *S. apetala* of Motherbunia island. Correlations among soil and plant samples were generally very weak and organic matter content of soil did not appear to play a significant role in the nutrient supply of *S. apetala*.

Introduction

Sonneratia apetala Buch.-Ham (Sonneratiaceae) is a common tree plant in the Sunderban Mangrove Forest and is the most suitable plant for afforestation in the newly accreted lands along the coast of Bangladesh. Mangrove ecosystems of the sub-tropical regions are poorly studied and this include the species composition, community structure and zonation (Tam *et al.* 1995). In respect of biological diversity, focuses have been given on identification, conservation and function and highly different object of concerns and scales were observed, from DNA to the biosphere level (Meffe and Carrol 1997). The mineral nutrition status of mangrove tree species is until now poorly understood. No data are available on the concentration of the elements in mangrove plant species, especially of coastal zone and mangrove forest of Bangladesh which are very important from the view point of conservation and management policies of mangrove plantation and forests. The early growth of some forest species are limited by nutrient deficiency that underscores the importance of more study on mineral nutrients (Nussbaum *et al.* 1995) of mangrove species such as *S. apetala*.

Levels of plant mineral concentrations have important roles on herbivores and thus on trophic interactions and ecosystem functioning (Smith and Smith 2001). Growth and productivity of plant has direct effects on its mineral nutrient status that is controlled by different factors of the environment, nutrient uptake potential fixed genetically and availability of nutrients in the soil (Van den Driessche 1974). Very little data are available on the uptake of nutrients by mangroves from the soil. The present study focused on to know the concentration of elements and heavy metals in *S. apetala*, and their spatial variation due to variation in tidal inundation.

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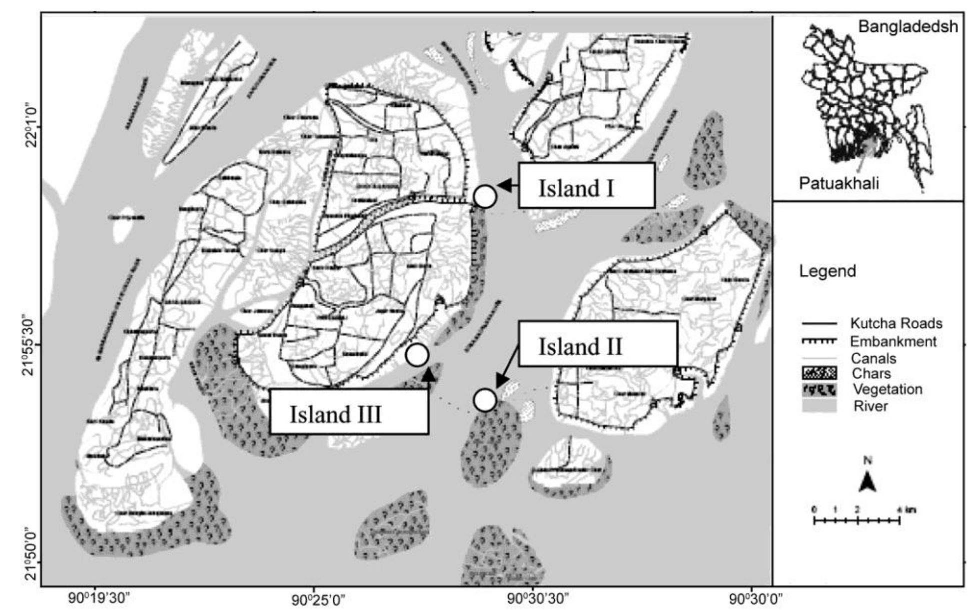
Materials and Methods

Geomorphology of the coastal region of Bangladesh, climate and dynamics of the study area has been described elsewhere (Ahmed *et al*. 2010).

