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Influence of Biochemical Properties of Mangrove Leaves on Quality of Rhizosphere Soils

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Abstract

Mangrove leaves contribute significantly to the productivity of various mangal ecosystems releasing different plant nutrients as well as maintaining detritus based food webs during their degradation in the soil-water system. Since biochemical compositions of these mangrove leaves play key roles in influencing the nature and magnitude of such decomposition processes, some major biochemical properties of the leaves of twenty four common mangrove species in Indian Sundarbans forest were studied in this investigation. The results were further correlated with some productivity attributes of these mangrove rhizosphere soils with the major objective of assessing the relevance of these properties in maintaining the productivity of the mangal soils. This primary study showed that there exists considerable variation in the occurrence of water soluble protein, carbohydrate and fat in the leaves of different mangrove species and these variations are likely to exert variable effects on the rhizosphere soil properties in various mangrove infested zones. For fetching comprehensive effects of nutrient cycling from these leaves, therefore, mixed populations of mangrove species are likely to be more important.

Keywords: ***Mangrove species; Leaf composition; Biochemical properties, Rhizosphere soils; Soil properties***

Introduction

Mangrove ecosystems are natural wetlands found in the intertidal zones in various tropical and sub-tropical regions of the world. The importance of such vegetation is unique in nature because they sustain the productivity of the coastal areas and support a high abundance of a diverse variety of wild life [1]. They also provide goods and food for the human population, which demonstrates their socio-economic role also. Mangroves are potential sources of organic matter and nutrients to the estuarine ecosystem [2]. Litter, mainly leaves, is exported from mangrove ecosystems by tidal waters either fresh or in various states of decomposition, in the form of large and fine pieces of leaf detritus which enrich the intertidal sediments with nutrients [3,4]. Aksornkoae [5] suggested the beneficial behavior of mangroves to be the result of high leaf production, leaf fall and breaking down of the detritus. The significance of mangrove leaf litter in the maintenance of detritus based food webs in the estuarine environment has been emphasized by workers like Odum and Herld, Lee, Golley et al. and Ong et al. [6-9] and others. The nature and magnitude of such breakdown of these leaf litters depend largely on the biochemical compositions of the mangrove leaves which influence their decomposability and, in turn, the capacity to release different

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nutrients to benefit various aquatic as well as sediment flora present in these coastal zones. Under this context, knowledge about the major biochemical properties of the leaves of various mangrove species is likely to serve as a guide line to relative degradability of these leaves and the possibility of releasing different plant nutrients into soluble forms

Of various mangals of the world, the Sundarbans mangroves, distributed in Bangladesh and India, constitute the largest single chunk of such forest. Of the total area of this forest, Indian Sundarbans covers 9630 sq.km out of which 4226.6 sq.km has been reported to be under the present day Sundarbans mangroves [10]. The uniqueness of the Sundarbans mangroves lies not only in terms of numerical diversity but also the distribution of these floristic components into different tidal niches and saline regimes [11-13] has inventoried 110 species of mangroves, mangrove associates, back mangroves, parasites and epiphytes in the entire Sundarbans. These mangroves play an important ecological role in the coastal areas because they are a source of organic matter for the ecosystem [14,15]. The interrelationship of mangrove vegetation with bottom soil characteristics of mangrove vegetation has been reported by Dasgupta et al. [16]. In the present investigation, therefore, an effort was made to study some general biochemical compositions viz. water soluble protein, carbohydrate and lipid contents in the leaves of twenty four numbers of commonly occurring mangrove species of Indian Sundarbans and to assess the relationships of such compositions with relevant properties of their rhizosphere soils. It is hoped that the study will be able to provide some useful information for more efficient productivity management of mangrove ecosystem through efficient utilization of the mangrove leaf litters.

Materials and Methods

Leaf samples of twenty four commonly occurring mangrove plant species (**TABLE 1**) were collected randomly from three spots under each of eastern, western and central areas of undisturbed parts of the mangrove forest of Indian Sundarbans. Simultaneously, bottom soil samples were also collected at 15 cm depth from the rhizosphere of each of the spots, The plant and soil samples were processed and used for the following analysis.

Plant leaves

Carbohydrate: The carbohydrate content of the leaves was determined by hydrolyzing the polysaccharides into simple sugars by acid hydrolysis (5 ml of 2.5 N. HCl) in boiling water bath for about 3 hours. After cooling at room temperature, the solution was neutralized with sodium carbonate. The volume was made to 100 ml and then centrifuged. The supernatant solution was used for analysis. To the aliquots of samples taken, anthrone reagent was added and again heated in a boiling water bath for 8 minutes. The sample was cooled rapidly and the green to dark green color was read at 630 nm in the spectrophotometer. Amount of carbohydrate present was determined by plotting on a standard curve.

Protein: The water soluble protein content was determined by Lowry's method. 0.1 g of leaf sample was homogenized with 2 ml of DW. 1.5 ml of this homogenized sample was taken from the total solution and centrifuged at 14000 rpm at 400°C for 20 minutes. Then 1.2 ml of the supernatant liquid was taken and the protein content was estimated by Lowry's Method using the Folin reagent [17].

Lipid: The lipid content was analyzed by acid hydrolyzing the samples. Total lipids that are extractable in chloroform - methanol solution were estimated by the gravimetric method. The moisture content of these air-dried samples was first

determined. The samples were then extracted with chloroform: methanol: water (2:1:0.8, volumetrically), following. The chloroform layer containing the lipids was then collected. This chloroform was completely evaporated to obtain the total lipid of the sample. The total content was determined gravimetrically and expressed as a percentage on a dry weight basis.

TABLE 1**. Mean protein, carbohydrate and lipid contents of some mangrove leaves of Sundarbans Tiger Reserve.**

Sl. No.	Name of the Species	Protein (mg/g)	Carbohydrate (mg/g)	Lipids (%)
1	*Rhizophora mucronata* Lamk	1.1	70.0	3.78
2	*Rhizophora apiculata* Blume	1.35	90.0	3.0
3	*Bruguiera gymnorhiza*(L.)Lamk.	2.5	66.0	3.92
4	*Bruguiera sexangula*(L.)Poir	0.7	70.0	4.0
5	*Bruguiera cylindrica*(L.)Blume	2.9	69.5	0.63
6	*Bruguiera parviflora* W. & A.	1.34	58.5	4.1
7	*Ceriops decandra*(Griff.)Ding. Hou	3.0	39.0	0.34
8	*Ceriops tagal*(Perr.)Robin	3.0	41.0	0.28
9	*Kandelia candel*(L.) Druce	0.9	46.5	4.54
10	*Avicennia officinalis* L.	2.75	64.0	3.5
11	*Avicennia alba* Blume	4.45	77.0	4.0
12	*Avicennia marina*(Forsk.)Vierh.	5.15	64.6	4.2
13	*Sonneratia apetala* Buch. Ham	5.3	29.3	3.01
14	*Sonneratia caseolaris* (L.) Engler	5.9	26.0	4.35
15	*Sonneratia griffithii* Kurz.	7.00	36.0	4.6
16	*Aegiceras corniculatum*(L.) Blanco.	0.78	26.6	6.2
17	*Aegialitis rotundifolia* Roxb.	0.75	32.0	4.0
18	*Heritiera fomes* Ham.	2.90	27.3	4.5
19	*Xylocarpus granatum* Koen.	4.6	20.0	4.61
20	*Xylocarpus mekongensis* Pierre	5.50	36.0	4.7
21	*Aglaia cucullata* (Roxb.). Pellegrin.	4.10	10.0	4.8
22	*Nypa fruticans* (Thunb.) Wurmb.	1.10	20.0	3.1
23	*Phoenix paludosa* Roxb.	5.1	67.0	1.34
24	*Exoecaria. agallocha* L.	5.2	75.0	2.3

