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Variation in Relationship Between Salt Ion Excretion and Accumulation of Organic Carbon in Sundarban Mangroves Under Various Seasonal Conditions

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Abstract - **In the present study, the relationship between photosynthetic activity (organic carbon accumulation) and salt excretion was observed in six salt excretory mangrove species of Sundarban. The study encompassed three different sites and stretched over a period of three prominent (premonsoon, monsoon and postmonsoon) seasons in order to evaluate the spatio-temporal variations. In general, a positive correlation was observed among rate of excretion of salt ions from the leaves to that of the rate of accumulation of organic carbon in the leaves of the species studied. The only deviations occurred during monsoon especially in the sodium and potassium ion excretion along with the photosynthetic activity, which supported the dependence of salt ion excretion on processes like photosynthesis strongly.**

Keywords: **Mangrove, Sundarban, Salt Excretion, Photosynthetic Activity, Organic Carbon**

I. Introduction

Mangroves are plants that grow at the soil water interface in coastal tropics and subtropics where the plants exist in high saline conditions, with tidal water flow and diurnal submergence along with physiologically dry muddy soil. The mangroves form a unique ecological community (the 'mangal') in tropical regions and tidal lowlands. Mangroves are considered to be ecologically significant as they serve as bulwarks to protect the adjacent land from battering waves and thrashing storm winds caused erosion [1]. They are also of immense importance in preventing terrigenous nutrients from affecting the fragile coral reefs nearby [2]. There are evidences that high NaCl content is one factor leading to oxidative stress in plant cells [3]. The aim of the present study was to ascertain the effect of photosynthesis (in the form of accumulation of organic carbon in leaves) in mangroves on their ability to excrete excess salt from their body at different stations in Sundarban during premonsoon, monsoon and postmonsoon periods to evaluate the effects in various environmental stress conditions. The mangroves are special because of their ability to negate the effect of excess salt in their body by either storing them in special organs, selective permeability of the roots or by excluding them through salt glands on the leaves [4] and at the same time mangroves are considered to be mass storage of atmospheric CO_2 through its sequestration during photosynthesis [5]. This sort of study hasn't been conducted in Sundarban mangroves extensively and is of immense importance in order to ascertain the threats these plants would face in terms of global weather change and the relationship b/w the two very important physiological processes (photosynthesis and salt excretion) that we generated from our study will also help us to understand the delicate balance existing b/w the salt excretory mangrove species of Sundarban and their ambient environment.

II. Material And Methods

At the initial phase of the study large number of leaf samples of mangrove species *(Avicennia marina, A. alba, A. officinalis, Aegialitis rotundifolia, Acanthus ilicifolius and Aegiceras sp.)* from different study areas at Sundarbans (Fig.1) (Bhagabatpur [20º39.1'N to 88º7.34'E], Chandanpiri [21º40.49'N to 88º7.34'E] and Sagar Island (Chemaguri) [21º39.52'N to 88º17.37'E]) were chosen for the study.

A. Determination of the Rate of Salt Excretion

At first, about 30 leaves from each of the mangroves species under consideration were washed clean with distilled water to remove the existing salt crystals and were covered with clean and transparent polythene bag in order to minimize contaminations from dirt particles and other external salt sources. The bags were kept on for a period of ten hours. Sampling was done by rinsing the leaves with 25ml of distilled water to dissolve the salt crystals present on the leaf surface while still attached to the plant to minimize collection error.

The solutions were collected in 50 ml plastic (TARSON) containers and were further analyzed for the estimation of different ions (Na, K, & Cl). The flame photometer [Systronics Digital Flame Photometer-125, Serial No.-1473] was employed to estimate the sodium and potassium ion contents in these solutions and for the estimation of chloride ions standard gravimetric method was applied [6]. After the series, the leaves were detached from the bush and later traced on a millimeter graph paper to determine the leaf area.

B. Determination of the Rate of Accumulation of Organic Carbon in the Leaves

From the collected leaves about ten healthy leaves from each of the mangrove species were taken for the analysis of organic carbon accumulation rate. The leaves were dried in a hot air oven at 60ºC for a couple of days till they were absolutely free of any moisture content. The next step was to grind them to a powder using porcelain mortar and pestle. From the powdered dry leaf samples 0.25 gm were measured for each species and the organic carbon content was estimated using the standard Walkley and Black method [5] .