The coastal zone of Bangladesh was surveyed at the Rangabali Police Station of Galachipa Upazilla (subdistrict) of Patuakhali District (21°53'10" - 22°0'0" N and 90°27'0" - 90°30'30" E) (Map 1). *Sonneratia apetala* is the most successful species in the plantation program in the newly accreted islands. Leaves of the mangrove tree species *S. apetala,* locally known as Kewra, were collected from three different chars (islands), namely Char Motherbunia, Char Taposi and Char Kashem (hereinafter referred to as Island I, Island II and Island III, respectively). Soil samples were also collected under different hydrological conditions. Matured leaves were collected at the



Map 1. Locations of sampling in Char Motherbunia (Island I), Char Taposhi (Island II) and Char Kashem (Island III) in Galachipa. (Source: Local Government Engineering Department, Government of Bangladesh, 1994). ○, Indicates the sampling locations.

at the time of soil collection (27 February, 2006). Plantation program started in the Char Motherbunia in 1983, whereas the plantation initiated in Char Kashem and in Char Taposhi in 1985 and 1988, respectively. Fifteen composite samples of leaves and soil were collected from the Char Motherbunia (island I) along the three lines, five points from each line from each islan. The distance between the points and lines were about 200 m. In the Island I, the first line was demarcated on the recently (one year) accreted land, the second line was on the land accreted about two years and third line was on the three-year-old land. No such demarcation could be made in the other two islands (Ahmed *et al.* 2010). From Char Taposhi and Char Kashem, leaves were collected from different trees along the lines as most of the leaves were affected by fungi. Leaves samples of five different plants were collected from Char Taposhi and leaves of 7 plants were collected from Char Kashem.

Leaves were dried at 70º C in the heating cabinet immediately after arrival in the laboratory, finely grounded (particles size less than 1mm) and stored at room temperature until analyses. Samples were analysed according to the methods described by Ogner *et al.* (2000). For C and N, Elementar Vario EL with TCD detector was used. For the determination of total elements, Thermo Jarell Ash ICP-IRIS HR Duo was used. The elements Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Ga, K, Li, Mn, Mo, Na, Ni, P, Pb, S, Sc, Se, Sr, Ti, V, Y and Zn were determined by a simultaneous ICP-AES technique by axial or radial viewing of plasma (Ogner *et al.* 2000).

Different variables of plant samples were subjected to analysis of variance (ANOVA). Island and location were used as factors. Differences in concentrations of some of the elements of plant samples were tested with one-way ANOVA using Islands as factor by Minitab 14 software. The Tukey multiple comparison tests were used to test for pair wise differences between Islands at a significant level of 0.05 using Minitab 14 software. Some of the variables were not normally distributed (Anderson-Darling test was done using Minitab 14) and the Kruskal-Wallis non parametric ANOVA was run for these varibles (i.e. B, Co, Fe, Mg, S, Al, As, Cr, Ga, Li, Ni, Pb, Se, Sc, Ti, V, Y). Pearson correlations between some of the physical and chemical parameters of the soil samples and plant materials have also been done.

Results and Discussion

Sonneratia apetala was characterized by a significant variation in the concentration of element levels. For example, the coefficient of variation (CV) ranged from 2 to 154% and concentrations of the variable minerals had a variation of maximum 45 times such as in case of Ti (Table 1). Concentrations of some elements in the leaves were significantly different among three Islands such as C ($P = 0.0001$), Mn ($P < 0.000$), Na ($P < 0.000$), P ($P = 0.035$), Zn ($P < 0.000$) and Sr ($P < 0.000$), where the C levels at Islands I and III were fairly similar, which in turn differed from that of Island II. Manganese content of leaves at Island I differed significantly from that at

Table 1. Descriptive statistics of concentration of elements in leaves of *S. apetala* of all three islands based on dry matter. n = 27, TOR = Dry matter.