Soil

1. pH - pH was determined by a potentiometric method using a pH Meter.
2. Electrical Conductivity (EC) - EC was determined with the help of an EC bridge known as Conductivity Cell.
3. Salinity - Cl^- ions was estimated by titration with silver nitrate ($AgNO_3$) in the presence of chromate ions.The salinity was determined from the chlorinity values using the following formula:

$$\text{Salinity (ppt)} = \text{Chlorinity(ppt)}x1.805+0.03$$

4. Organic Carbon (OC) - The rapid titrimetric method of Walkley & Black [18] using the heat of dilution was used for determination of organic carbon in soils. This method has an advantage that it excludes less active elementary carbon of soil (e.g. graphite) and includes only that part of OC.
5. Available nitrogen - The amount of N under easily mineralizable form was determined by oxidizing the soil organic matter with a mild oxidizing agent so that only the easily mineralizable forms of organic nitrogen are oxidized. 0.32 percent potassium permanganate (KMnO4) was used for this purpose [19].
6. Cation Exchange Capacity (CEC) - The total quantity of cations which a soil can adsorb by cation exchange is termed as Cation Exchange Capacity (CEC) of the soil. The CEC of the soils was estimated by following USDA [20] and was expressed as milli equivalent per 100g of soils.
7. Available Phosphorus- The available phosphorous was estimated by using Olsen's sodium bicarbonate extractable method due to the alkaline nature of the soils in the Indian Sundarbans [21].
8. Exchangeable Sodium and Potassium - The exchangeable Na+ and K+ ion concentrations in the soil samples were determined flame photometrically following Jackson [22].

Results and Discussion

Biochemical properties of the mangrove leaves have been presented in **TABLE 1**. Carbohydrate forms the major structural and basic storage unit in all autotroph organisms. The basic unit of carbohydrates is the monosaccharides, which cannot be further split into simple sugars. On analysis of the carbohydrate contents of the major mangrove species, the values exhibited wide variations and the said value was found to be the highest in *Rhizophora apiculata* (90.0 mg/g) followed by *Avicennia alba* (77.0 mg/g) and the lowest was observed in *Aglaia cucullata* (10.0 mg/g). The carbohydrate content of the other mangroves were *Rhizophora mucronata* (70.0 mg/g), *Bruguiera gymnorhiza* (66.0 mg/ g), *Bruguiera sexangula* (70.0 mg/g), *Bruguiera cylindrica* (69.5 mg/g), *Bruguiera parviflora* (58.5 mg/g), *Ceriops decandra* (39.0 mg/g), *Ceriops taga*l (41.0 mg/g), *Kandelia candel* (46.5 mg/g), *Avicennia officinalis* (64.0 mg/g), *Avicennia marina* (64.6 mg/g), *Sonneratia apetala* (29.3 mg/g), *Sonneratia caseolaris* (26.0 mg/g), *Sonneratia griffithii* (36.0 mg/g), *Aegiceras corniculatum* (26.6 mg/g), *Aegialitis rotundifolia* (32.0 mg/g), *Heritiera fomes* (27.3 mg/g), *Xylocarpus mekongensis* (36.0 mg/g), *Xylocarpus granatum* (20.0 mg/g), *Nypa fruticans* (20.0 mg/g), *Phoenix paludosa* (67.0 mg/g) and *Exoecaria agallocha* (75.0 mg/g) (**TABLE 1**).

Carbohydrates being very easily decomposable components of organic matter did not exert much influence on the studied soil properties except available potassium status **(TABLE 2)**

TABLE 2. **Correlation co-efficient of mangrove rhizosphere soils in relation to some biochemical properties of mangrove leaves.**

Rhizosphere soil properties	**Biochemical Properties of leaves**		
	Water Soluble Protein	Carbohydrate	Lipid
pH	-0.16387	0.124717	-0.02538
Salinity	-0.168976	0.261639	-0.212185
Organic Carbon	-0.176245	-0.222076	0.23586
Available Nitrogen	-0.056698	0.031998	-0.049856
Available Phosphorus	-0.29851	0.06167	-0.37092
Exchangeable K^+	-0.092335	0.462275*	-0.42276*
Exchangeable Na^+	0.114043	-0.50731*	-0.07493

***** = Significant at 5% level

the rapid rate of decomposition of such organic matter is likely to release a good amount of the major and micro plant nutrients held in organic forms in the leaf litters. While nitrogen content in carbohydrates is generally of low order, a limited amount of mineralized nitrogen could be released from this organic component of mangrove leaves. Being highly soluble in water, this nutrient became dissolved in water and escaped from the soil phase more easily.

Similar was the behavior of mineralized phosphorus which remained largely in labile form under the near neutral pH **(TABLE 3A,B)** and organic matter rich environment **(TABLE 4A,B)** of the soils. On the other hand, increased cation exchange capacity of the mangrove soils tended to retain some of the released potassium in the soil exchange phase **(TABLE 5A,B).** This behavior resulted in a statistically significant correlation of available soil potassium to carbohydrate contents of mangrove leaves in the present study.

TABLE 3A**. pH values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve.**

Sp. name	Eastern Zone			Western Zone			Central Zone		
	Arbesi	Khatuajhuri	Harinbhanga	Matla	Netidhopani	Chottohardi	Chamta	Chandkhali	Goasaba
Rhizophora mucronata Lamk	8.1	8.5	8.3	8.3	7.8	8.3	8.1	8.2	8.2
Rhizophora. apiculata Blume	8.3	8.4	8.3	8.2	8.1	8.0	8.1	8.4	8.1
Bruguiera gynmorhiza (L.)Lamk.	8.2	8.4	8.2	8.3	8.2	8.1	8.1	8.2	8.2
Bruguiera cylindrica (L.)Blume	-	-	-	8.1	-	8.1	8.1	8.1	8.3
Bruguiera sexangula (L.)Poir	7.8	8.3	8.1	-	-	8.0	8.1	-	8.2
Bruguiera parviflora W. & A.	-	-	8.3	8.2	7.8	8.3	8.1	8.2	8.3
Kandelia candel (L.) Druce	8.3	7.9	8.0	8.1	-	8.2	8.1	8.2	8.2
Ceriops decandra (Griff.)Ding. Hou.	8.1	8.3	8.2	8.1	7.7	8.0	8.4	8.4	8.3
Ceriops tagal (Perr.)Robin	8.1	8.2	8.1	8.2	7.9	8.3	8.4	8.2	8.4
Avicennia alba Blume	8.1	8.1	8.1	8.2	8.0	8.2	8.1	8.1	8.3
Avicennia officinalis L.	8.1	8.1	8.4	8.1	8.1	8.5	8.1	8.0	8.3
Avicennia marina (Forsk.)Vierh.	8.0	8.2	8.2	7.9	7.7	8.3	8.2	8.1	8.2
Sonneratia apetala Buch. Ham.	7.6	8.2	8.2	8.0	7.7	8.4	8.1	8.2	8.1
Sonneratia caseolaris (L.) Engler	-	-	-	-	-	-	-	-	-
Sonneratia griffithii Kurz.	8.2	8.1	8.2	8.1	8.3	8.2	8.2	8.3	8.3
Xylocarpus granatum Koen.	8.1	8.1	8.4	8.2	8.2	8.3	8.1	8.2	8.1
Xylocarpus mekongensis Pierre	8.1	8.2	8.2	8.2	8.1	8.0	8.1	8.2	8.1
Aegiceros corniculatum (L.) Blanco.	8.4	8.1	8.2	8.1	7.7	8.4	8.1	8.2	8.3
Aegialitis rotundifolia Roxb.	8.3	8.2	8.3	8.2	8.1	8.2	8.1	8.1	8.2
Heritiera fomes Buch. Ham.	8.2	8.2	8.2	8.1	8.1	8.1	8.1	8.2	8.3
Nypa fruticans (Thunb.) Wurmb.	7.9	8.0	7.8	7.9	7.7	7.9	7.8	8.2	8.1
Phoenix paludosa Roxb.	8.0	8.1	8.1	8.0	8.2	8.2	8.1	8.0	8.2
Exoecaria. agallocha L.	8.2	8.1	8.1	8.2	8.1	8.3	8.1	8.2	8.3