Variables	Mean	SE mean	Coef. Var.	Variables	Mean	SE mean	Coef. Var.
N (%)	2.25	0.146	33.73	Ni (ppm)	1.23	0.077	32.67
P "	0.28	0.019	35.18	Pb "	0.54	0.047	45.37
K "	271.80	0.074	21.44	As "	0.86	0.057	34.66
Ca "	1.71	0.141	42.97	Li "	0.61	0.056	47.46
Mg "	0.39	0.023	31.27	Sr "	61.11	5.730	48.74
S "	0.81	0.048	30.47	Se "	2.30	0.047	10.72
Na "	1.07	0.081	39.60	Sc "	0.11	0.005	24.85
Mn (ppm)	1074.60	95.000	45.93	Ga "	3.91	0.373	49.61
Fe "	363.50	65.200	93.17	Ba "	7.83	0.664	44.05
Zn "	23.62	0.791	17.39	Ti "	7.36	2.190	154.52
B "	30.53	1.67	28.47	V "	0.38	0.071	97.01
Cu "	10.21	0.863	43.91	Y "	0.16	0.0165	68.22
Mo "	0.46	0.024	27.45	C (%)	45.41	0.193	2.20
Al "	269.70	62.600	120.52	TOR "	90.94	0.085	0.49
Co "	0.28	0.032	59.15	C/N	22.35	1.300	30.12
Cr "	1.43	0.131	47.87				

at Islands II and III, while the latter two Islands had about the same Mn level. Island I showed significant difference from Island III for P, but did not differ from Island II. The higher organic C, N_{tot} and P_{tot} content of the leaves of the plants of Island I coincide with the higher values (significant and non-significant) in soil samples in the same Island. On the other hand, higher K_{tot} and S_{tot} content were found in Island II with concomitant lowest values in soil samples. C : N in the leaves was higher in the mature leave samples of Islands II and III than comparatively younger leaves of Island I. Mangrove species had shown variation in the elemental concentration with leaf age (Kao *et al.* 2002)and seasons (Wang *et al.* 2003). Island II differed significantly from Island I in Na, Sr and Zn, and from Islands III in Zn and Sr content. Sodium concentration did not differ among the Islands, which was also the case for Ba, Ca, Cu and K (Fig. 1). Nutrient resorption, a keystone process (Killingbeck 1996), regulates the flow of nutrients within forest ecosystems (Hörtensteiner and Feller 2002,). In the nutrient resources conservation, it plays an important role (Ellis *et al*. 2006) and might be affected by the abiotic and biotic stress (May and Killingbeck 1992). Remobilization of chemical constituents such as N, C and O in leaves accomplished it and ultimately these elements are relocated into the perennial structures of plants (Killingbeck 1996, Chapin *et al*. 1990)

Kurskal-Wallis tests showed that the Islands differed significantly as regard to B, Fe, Ga, Li, Mg, S and N content, whereas Al, As, Co, Cr, Ni, Pb, Se, Ti and V did not differ significantly. Beryllium and Cd content were at or below the detection level (Be = 0.03 ppm, Cd = 0.2 ppm) in all samples of the three Islands. In some cases, some elements were at or below the instrumental detection levels in one or two Islands or in one or two locations of Island I. For examples, As was at or below the level (0.7 ppm) in Island III whereas Co content was at this level (0.2 ppm) in location 2 of Islands I and II.

Within Island I, location 1 differed significantly from locations 2 and 3 in Ba, Ca, Cu, Mn, Na concentrations, whereas locations 2 and 3 were not different (Fig. 2). Location 2 differed from locations 1 and 3 in P, and location 3 differed from the two others in C concentration levels. As regard foliar Sr concentrations, location 1 differed from locations 2 and 3.

Potassium and Zn concentrations did not differ among the locations. Kruskal-Wallis test showed that Al, B, Cr, Fe, Ga, Mg, S and Ti concentrations differed significantly among the locations whereas As, Co, Li, Mo, Ni, Pb, Sc, Se, V, and Y did not differ. However, it was difficult to compare the three locations properly as some elements were at or below the detection level in some locations.

In location 3, Island I, sample numbers 4 and 5 had exceptionally high heavy metal concentrations, for example, 1396 ppm Al, 1671 ppm Fe, 50 ppm Ti, 2.8 ppm Ni, and 1.3 ppm Pb were recorded. Such high values suggest local contaminations (Tam *et al.* 1995). The likely contaminated locations were at the landward edges and this portion of the Island raised two years before location 1.

It is important to establish whether there is any significant plant-soil relationship in mangrove ecosystems independent of broad-scale hydrologic influence (Gleason *et al*. 2003). Pearson's correlations between N_{tot}, P_{tot}, K_{tot}, S_{tot} and organic C of soil and plant samples of the Island 1 showed that soil N_{tot} content only had significant positive moderate correlation with plant N_{tot} (Table 2). Soil P_{tot} did not show any significant relation with other plant variables whereas soil organic C content had weak positive significant relation with plant N_{tot} and P_{tot}. Soil organic matter had moderate significant positive relation with plant N_{tot} and P_{tot} only.

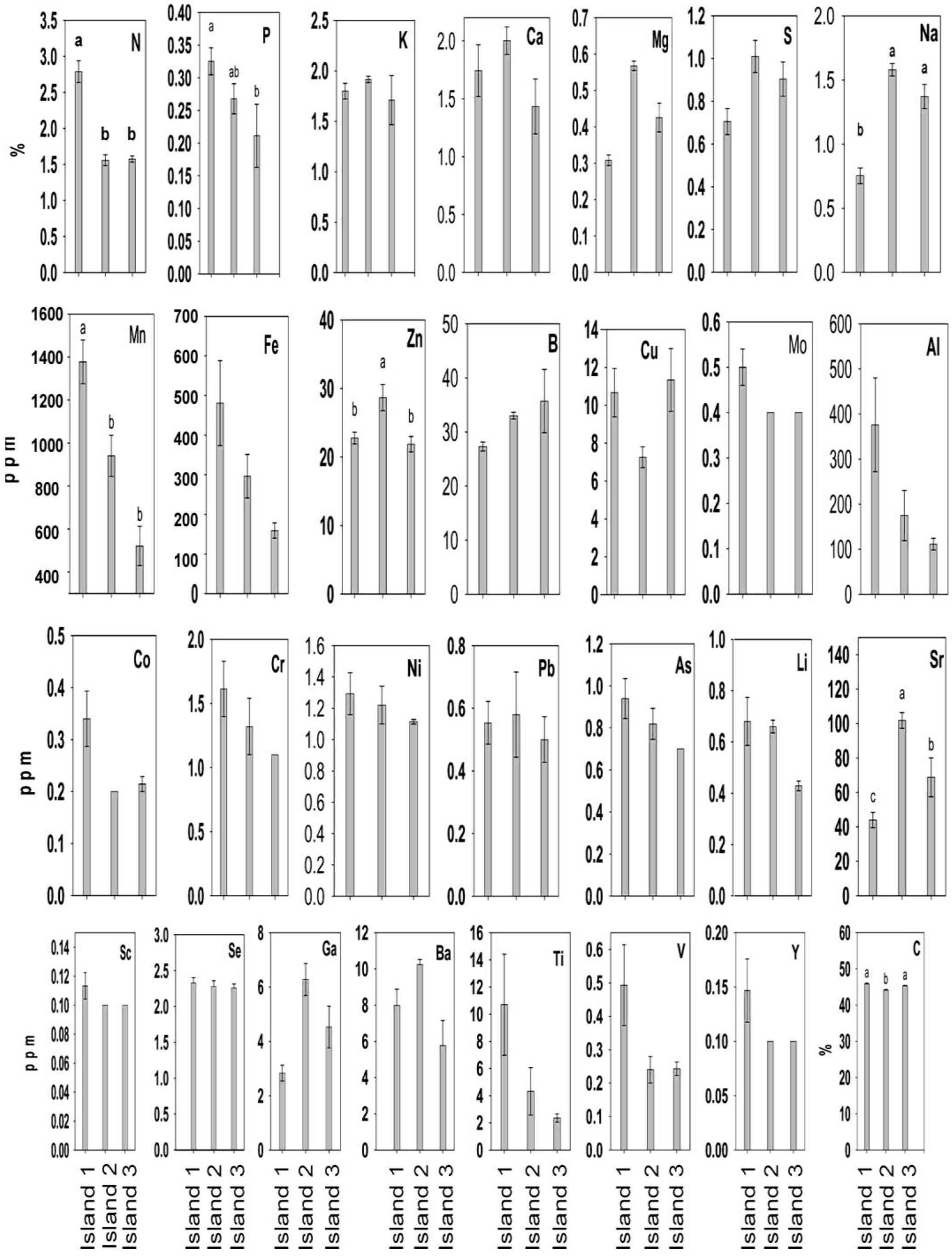


Fig. 1. Concentration of elements in the leaves of *Sonneratia apetala* occurring in the three islands. Values are means with ± 1 SE. Bars without SE indicates that concentration of that element in the respective island was at or below the analytical detection level. Different letters at the top of the bars indicate significance at the $p = 0.05$ level.