TABLE 3B. **pH values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve**

Sp. name	Northern Zone			Southern Zone		
	Jhilla	Pirkhali	Panchmukhani	Bagmara	Gona	Mayadwip
Rhizophora mucronata Lamk	7.8	7.8	7.5	7.9	8.4	8.3
Rhizophora. apiculata Blume	8.1	7.8	7.6	7.7	8.3	8.2
Bruguiera gynmorhiza (L.)Lamk.	7.9	7.9	7.5	8.0	8.4	8.3
Bruguiera cylindrica (L.)Blume	-	7.8	7.3	-	8.1	-
Bruguiera sexangula (L.)Poir	7.8	-	7.8	-	-	-
Bruguiera parviflora W. & A.	-	7.7	7.5	7.9	8.0	7.9
Kandelia candel (L.) Druce	-	7.8	7.9	8.2	8.1	7.7
Ceriops decandra (Griff.)Ding. Hou.	8.2	7.9	7.7	8.1	8.3	7.9
Ceriops tagal (Perr.)Robin	8.1	7.6	7.9	8.2	8.4	7.7
Avicennia alba Blume	8.0	7.8	7.6	7.9	7.9	7.7
Avicennia officinalis L.	8.1	7.9	7.8	8.0	8.0	7.9
Avicennia marina (Forsk.)Vierh.	8.0	7.8	7.6	7.9	8.0	7.7
Sonneratia apetala Buch. Ham.	8.2	7.6	7.3	8.1	8.3	7.7
Sonneratia caseolaris (L.) Engler	-	-	-	7.9	-	-
Sonneratia griffithii Kurz.	7.7	7.8	7.7	7.9	8.2	8.3
Xylocarpus granatum Koen.	7.9	8.1	7.8	8.0	8.1	8.2
Xylocarpus mekongensis Pierre	8.1	8.0	8.0	8.1	8.3	7.9
Aegiceros corniculatum (L.) Blanco.	7.9	7.8	7.9	8.0	8.1	8.1
Aegialitis rotundifolia Roxb.	8.0	7.8	7.9	8.1	8.4	8.2
Heritiera fomes Buch. Ham.	7.6	7.8	8.0	7.9	8.0	8.0
Nypa fruticans (Thunb.) Wurmb.	7.9	7.7	-	7.8	8.1	8.2
Phoenix paludosa Roxb.	7.9	7.9	7.8	7.9	8.3	8.4
Exoecaria. agallocha L.	7.8	8.0	7.7	7.9	8.2	8.5

TABLE 4A. **Organic Carbon (%) values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve.**

Sp. name	Eastern Zone			Western Zone			Central Zone		
	Arbesi	Khatuajhuri	Harinbhanga	Matla	Netidhopani	Chottohardi	Chamta	Chandkhali	Goasaba
Rhizophora mucronata Lamk	0.6	1.95	1.0	0.86	0.55	1.18	1.02	0.85	0.17
Rhizophora. apiculata Blume	0.7	1.86	1.0	1.0	0.51	1.68	0.31	0.75	0.14
Bruguiera gynmorhiza (L.)Lamk.	0.35	1.9	1.1	0.88	0.9	1.15	1.0	1.7	0.11
Bruguiera cylindrica (L.)Blume	-	-	-	0.13	-	0.15	0.19	0.14	0.13
Bruguiera sexangula (L.)Poir	0.12	0.99	1.3	-	-	1.8	1.0	-	0.15
Bruguiera parviflora W. & A.	-	-	1.37	0.76	1.76	2.0	0.12	1.5	0.18
Kandelia candel (L.) Druce	0.8	1.7	1.4	0.8	-	1.8	1.1	1.6	0.20
Ceriops decandra (Griff.)Ding. Hou.	0.5	0.6	1.0	0.8	1.1	0.5	1.5	1.1	0.81
Ceriops tagal (Perr.)Robin	1.2	1.1	1.1	1.4	0.8	0.6	1.3	1.2	1.0
Avicennia alba Blume	0.5	1.4	1.5	1.0	1.1	1.23	1.32	0.43	0.13
Avicennia officinalis L.	1.7	1.78	2.02	1.78	1.82	1.8	0.38	0.25	0.13
Avicennia marina (Forsk.)Vierh.	1.56	0.64	1.4	1.17	1.1	2.0	1.4	1.48	1.32
Sonneratia apetala Buch. Ham.	0.1	1.7	0.13	1.16	1.1	2.0	1.4	1.44	1.21
Sonneratia caseolaris (L.) Engler	-	-	-	-	-	-	-	-	-
Sonneratia griffithii Kurz.	1.14	1.11	1.16	0.87	0.89	1.1	0.15	0.76	0.13
Xylocarpus granatum Koen.	1.45	1.5	1.15	0.86	1.18	1.23	0.38	1.4	0.18
Xylocarpus mekongensis Pierre	0.5	0.3	0.13	0.86	0.94	1.1	1.6	1.5	1.44
Aegiceros corniculatum (L.) Blanco.	1.1	1.7	0.7	1.87	1.1	2.2	1.6	0.5	1.35
Aegialitis rotundifolia Roxb.	0.8	0.62	0.69	1.34	1.38	1.2	1..8	1.7	1.56
Heritiera fomes Buch. Ham.	1.0	0.7	1.02	0.56	1.12	1.5	1.8	1.74	0.15
Nypa fruticans (Thunb.) Wurmb.	1.1	0.73	1.08	1.33	1.14	1.47	0.87	1.86	0.53
Phoenix paludosa Roxb.	0.57	0.79	0.31	0.23	0.55	0.46	0.5	0.61	0.5
Exoecaria. agallocha L.	0.13	1.1	0.33	0.25	0.57	1.5	0.38	0.4	1.11

TABLE 4B.**Organic Carbon (%) values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve.**

Sp. name	Northern Zone			Southern Zone		
	Jhilla	Pirkhali	Panchmukhani	Bagmara	Gona	Mayadwip
Rhizophora mucronata Lamk	0.58	0.51	0.53	0.58	1.1	1.2
Rhizophora. apiculata Blume	0.63	0.54	0.51	0.56	1.09	1.02
Bruguiera gynmorhiza (L.)Lamk.	0.33	0.38	0.35	0.38	0.41	1.06
Bruguiera cylindrica (L.)Blume	-	0.51	0.11	-	0.17	-
Bruguiera sexangula (L.)Poir	0.18	-	0.13	-	-	-
Bruguiera parviflora W. & A.	-	0.37	0.44	0.58	0.6	1.02
Kandelia candel (L.) Druce	-	0.54	1.37	1.4	1.42	0.09
Ceriops decandra (Griff.)Ding. Hou.	1.3	0.7	1.15	1.12	1.07	1.08
Ceriops tagal (Perr.)Robin	1.23	0.78	1.1	1.18	1.14	1.1
Avicennia alba Blume	1.68	0.51	1.2	1.5	1.54	0.09
Avicennia officinalis L.	0.47	0.5`	0.79	0.82	0.81	1.02
Avicennia marina (Forsk.)Vierh.	0.51	0.64	0.66	0.71	0.74	0.09
Sonneratia apetala Buch. Ham.	0.1	0.7	0.11	0.5	0.52	0.09
Sonneratia caseolaris (L.) Engler	-	-	-	0.2	-	-
Sonneratia griffithii Kurz.	1.11	1.13	0.51	1.4	1.43	1.07
Xylocarpus granatum Koen.	1.32	1.7	0.9	1.13	1.15	1.1
Xylocarpus mekongensis Pierre	0.47	0.53	0.83	0.79	0.82	1.09
Aegiceros corniculatum (L.) Blanco.	1.09	0.51	1.17	1.15	1.18	1
Aegialitis rotundifolia Roxb.	0.76	0.51	0.57	0.4	0.48	1.04
Heritiera fomes Buch. Ham.	1.06	0.66	0.56	0.59	1.1	1
Nypa fruticans (Thunb.) Wurmb.	1.14	1.13	-	1.11	1.13	1.11
Phoenix paludosa Roxb.	1.9	1.79	1.81	1.87	1.95	1.05
Exoecaria. agallocha L.	0.64	0.58	0.66	0.64	0.69	1.01

TABLE 5A**. Exchangeable K^+ (meq 100 gm^{-1} soil) values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve.**

Sp. name	Eastern Zone			Western Zone			Central Zone		
	Arbesi	Khatuajhuri	Harinbhanga	Matla	Netidhopani	Chottohardi	Chamta	Chandkhali	Goasaba
Rhizophora mucronata Lamk	16.8	25	24.1	17.9	13.1	16.2	12.4	19.7	27.2
Rhizophora. apiculata Blume	17.3	23.4	24.1	19.1	12.3	18.3	16.8	21.3	19.2
Bruguiera gynmorhiza (L.)Lamk.	28.1	18.5	19	13.4	9	37.2	16.4	21.8	20.6
Bruguiera cylindrica (L.)Blume	-	-	-	11.3	-	17.3	18.6	22.2	20
Bruguiera sexangula (L.)Poir	16.1	28.6	28.9	-	-	19.5	30.7	-	21.1
Bruguiera parviflora W. & A.	-	-	25.7	10.4	8.3	7	22.3	10.8	11.2
Kandelia candel (L.) Druce	7.06	26.6	18.2	11.3	-	12.4	26.7	32.5	25
Ceriops decandra (Griff.)Ding. Hou.	30	29.1	29.2	15.2	10.1	17.1	14.1	18.3	16.7
Ceriops tagal (Perr.)Robin	30	24.3	27.8	14.8	9.5	9.7	20	22.1	20.6
Avicennia alba Blume	23.4	21.5	25.6	15.7	17.3	16.7	30.8	23.5	20
Avicennia officinalis L.	10.9	18.3	31.9	27.7	24.6	37.2	11.4	14.7	20
Avicennia marina (Forsk.)Vierh.	23.4	24	32.2	10.7	10.1	7	8.2	10.3	11.4
Sonneratia apetala Buch. Ham.	19.3	6.5	33.4	7.8	10.1	6.3	23.3	23	23.8
Sonneratia caseolaris (L.)Engler	-	-	-	-	-	-	-	-	-
Sonneratia griffithii Kurz.	18.7	21.8	22.4	17.7	18.5	18	21.7	19.3	20
Xylocarpus granatum Koen.	23.7	24	26.2	11.8	9.3	10.1	19.9	24.5	25
Xylocarpus mekongensis Pierre	30	15.1	29.8	11.8	14.5	27.7	12.9	11.2	14.2
Aegiceros corniculatum (L.)Blanco.	18.7	32.9	37.4	9.8	10.1	7.4	12.9	22.1	14.6
Aegialitis rotundifolia Roxb.	7.06	12.3	13.7	14.3	15.6	14.2	8.6	10.7	9.8
Heritiera fomes Buch. Ham.	22.8	21	26.7	13.3	14.7	13	17	23.7	24.6
Nypa fruticans (Thunb.) Wurmb.	12.2	22.2	23	23.5	5.6	32.5	19	21.3	18.7
Phoenix paludosa Roxb.	21.1	25.7	27.8	24.5	27.8	23.7	14.8	15	13.6
Exoecaria. agallocha L.	21.1	27.2	24.9	10.9	11.2	7.6	12.1	10.5	23.6

TABLE 5B**. Exchangeable K^+ (meq 100 gm^{-1} soil) values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve.**

Sp. name	Northern Zone			Southern Zone		
	Jhilla	Pirkhali	Panchmukhani	Bagmara	Gona	Mayadwip
Rhizophora mucronata Lamk	21.3	14.5	13.5	23.6	20.1	22.4
Rhizophora. apiculata Blume	22.3	14.5	12.4	24	20.5	22.1
Bruguiera gynmorhiza (L.)Lamk.	18.5	28.1	19	21.8	23.4	20.6
Bruguiera cylindrica (L.)Blume	-	14.5	20.9	-	22.1	-
Bruguiera sexangula (L.)Poir	15.4	-	19.2	-	-	-
Bruguiera parviflora W. & A.	-	15.7	20.4	23	26.7	22.3
Kandelia candel (L.) Druce	-	17.8	21.8	24.6	27.5	29.6
Ceriops decandra (Griff.)Ding. Hou.	27.5	29	29.1	24.6	26.1	25
Ceriops tagal (Perr.)Robin	20.4	27.8	24.3	24.8	29.5	29.6
Avicennia alba Blume	11.4	14.5	13.8	23.4	29.4	29.6
Avicennia officinalis L.	10.9	21.9	18.3	24.7	27.6	29
Avicennia marina (Forsk.)Vierh.	13.6	26.2	24	20.7	24.6	29.6
Sonneratia apetala Buch. Ham.	11.3	20.9	16.8	19.7	20.4	29.6
Sonneratia caseolaris (L.)Engler	-	-	-	13.7	-	-
Sonneratia griffithii Kurz.	12.4	16.8	14.5	18.9	20.1	22.6
Xylocarpus granatum Koen.	5.5	8.4	6.5	15.6	17.8	21.1
Xylocarpus mekongensis Pierre	13.6	19.8	15.1	13.8	14.5	27.7
Aegiceros corniculatum (L.)Blanco.	13.5	14.5	15.6	14.2	14.6	17
Aegialitis rotundifolia Roxb.	8	14.5	13	14	14.5	15
Heritiera fomes Buch. Ham.	12.7	16.5	14	13.3	17.8	23.4
Nypa fruticans (Thunb.) Wurmb.	12.2	15	13.2	15.7	19.5	21.4
Phoenix paludosa Roxb.	12.1	17.3	15.7	24.5	16.3	27.8
Exoecaria. agallocha L.	15.7	27.1	24.3	25.6	27.8	29

Such increment in the amount of the exchangeable potassium probably resulted in the removal of some of the exchangeable sodium from the soil exchange complex **(TABLE 6A,B)** resulting in a significant negative correlation between carbohydrates contents of mangrove leaves and exchangeable sodium status in soils **(TABLE 2).** However, the relationships between other soil properties and carbohydrate contents of mangrove leaves were not statistically significant in any of the cases. The results show that the nutrients released through rapid rates of decomposition of carbohydrates were largely released to water phase resulting in nutrient enrichment of the water rather than the soil. The study indicates that the areas harboring mangrove species with higher carbohydrate contents are likely to benefit more the aquatic productivity than the soil phase. However, no study could be undertaken on this aspect under the present work program.

TABLE 6A.**Exchangeable Na^+ (meq 100 gm^{-1} soil) values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve.**