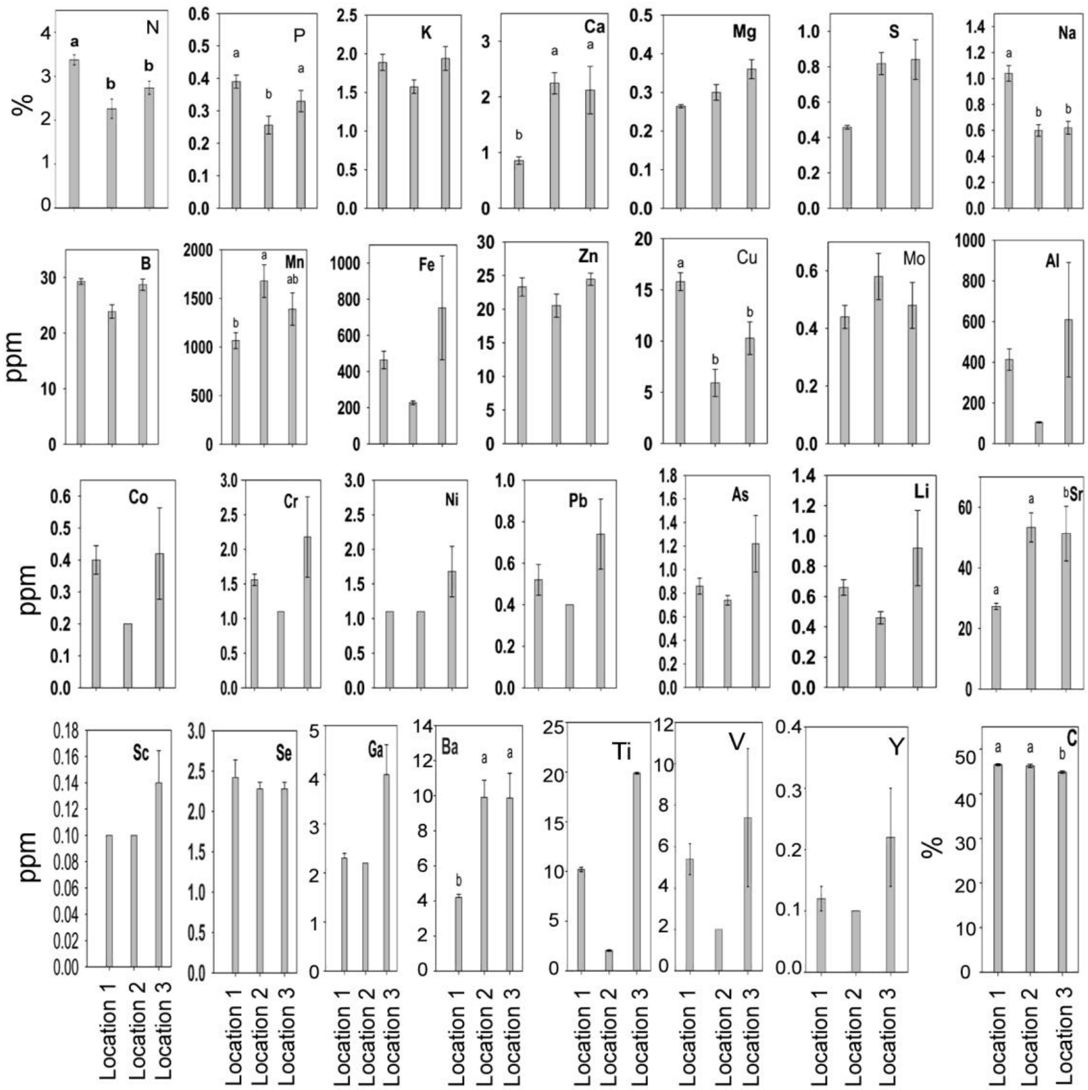


Fig. 2. Variation in the concentration of elements in the leaves of *Sonneratia apetala* collected from three locations of island I with ± 1 SE. Bars without SE indicates that the value of the element at that site is at or below the analytical detection level. Different letters at the top of the bars indicate significance at the $p = 0.05$ level.

It has been indicated that foliar analysis for the assessment of nutritional status of forest trees was better than stem and branch wood analysis because high variability of results are observed in the latter (Drechsel and Zech 1991,Wu *et al*. 2007). To compare the nutrient status of different species and sites, the data on nutrient accumulation in leaves of plants on different sites are useful (Vitousek and Sanford 1986). No clear spatial pattern of variations were found in the elemental concentrations in the leaves of *S. apetala*. But high degree of variability was observed in the nutrient level of plant samples that were indicated by large deviation of data (Thong *et al*. 1993).

The extraordinary higher values of heavy metals such as Al, As, Fe, Pb, Ti, and other metals such as Li, Sc, V and Y found in the sample numbers 4 and 5 of location 3 in Island I might be due to local unknown contamination.

Table 2. Correlation matrix for some variables (total values) of soil and plant samples of island 1.

	1	2	3	4	5	6	7	8	9	10	11
1. Soil N		0.311	0.130	0.150	0.025	0.025	0.044	0.153	0.822	0.188	0.479