Sp. name	Eastern Zone			Western Zone			Central Zone		
	Arbesi	Khatuajhuri	Harinbhanga	Matla	Netidhopani	Chottohardi	Chamta	Chandkhali	Goasaba
Rhizophora Sp *mucronata* Lamk	47.9	42.6	35.1	53.5	44.6	58.3	37.4	30	42.4
Rhizophora. apiculata Blume	42.1	48.3	35.1	51.8	41.4	55.1	38.1	28.2	47.9
Bruguiera gynmorhiza (L.)Lamk.	37.5	49.7	44.3	55.7	42.7	60	38.6	37.1	41.1
Bruguiera cylindrica (L.)Blume	-	-	-	52.6	-	57.1	43.7	40.6	61.9
Bruguiera sexangula (L.)Poir	36.9	53.3	37.1	-	-	58.3	41.3	-	52.8
Bruguiera parviflora W. & A.	-	-	36.1	38.7	40.9	37.1	33.5	27.7	35.1
Kandelia candel (L.) Druce	37.9	53.4	49	41	-	41.2	40.7	38.9	45.5
Ceriops decandra (Griff.)Ding. Hou.	36.6	51.8	39.3	49	36	53.5	46	32	48.7
Ceriops tagal (Perr.)Robin	48.5	59.9	53.7	67.3	51.7	69.2	39.1	41.2	45.6
Avicennia alba Blume	36.6	37.1	36.9	44.8	45.3	47.1	51.1	47.5	61.9
Avicennia officinalis L.	49	52.2	51.5	58.5	56.7	60	44.1	29.4	61.9
Avicennia marina (Forsk.)Vierh.	33.4	46	39.5	53.7	49	50.1	24.7	21.1	36.5
Sonneratia apetala Buch. Ham.	28.4	46.3	61.1	64.5	49	53.6	43	40.2	46.9
Sonneratia caseolaris (L.)Engler	-	-	-	-	-	-	-	-	-
Sonneratia griffithii Kurz.	44.5	47.7	48.6	49.6	45.8	51.2	57.6	52.1	61.9
Xylocarpus granatum Koen.	42.3	48	46	46	41	48.9	42.2	37.8	51.7
Xylocarpus mekongensis Pierre	36.6	41.2	48.3	46.1	38.5	47.4	37	33.5	42.7
Aegiceros corniculatum (L.)Blanco.	54.8	70.8	40	54.7	49	57	37	36.7	53.8
Aegialitis rotundifolia Roxb.	53.4	55.1	57.3	67.4	62.3	72.7	82	64.4	84.9
Heritiera fomes Buch. Ham.	44.1	54.5	44.4	58.3	51.8	59.3	32.5	30.8	58.9
Nypa fruticans (Thunb.) Wurmb.	43.2	75.8	45.8	56.7	49	58.8	56.3	40.7	61.7
Phoenix paludosa Roxb.	48.7	50.8	52.3	46.7	40.1	49	41.1	38.1	44.3
Exoecaria. agallocha L.	37.4	40	35.9	40.1	37.2	42.4	49.2	38.6	49

TABLE 6 B. **Exchangeable Na^+ (meq $100gm^{-1}$ soil) values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve.**

Sp. name	Northern Blocks			Southern Blocks		
	Jhilla	Pirkhali	Panchmukhani	Bagmara	Gona	Mayadwip
Rhizophora mucronata Lamk	26.1	44.2	28.1	52.2	55.8	61.5
Rhizophora. apiculata Blume	20.1	44.2	27.1	55.3	58.9	63.7
Bruguiera gynmorhiza (L.)Lamk.	27.1	47.2	21.2	42.9	56.0	60.0
Bruguiera cylindrica (L.)Blume	-	44.2	24.8	-	55.2	-
Bruguiera sexangula (L.)Poir	22.1	-	22.2	-	-	-
Bruguiera parviflora W. & A.	-	43.3	29.4	44.7	47.1	53.3
Kandelia candel (L.) Druce	-	47.1	32.6	45.7	53.7	57.1
Ceriops decandra (Griff.)Ding. Hou.	38.7	64.1	41.2	55.6	59.3	62.9
Ceriops tagal (Perr.)Robin	32.1	33.7	32.8	38.9	45.3	57.1
Avicennia alba Blume	28.6	44.2	34.2	56.7	55.2	57.1
Avicennia officinalis L.	32.1	44.6	33.6	58.5	59.3	60.0
Avicennia marina (Forsk.)Vierh.	29.1	40.0	31.1	48.2	53.7	57.1
Sonneratia apetala Buch. Ham.	38.1	47.1	54.8	47.6	51.9	57.1
Sonneratia caseolaris (L.) Engler	-	-	-	57.7	-	-
Sonneratia griffithii Kurz.	31.2	44.2	36.1	54.4	59.7	62.7
Xylocarpus granatum Koen.	26.1	29.3	30.3	52.5	55.1	57.0
Xylocarpus mekongensis Pierre	31.6	39.0	38.3	46.1	50.2	53.5
Aegiceros corniculatum (L.) Blanco.	27.7	44.2	31.5	47.2	51.4	53.8
Aegialitis rotundifolia Roxb.	29.4	44.2	33.8	44.2	52.7	57.9
Heritiera fomes Buch. Ham.	28.4	40.1	32.1	51.1	59.7	68.1
Nypa fruticans (Thunb.) Wurmb.	29.0	46.7	-	52.5	58.3	60.2
Phoenix paludosa Roxb.	36.4	49.8	38.0	52.4	58.7	61.3
Exoecaria. agallocha L.	36.4	45.5	37.1	49.0	53.5	58.0

Protein forms the structural and functional basis of the cells of all the living organisms. Proteins are the basic units of amino acids joined together by peptide bonds, and, therefore, rich in nitrogen. The highest protein content was observed in *Sonneratia griffithii* (7.0 mg/g), while the lowest protein content was observed in *Bruguiera sexangula* (0.7 mg/g). The protein content of other mangroves were *Rhizophora mucronata* (1.1 mg/g), *Rhizophora apiculata* (1.35 mg/g), *Bruguiera gymnorhiza* (2.5 mg/g), *Bruguiera cylindrical* (2.9 mg/g), *Bruguiera parviflora* (1.34 mg/g), *Ceriops decandra* (3.0 mg/g), *Ceriops tagal* (3.0 mg/g), *Kandelia candel* (0.9 mg/g), *Avicennia officinalis* (2.75 mg/g), *Avicennia alba* (4.45 mg/g), *Avicennia marina* (5.15 mg/g), *Sonneratia apetala* (5.3 mg/g), *Sonneratia caseolaris* (5.9 mg/g), *Aegiceras corniculatum* (0.78 mg/g), *Aegialitis rotundifolia* (0.75 mg/g), *Heritiera fomes* (2.9 mg/g), *Xylocarpus granatum* (4.6 mg/g), *Xylocarpus mekongensis* (5.5 mg/g), *Aglaia cucullata* (4.1 mg/g), *Nypa fruticans* (1.10 mg/g), *Phoenix paludosa* (5.1 mg/g) and *Exoecaria agallocha* (5.2 mg/g) (**TABLE 1**).

In terms of degradability, protein occupies an intermediate position in between carbohydrate and lipid [23]. In the present study, the concentration of water soluble protein in different mangrove leaves were observed to be comparatively lower in most of the cases. As a result, the impacts of the protein content of the mangrove leaves on the soil properties were not practically visible. However, the mangrove species having comparatively higher leaf protein values showed relatively higher available nitrogen status in the soils (**TABLE 7A,B**).

TABLE7A**. Available Nitrogen (mg kg-1) values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve.**

Sp. name	Eastern Zone			Western Zone			Central Zone		
	Arbesi	Khatuajhuri	Harinbhanga	Matla	Netidhopani	Chottohardi	Chamta	Chandkhali	Goasaba
Rhizophora mucronata Lamk	34.1	52.5	38.1	50	31.9	41.1	40.2	52.3	63.8
Rhizophora. apiculata Blume	35.6	38.3	38.1	52.5	31	38.1	38.1	36.7	60.3
Bruguiera gynmorhiza (L.)Lamk.	29.6	42.7	38.9	50	51	40.2	48.4	50.4	59.8
Bruguiera cylindrica (L.)Blume	-	-	-	28.7	-	29	29.4	28.9	71.7
Bruguiera sexangula (L.)Poir	54.7	44.4	40.5	-	-	36.4	42.7	-	67.1
Bruguiera parviflora W. & A.	-	-	42.4	36.9	42.7	63.2	54.6	59.8	64.9
Kandelia candel (L.) Druce	47.8	15.8	52.9	38.4	-	39.9	39.4	41	60.2
Ceriops decandra (Griff.)Ding.Hou.	57	45	46.1	38.4	34.1	38.1	55	46.1	68
Ceriops tagal (Perr.)Robin	55.8	49.2	52.5	51.2	57.5	42.7	49.5	44.8	63.4
Avicennia alba Blume	57	54.3	55.6	46	60.3	44.1	42.7	43.4	71.7
Avicennia officinalis L.	35.8	37.4	51.2	99.6	51.5	39.6	54.6	50.7	71.7
Avicennia marina (Forsk.)Vierh.	38.4	42.7	30.7	54.7	34.1	63.2	61.5	44.6	66.1
Sonneratia apetala Buch. Ham.	49.5	54.6	49.5	46	34.1	44.4	55.5	59.1	67.6
Sonneratia caseolaris (L.) Engler	-	-	-	-	-	-	-	-	-
Sonneratia griffithii Kurz.	51.2	53.8	53	33.3	35.6	34.1	54.9	60.3	71.7
Xylocarpus granatum Koen.	44.4	39.2	47	49.5	65.5	64.5	51.6	43.5	69.4
Xylocarpus mekongensis Pierre	57	35.6	41	49.5	56.9	73.4	53.3	59.8	59
Aegiceros corniculatum (L.)Blanco.	40.1	47.8	58	42.7	34.1	95.6	53.3	41	66.7
Aegialitis rotundifolia Roxb.	47.8	53.3	60.2	42.8	71	74.3	61.4	63	69.7
Heritiera fomes Buch. Ham.	44.5	37.5	42.4	40.7	41.5	41.1	80.3	71	57
Nypa fruticans (Thunb.) Wurmb.	46.1	39.2	42.9	32.7	34.1	33.7	38.9	41	53.5
Phoenix paludosa Roxb.	47	60.9	70	43.9	52	50.2	39.2	41.9	67.5
Exoecaria. agallocha L.	45.2	52.9	49.8	58.3	65.3	66.6	50	36.7	69

TABLE 7B**. Available Nitrogen (mg kg^{-1}) values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve.**

Sp. name	Northern Zone			Southern Zone		
	Jhilla	Pirkhali	Panchmukhani	Bagmara	Gona	Mayadwip
Rhizophora mucronata Lamk	41	42.7	59.1	50	68.7	42.7
Rhizophora. apiculata Blume	40.7	42.7	60.3	52.1	64.9	44.8
Bruguiera gynmorhiza (L.)Lamk.	39.9	42.3	59.5	50.2	66.6	46.1
Bruguiera cylindrica (L.)Blume	-	42.7	70	-	63.1	-
Bruguiera sexangula (L.)Poir	34.6	-	35.5	-	-	-
Bruguiera parviflora W. & A.	-	33.8	60.3	52.5	61.7	42.7
Kandelia candel (L.) Druce	-	35.7	62.8	52.9	63	46.1
Ceriops decandra (Griff.)Ding. Hou.	35.8	44.8	65.3	52.3	63.8	43.7
Ceriops tagal (Perr.)Robin	35.5	44.2	63.6	44.9	58.9	41
Avicennia alba Blume	38.4	42.7	58.4	27.3	53.8	46.1
Avicennia officinalis L.	43.9	49.5	73.3	48.7	67.1	48
Avicennia marina (Forsk.)Vierh.	44.5	53	76	52.1	63.4	46.1
Sonneratia apetala Buch. Ham.	48	61.1	70	66.3	85.5	46.1
Sonneratia caseolaris (L.)Engler	-	-	-	18	-	-
Sonneratia griffithii Kurz.	38.9	42.7	58.9	51.2	64.1	45.1
Xylocarpus granatum Koen.	51.1	58.8	68.1	55.9	67.5	49.1
Xylocarpus mekongensis Pierre	40.1	45.5	62.8	57.3	69.1	51
Aegiceros corniculatum (L.)Blanco.	37.7	42.7	57.5	39.4	58	40.3
Aegialitis rotundifolia Roxb.	37.8	42.7	56.9	35.8	58.7	41.9
Heritiera fomes Buch. Ham.	46.6	58.5	67.5	56	62.9	66.6
Nypa fruticans (Thunb.) Wurmb.	47.5	59	69.7	42.8	56.2	38.6
Phoenix paludosa Roxb.	39.2	44.8	64.5	48.6	63.6	43.5
Exoecaria. agallocha L.	47.8	60.4	68.6	50.3	69.8	52.1

As for example, *Sonneratia* plants showed comparatively higher protein content in the leaves ranging between 5.3 and 7.0 mg/gm. When accumulated to bottom soils these leaves tended to release a higher amount of nitrogen to available form during the course of their decomposition. Thus, the mangrove rhizosphere soils with *Sonneratia* vegetation showed the relatively higher occurrence of available nitrogen in soils. Similar was the case for *Phoenix* and *Exoecaria* also. However, the comparatively lower occurrence of this component as organic matter in mangrove leaves and also the water solubility of released nitrogen, as discussed earlier, did not permit this impact of leaf protein on the availability of nitrogen to be

significant in mangrove rhizosphere soils. In this case, also, the nitrogen, mineralized from protein component, was released largely to the water phase and was likely to benefit more the aquatic phase than the soil phase.

In this study, the highest lipid content was found in *Aegiceras corniculatum* (6.2%) and the lowest lipid content was found in Ceripos tagal (0.28%). Both the species of *Xylocarpus* and three species of *Sonneratia* and *Kandelia candel* also showed high lipid contents in their leaves. It may be said that this high percentage may be due to the presence of some essential oils in these mangroves. Since lipid is more resistant to decomposition, the mangrove leaves with high lipid content did not degrade easily and contributed more to the organic carbon content of mangrove habitats when accumulated in the soils. Therefore, different species of *Avicennia* and *Nypa* which showed higher lipid content in leaves were found to exhibit higher organic carbon content in their rhizosphere soils **(TABLE 4A,B).**

On the other hand, species like *Exoecaria* and *Phoenix* which showed lower lipid content in their leaves had a lower amount of organic carbon in their habitat soils. This behavior was reflected in a positive correlation between the lipid content of mangrove leaves and the organic carbon content of the respective rhizosphere soils. However, the relationship was not statistically significant. Availability of phosphorus in mangrove soils also showed a similar trend of behavior **(TABLE 8A,B)** and showed a positive correlation with the lipid content of the leaves. Such beneficial effects of soil organic matter on the availability of phosphorus in mangrove soils have been discussed earlier. However, in this case, also, the relationship did not appear to be statistically significant.

TABLE 8A**. Available Phosphorus (mg kg^{-1}) values of mangroves Rhizosphere soils in different zones of Sundarbans Tiger Reserve.**

Sp. name	Eastern Zone			Western Zone			Central Zone		
	Arbesi	Khatuajhuri	Harinbhanga	Matla	Netidhopani	Chottohardi	Chamta	Chandkhali	Goasaba
Rhizophora mucronata Lamk	17.8	13.1	14.5	20.3	21.3	17.3	8.5	18.2	13
Rhizophora. apiculata Blume	17.2	15.6	14.5	21.1	21.6	18	10	13.4	10.7
Bruguiera gynmorhiza(L.)Lamk.	17.5	18.5	18	20.2	20.6	17.5	19.1	18.7	15.4
Bruguiera cylindrica (L.)Blume	-	-	-	21.4	-	21.7	15.3	16.7	10.8
Bruguiera sexangula (L.)Poir	19.4	15	14.3	-	-	20.3	13	-	14.7
Bruguiera parviflora W.& A.	-	-	15.1	11.2	10	16	14.7	15.6	14.8
Kandelia candel (L.) Druce	20.4	17.5	17.5	14.3	-	15.7	13	12.5	13.1
Ceriops decandra (Griff.)Ding. Hou.	17.5	20.6	18.7	15.6	21	12.9	15	14.1	15.2
Ceriops tagal (Perr.)Robin	17.9	16.8	16.5	22.1	21.3	15	15.8	17.2	16.8
Avicennia alba Blume	18.5	15.6	16.8	13.5	18.7	13	0.3	10.4	10.8
Avicennia officinalis L.	22	20.4	21.3	15.7	16.9	12.6	10	12.3	10.8
Avicennia marina (Forsk.)Vierh.	17.3	15.5	15	17.1	21	16	10	12.7	9.8
Sonneratia apetala Buch. Ham.	12.5	21.6	18.5	16.3	21	15	14	15.6	13.7
Sonneratia caseolaris (L.)Engler	-	-	-	-	-	-	-	-	-
Sonneratia griffithii Kurz.	11.5	10.4	10.1	11.3	15.3	15.5	14.7	15	10.8
Xylocarpus granatum Koen.	17.3	15	22	15	15.7	14.8	13.7	19.1	13
Xylocarpus mekongensis Pierre	17.5	21.7	20.5	15	12.3	7.5	14	22.1	13.9
Aegiceros corniculatum (L.)Blanco.	16.7	21.8	21.1	20.5	21	7.5	14	22.1	14
Aegialitis rotundifolia Roxb.	20.4	17.6	18.3	18.7	19.1	15.3	8.8	13.4	9.6
Heritiera fomes Buch. Ham.	19.7	20.4	21.8	13.4	14.7	12.1	15.6	14.6	10
Nypa fruticans (Thunb.) Wurmb.	16.7	16.5	15	17.3	20	16.3	10.3	12.5	9.7
Phoenix paludosa Roxb.	22.1	16.3	17.5	16.7	17.8	15.2	15.5	16.3	14.8
Exoecaria. agallocha L.	15	16	17.7	13.4	15	12.5	14.2	14	11.2