2. Soil P	0.281		0.072	0.264	0.334	0.335	0.269	0.218	0.157	0.427	0.699
3. Soil K	0.409	0.477		0.107	0.094	0.094	0.993	0.69	0.280	0.593	0.449
4. Soil S	0.391	0.308	0.432		0.414	0.415	0.834	0.906	0.859	0.398	0.359
5. Soil C	0.574	0.268	0.448	0.228		0.000	0.037	0.049	0.162	0.278	0.824
6. Soil OM	0.574	0.268	0.448	0.228	1.000		0.037	0.050	0.162	0.279	0.827
7. Plant N	0.526	−0.305	−0.002	0.059	0.541	0.541		0.000	0.003	0.000	0.460
8. Plant P	0.388	−0.338	−0.110	0.033	0.515	0.515	0.948		0.000	0.001	0.930
9. Plant K	0.063	−0.384	−0.298	−0.050	0.380	0.380	0.718	0.884		0.038	0.289
10. Plant S	−0.360	0.222	0.150	0.235	−0.300	−0.299	−0.798	−0.780	−0.539		0.076
11. Plant C	0.198	0.109	0.211	−0.255	0.063	0.062	0.207	0.025	−0.293	−0.471	

When the values of the present study was compared with some mangroves of Asia (Futian, People's Republic of China, Tam *et al*. 1995; Fujian, PRC, Lin and Lin 1985; Tansui, Taiwan, Chen 1982) and Paciffic (Queensland, Australia, Spain and Holt 1980), it was found the mean N,P and K concentration in leaves of *S. apetala* was significantly higher than those of *Aegiceras corniculatum* (L.) Blanco of Futian , Queensland and Fujian and of *Kandelia candel* (L.) Druce of Futian mangrove forest (Table 3). Concentration of K also followed the same trends except Tanshi mangroves (here K level was not detected).

Table 3. Comparison of concentrations of different elements (%) and some heavy metals (ppm) in different mangrove species. Standard deviation is shown in parenthesis. ND = Not detected.