TABLE 8B. **Available Phosphorus (mg kg^{-1}) values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve.**

Sp. name	Northern Zone			Southern Zone		
	Jhilla	Pirkhali	Panchmukhani	Bagmara	Gona	Mayadwip
Rhizophora mucronata Lamk	14.2	10	11.4	12	10.1	12.5
Rhizophora. apiculata Blume	14.8	10	12.1	10.5	10.8	9.8
Bruguiera gynmorhiza (L.)Lamk.	15.7	14.6	14	10	10.2	9.3
Bruguiera cylindrica (L.)Blume	-	10	18.6	-	9.4	-
Bruguiera sexangula (L.)Poir	15.8	-	15	-	-	-
Bruguiera parviflora W. & A.	-	13.4	12.1	9.4	9.1	6.6
Kandelia candel (L.) Druce	-	15.6	14.2	11.2	10.1	7.8
Ceriops decandra (Griff.)Ding. Hou.	17.6	21.4	18.3	10.1	9.4	6.9
Ceriops tagal (Perr.)Robin	17.6	21.4	18.3	10.1	9.4	6.9
Avicennia alba Blume	15.1	10	13.1	10.6	9.2	7.8
Avicennia officinalis L.	15	12.1	12.9	11.2	10.1	8.3
Avicennia marina (Forsk.)Vierh.	14	11.6	12.5	11	9.7	7.8
Sonneratia apetala Buch. Ham.	20.1	16.7	18.6	12.1	9.8	7.8
Sonneratia caseolaris (L.)Engler	-	-	-	10.9	-	-
Sonneratia griffithii Kurz.	12.3	10	11	10.9	9.1	8.8
Xylocarpus granatum Koen.	19.1	17	17.5	11.7	11.1	10.1
Xylocarpus mekongensis Pierre	15.7	13.1	14.5	12	10.3	7.5
Aegiceros corniculatum (L.)Blanco.	14.1	10	12.1	12.3	11.5	10.2
Aegialitis rotundifolia Roxb.	13.8	10	11.6	12.5	10.3	8.2
Heritiera fomes Buch. Ham.	13.5	12.4	12.8	11.1	10.1	7.1
Nypa fruticans (Thunb.) Wurmb.	15	12.1	13.4	11.3	9.4	6.3
Phoenix paludosa Roxb.	16.4	13.6	14.5	11.4	10.8	7.2
Exoecaria. agallocha L.	20.7	12	22.2	11.2	10	8.5

On the other hand, lipid contents of mangrove leave resulted in a significant negative correlation with exchangeable potassium in the soils **(TABLE 9A,B, TABLE 10A,B)**

This primary study on some biochemical properties of mangrove leaves and their effects on rhizosphere soils show that various organic components of mangrove leaves are likely to exert variable effects on the soil and water properties in the mangrove forests. For getting comprehensive effects of nutrient cycling from these leaves, therefore, mixed populations of different mangrove species may be maintained in the mangal forests.

TABLE 9A. **EC (dsm^{-1}) values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve.**

Sp. Name	Eastern Zone			Western Zone			Central Zone		
	Arbesi	Khatuajhuri	Harinbhanga	Matla	Netidhopani	Chottohardi	Chamta	Chandkhali	Goasaba
Rhizophora mucronata Lamk	19.3	21.7	21.1	23.3	23.5	28.6	33.2	26.7	32.9
Rhizophora. apiculata Blume	24.3	23.6	21.1	24.6	22.5	25.2	23	24.4	26.8
Bruguiera gynmorhiza (L.)Lamk.	24.8	22.4	23.6	26.6	19.3	26.8	37.7	22.8	38.5
Bruguiera cylindrica (L.)Blume	-	-	-	-	-	34.5	37.4	25.4	37.7
Bruguiera sexangula (L.)Poir	20.4	23.2	25.1	-	-	35.8	40.6	-	41.7
Bruguiera parviflora W. & A.			24.8	25.9	21.1	26.8	24.9	21.2	28.1
Kandelia candel (L.) Druce	19.2	21.6	19.8	23.3		24.1	24.4	22.8	27.5
Ceriops decandra (Griff.)Ding. Hou.	20.3	24.6	22.5	24.1	19.3	19.5	20	29.2	33.2
Ceriops tagal (Perr.)Robin	22	24.3	27.6	26.7	26.4	29.4	31.6	27.5	35.2
Avicennia alba Blume	20.3	23.5	21.9	27.3	26.5	27.2	28.1	24.1	37.7
Avicennia officinalis L.	14.5	18.5	16	21.1	21.4	21.4	16.8	22.7	37.7
Avicennia marina (Forsk.)Vierh.	19.2	20	20.8	25.2	19.3	22	18	21.9	25.4
Sonneratia apetala Buch. Ham.	20	26.7	24.6	26.2	19.3	19.5	28.4	26	30.7
Sonneratia caseolaris (L.) Engler	-	-	-	-	-	-	-	-	-
Sonneratia griffithii Kurz.	23.5	22.8	26.2	31.3	29.9	33.2	34.8	30.2	37.7
Xylocarpus granatum Koen.	18.4	18.8	19.8	16.4	19.6	23.2	18.5	26	26.8
Xylocarpus mekongensis Pierre	20.3	26	25.7	16.4	25.9	25.7	25.9	29.2	33.6
Aegiceros corniculatum (L.) Blanco.	15.2	16.1	24.4	24	19.3	23.8	25.9	19.6	29.7
Aegialitis rotundifolia Roxb.	19.2	20.3	19.2	22.7	24.3	24.6	24.9	23.6	25.9
Heritiera fomes Buch. Ham.	21.4	21.9	23.5	25.9	25.6	27.5	28	25.9	25.1
Nypa fruticans (Thunb.) Wurmb.	18.5	17.9	20.9	24.1	21.1	24.8	25.7	22.8	28.3
Phoenix paludosa Roxb.	19.6	25.4	22.8	27.2	26.5	27	28.4	25.2	31.2
Exoecaria. agallocha L.	29.4	27.2	26.8	26.8	25.4	30	21.6	19.8	32.6

TABLE 9B. **EC (dsm^{-1}) values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve.**

Sp. name	Northern Zone			Southern Zone		
	Jhilla	Pirkhali	Panchmukhani	Bagmara	Gona	Mayadwip
Rhizophora mucronata Lamk	18.2	22	21.1	23.5	27.6	39.6
Rhizophora. apiculata Blume	22.7	19.8	22	23.3	26.7	40.6
Bruguiera gynmorhiza (L.)Lamk.	23.6	24.1	22.8	23	31.5	25.4
Bruguiera cylindrica (L.)Blume	-	22	25.9	-	28	-
Bruguiera sexangula (L.)Poir	20.8		21.1	-	-	-
Bruguiera parviflora W. & A.	-	26.8	26.7	23.3	30.2	28.3
Kandelia candel (L.) Druce	-	26	25.6	22	31.2	28
Ceriops decandra (Griff.)Ding. Hou.	22.8	25.4	24.3	23	29.7	27.3
Ceriops tagal (Perr.)Robin	21.6	18.5	21.6	24.3	31.3	16.8
Avicennia alba Blume	19.6	22	22.5	21.4	28.4	27.3
Avicennia officinalis L.	16.6	19.8	21.9	21.4	23.6	22.7
Avicennia marina (Forsk.)Vierh.	20.3	21.9	22.7	23.8	25.4	27.3
Sonneratia apetala Buch. Ham.	20.4	22	19.8	24.4	36.4	27.3
Sonneratia caseolaris (L.) Engler	-	-	-	15	-	-
Sonneratia griffithii Kurz.	21.6	22	20.8	19.3	26	25.4
Xylocarpus granatum Koen.	15.8	15.2	13.9	24.6	28.6	26.7
Xylocarpus mekongensis Pierre	19.6	22.2	21.1	24.3	34.8	27.2
Aegiceros corniculatum (L.) Blanco.	19.8	22	21.7	24.4	31.8	26.4
Aegialitis rotundifolia Roxb.	20.4	22	20.6	18	24.6	27
Heritiera fomes Buch. Ham.	19.5	20.1	19.2	21.4	23.8	20
Nypa fruticans (Thunb.) Wurmb.	18.4	20.4		25.1	30.2	26
Phoenix paludosa Roxb.	23.6	24	23.5	26	31.5	24.3
Exoecaria. agallocha L.	24	24.1	23.6	25.9	34.4	25.4

TABLE 10A. **Salinity (ppt) values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve.**

Sp. name	Eastern Zone			Western Zone			Central Zone		
	Arbesi	Khatuajhuri	Harinbhanga	Matla	Netidhopani	Chottohardi	Chamta	Chandkhali	Goasaba
Rhizophora mucronata Lamk	12.1	13.6	13.2	14.6	14.7	17.9	20.8	16.7	20.6
Rhizophora. apiculata Blume	15.2	14.8	13.2	15.4	14.1	15.8	14.4	15.3	16.8
Bruguiera gynmorhiza (L.)Lamk.	15.5	14	14.8	16.3	12.1	16.8	23.6	14.3	24.1
Bruguiera cylindrica (L.)Blume	-	-	-	18.9	-	21.6	23.4	15.9	23.6
Bruguiera sexangula (L.)Poir	12.8	14.5	15.7	-	-	22.4	25.4	-	26.1
Bruguiera parviflora W. & A.	-	-	15.5	16.2	13.2	16.8	15.6	13.3	17.6
Kandelia candel (L.) Druce	12	13.5	12.4	14.6	-	15.1	15.3	14.3	17.2
Ceriops decandra (Griff.)Ding. Hou.	12.7	15.4	14.1	15.1	12.1	12.2	12.5	18.3	20.8
Ceriops tagal (Perr.)Robin	13.8	15.2	17.3	16.7	16.5	18.4	19.8	17.2	22
Avicennia alba Blume	12.7	14.7	13.7	17.1	16.6	17	17.6	15.1	23.6
Avicennia officinalis L.	9.1	11.6	10	13.2	13.4	13.4	10.5	14.2	23.6
Avicennia marina (Forsk.)Vierh.	12	12.5	13	15.8	12.1	13.8	11.3	13.7	15.9
Sonneratia apetala Buch. Ham.	12.5	16.7	15.4	16.4	12.1	12.2	17.8	16.3	19.2
Sonneratia caseolaris (L.) Engler	-	-	-	-	-	-	-	-	-
Sonneratia griffithii Kurz.	14.7	14.3	16.4	19.6	18.7	20.8	21.8	18.9	23.6
Xylocarpus granatum Koen.	11.5	11.8	12.4	10.3	12.3	14.5	11.6	16.3	16.8
Xylocarpus mekongensis Pierre	12.7	16.3	16.1	10.3	16.2	16.1	16.2	18.3	21
Aegiceros corniculatum (L.) Blanco.	9.5	10.1	15.3	15	12.1	14.9	16.2	12.3	18.6
Aegialitis rotundifolia Roxb.	12	12.7	12	14.2	15.2	15.4	15.6	14.8	16.2
Heritiera fomes Buch. Ham.	13.4	13.7	14.7	16.2	16	17.2	17.5	16.2	15.7
Nypa fruticans (Thunb.) Wurmb.	11.6	11.2	13.1	15.1	13.2	15.5	16.1	14.3	17.7
Phoenix paludosa Roxb.	12.3	15.9	14.3	17	16.6	16.9	17.8	15.8	19.5
Exoecaria. agallocha L.	18.4	17	16.8	16.8	15.9	18.8	13.5	12.4	20.4

TABLE 10B. **Salinity (ppt) values of mangroves rhizosphere soils in different zones of Sundarbans Tiger Reserve**

Sp. name	Northern Zone			Southern Zone		
	Jhilla	Pirkhali	Panchmukhani	Bagmara	Gona	Mayadwip
Rhizophora mucronata Lamk	11.4	13.8	13.2	14.7	17.3	24.8
Rhizophora. apiculata Blume	14.2	12.4	13.8	14.6	16.7	25.4
Bruguiera gynmorhiza (L.)Lamk.	14.8	15.1	14.3	14.4	19.7	15.9
Bruguiera cylindrica (L.)Blume	-	13.8	16.2	-	17.5	-
Bruguiera sexangula (L.)Poir	13	-	13.2	-	-	-
Bruguiera parviflora W. & A.	-	16.8	16.7	14.6	18.9	17.7
Kandelia candel (L.) Druce	-	16.3	16	13.8	19.5	17.5
Ceriops decandra (Griff.)Ding. Hou.	14.3	15.9	15.2	14.4	18.6	17.1
Ceriops tagal (Perr.)Robin	13.5	11.6	13.5	15.2	19.6	10.5
Avicennia alba Blume	12.3	13.8	14.1	13.4	17.8	17.1
Avicennia officinalis L.	10.4	12.4	13.7	13.4	14.8	14.2
Avicennia marina (Forsk.)Vierh.	12.7	13.7	14.2	14.9	15.9	17.1
Sonneratia apetala Buch. Ham.	12.8	13.8	12.4	15.3	22.8	17.1
Sonneratia caseolaris (L.) Engler	-	--	-	9.4	-	-
Sonneratia griffithii Kurz.	13.5	13.8	13	12.1	18.6	15.9
Xylocarpus granatum Koen.	9.9	9.5	8.7	15.4	17.9	16.7
Xylocarpus mekongensis Pierre	12.3	13.9	13.2	15.2	21.8	17
Aegiceros corniculatum (L.) Blanco.	12.4	13.8	13.6	15.3	19.9	16.5
Aegialitis rotundifolia Roxb.	12.8	13.8	12.9	11.3	15.4	16.9
Heritiera fomes Buch. Ham.	12.2	12.6	12	13.4	114.9	12.5
Nypa fruticans (Thunb.) Wurmb.	11.5	12.8		15.7	18.9	16.3
Phoenix paludosa Roxb.	14.8	15	14.7	16.3	19.7	15.2
Exoecaria. agallocha L.	-	15	15.1	14.8	16.2	21.5

Conclusion

The concentrations of N, P and N:P ratio in the medium influence on the growth and uptake of N, P of *H. acutigluma*. The plants grew well at 120 mg N/L and 5 mg P/L. The phosphate concentration of 20 mg P/L could inhibit the growth of *H. acutigluma*. The mole ratio of N/P of lower than 13.3 could limit the growth and uptake of N, P of *H. acutigluma*, especially at low and medium N conditions. The treatment efficiency of NH_4^+-N, NO_3^--N, TN, PO_4^{3-}-P and TP were 85.7%-95.1%, 70.1%-81.6%, 64.8%-74.3%, 48.8%-80.3% and 35.9%-76.9%, respectively. In N_3P_1 conditions, *H. acutigluma* could help to decrease N and P by 6.4% and 29.5%, respectively. The results in this study clearly showed that *H. acutigluma* were able to grow and uptake of N, P from the wastewater containing a high concentration of N, P from intensive farming of catfish.

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