Mangroves	Species	N	P	K	Cu	Zn	Mn	Source
Rangabali, Bangladesh	*Sonneratia apetala*	2.25 (0.76)	0.28 (0.1)	1.8 (0.15)	10.21 (4.48)	23.62 (4.11)	1076 (494)	Present study
Futian, PRC	*Aegiceras corniculatum*	1.31 (0.01)	0.14 (0.04)	0.53 (0.09)	4.12 (0.76)	85.2 (28.6)	166 (89)	Tam *et al.* (1995)
	Kandelia candel	1.39 (0.01)	0.13 (0.01)	0.59 (0.12)	4.05 (1.12)	69.7 (25.2)	1048 269)	
Queensland Australia	*Aegiceras corniculatum*	0.85 (0.06)	0.10 (0.01)	0.48 (0.08)	5.8 (1.1)	15.5 (3.0)	158 (67)	Spain and Holt (1980)
Fujian, PRC	*Aegiceras corniculatum*	1.22 (0.01)	0.12 (0.00)	0.87 (ND)	ND	ND	ND	Lin and Lin (1985)
	Kandelia candel	1.88 (0.20)	0.15 (0.01)	0.89 (ND)	ND	ND	ND	
Tanshui, Taiwan	*Kandelia candel*	1.90	0.15	ND	ND	ND	ND	Chen (1982)

Among the heavy metal concentrations in present study the Cu content (3.9 to19.6 ppm) of *S. apetala* was higher than those of *A. corniculatum* and *K. candel* (Table 3). Copper present in the leaves of *S. apetala* has higher values than tissues of *Avicennia marina* (2-12 mg/kg). Zinc content found in the present study was significantly higher than that of *A. corniculatum* of Queensland whereas the value was significantly lower than the both species of Futian forest (Tam *et al.* 1995). Manganese content of both *K. candel* and *S. apetala* was almost similar but the values of *S. apetala* were exceptionally higher than that of *A. corniculatum* of Futian and Queensland mangroves. However, the concentrations of Cu, Zn and Mn of plant materials have been mentioned to be within the range of 2.5 - 25, 15 - 100 and 50 -1000 g/g, respectively (Allen *et al*. 1974), it could be suggested that *S. apetala* did not accumulate in access Cu and Zn in their tissues in three Islands and Mn in Islands II and Island III. Thus heavy metal pollution, in respect to these three metals, is not a problem in three Islands planted with *S. apetala* although relatively higher Mn values than suggested by Allen *et al*. (1974) was found in Island I suggesting higher level of incorporation of Mn by *S. apetala*, that could be a function of sediment-water interaction (Preda and Cox 2002).

Statistical analysis of correlation matrix of soil and plant samples showed that the plant and soil variables were not significantly correlated as a whole although there were some significant correlations. This indicate that there is no simple, straight forward relationship between crude chemical properties of soil and plant nutrient uptake in mangrove ecosystems, which has also been shown to be the case in other types of wetlands such as bogs and fens (Ohlson 1989, Ohlson 1995). Organic matter of soil did not appear to play a very significant important role in nutrient supply or relate to nutrient concentrations of the leaves of *S. apetala*. Microbial activities play an important role in nutrient release from organic matter which was also revealed from a study of mangrove Island in Florida that microbial activities and organic matter fractions can vary greatly among mangrove species (Carlson *et al*. 1983).

Acknowledgements

The authors gratefully acknowledge the financial support provided by the authority of Dhaka University, Bangladesh and the Norwegian University of Life Sciences, Ås, Norway. The help of Mr. J.E. Jacobsen, of Norwegian Forest and Landscape Institute, Ås, Norway for chemical analysis of plant materials and Mr. Daniel Mushi in statistical analysis of data is also acknowledged. Thanks are due to the staff of Bangladesh Forest Research Institute, Rangabali station, Patuakhali district for field assistance.

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(Manuscript received on 27 December 2009; revised on 9 March 2010)