III. Results And Discussion

From the tables (Table I, II & III), it is quite clear that the general trend of organic carbon accumulation in leaves of all the six mangrove species followed a very prominent and similar path throughout the three seasons at all the three sites in Sundarban. The highest rate of accumulation is associated with Avicennia marina, gradually decreasing among the others only to have its second maxima in Acanthus ilicifolius. The prevalent trend was only challenged during the monsoon in the form of minor exceptions. At all the sites the rate of accumulation of organic carbon was highest during premonsoon season followed closely by postmonsoon [7]. The less cloud cover can explain this and high sunlight intensity triggering enhanced photosynthetic activity in general compared to the frequent overcast conditions encountered during monsoon [8]. A very interesting observation was drawn from it as the charts showed a range of variation in the rate of accumulation of organic carbon in different mangroves to be steeper during the high sunlight intensity months of premonsoon and postmonsoon seasons

Table I Table Showing Rate of Excretion of Salt Ions and Organic Carbon Content in Leaves of Mangroves at Bhagabatpur.

Name of the species	**Chandanpiri**	**Premonsoon**		
	Na	**K**	**Cl**	**OrgC**
Avicennia marina	3.3935	0.32	5.8665	0.6485
Avicennia alba	2.0319	0.099	4.6995	0.5138
Avicennia officinalis	1.2889	0.0324	3.8036	0.2838
Aegialitis rotundifolia	0.9014	0.0319	3.4275	0.2875
Acanthus ilicifolius	0.9333	0.1452	4.8553	0.4235
Aegiceras sp.	2.5596	0.1023	3.3063	0.3255
		Monsoon		
	Na	**K**	**Cl**	**OrgC**
Avicennia marina	4.0977	0.564	7.052	0.7275
Avicennia alba	1.6867	0.1582	3.9581	0.555
Avicennia officinalis	0.878	0.1229	3.3264	0.3693
Aegialitis rotundifolia	0.9408	0.1555	3.6372	0.3098
Acanthus ilicifolius	0.862	0.1999	4.0453	0.46
Aegiceras sp.	1.6302	0.1619	2.204	0.365
		Postmonsoon		
	Na	**K**	**Cl**	**OrgC**
Avicennia marina	5.7033	0.378	9.0592	0.7615
Avicennia alba	2.9358	0.1746	5.6326	0.58
Avicennia officinalis	2.1341	0.0676	5.1541	0.3961
Aegialitis rotundifolia	3.8857	0.2152	3.5444	0.2786
Acanthus ilicifolius	3.3811	0.9718	4.4239	0.417
Aegiceras sp.	9.5279	2.4312	3.1699	0.3305

TABLE II TABLE SHOWING RATE OF EXCRETION OF SALT IONS AND ORGANIC CARBON CONTENT IN LEAVES OF MANGROVES AT CHANDANPIRI.

Name of the species	**Chandanpiri**	**Premonsoon**		
	Na	**K**	**Cl**	**OrgC**
Avicennia marina	3.3935	0.32	5.8665	0.6485
Avicennia alba	2.0319	0.099	4.6995	0.5138
Avicennia officinalis	1.2889	0.0324	3.8036	0.2838
Aegialitis rotundifolia	0.9014	0.0319	3.4275	0.2875
Acanthus ilicifolius	0.9333	0.1452	4.8553	0.4235
Aegiceras sp.	2.5596	0.1023	3.3063	0.3255
		Monsoon		
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Avicennia officinalis	2.1341	0.0676	5.1541	0.3961
Aegialitis rotundifolia	3.8857	0.2152	3.5444	0.2786
Acanthus ilicifolius	3.3811	0.9718	4.4239	0.417
Aegiceras sp.	9.5279	2.4312	3.1699	0.3305

TABLE III TABLE SHOWING RATE OF EXCRETION OF SALT IONS AND ORGANIC CARBON CONTENT IN LEAVES OF MANGROVES AT CHEMAGURI

Name of the species	**Chemaguri**	**Premonsoon**		
	Na	**K**	**Cl**	**OrgC**
Avicennia marina	14.5983	0.6169	15.2914	0.5922
Avicennia alba	8.3964	1.7831	13.4195	0.4437
Avicennia officinalis	2.6313	0.3791	8.6119	0.2812
Aegialitis rotundifolia	2.6522	0.128	6.4568	0.3468
Acanthus ilicifolius	7.7854	2.7663	11.9074	0.3468
Aegiceras sp.	6.069	1.1419	6.2425	0.2797
		Monsoon		
	Na	**K**	**Cl**	**OrgC**
Avicennia marina	10.5586	2.4788	5.477	0.6612
Avicennia alba	3.7624	0.4048	4.935	0.4937
Avicennia officinalis	0.7709	0.1146	3.4156	0.3118
Aegialitis rotundifolia	3.8857	0.2152	3.5444	0.2768
Acanthus ilicifolius	3.3811	0.9718	4.4239	0.417
Aegiceras sp.	9.5279	2.4312	3.1699	0.3305
		Postmonsoon		
	Na	**K**	**Cl**	**OrgC**
Avicennia marina	32.2278	16.7016	12.4377	0.6837
Avicennia alba	3.7624	0.4048	4.935	0.4937
Avicennia officinalis	0.7709	0.1146	3.4156	0.3118
Aegialitis rotundifolia	3.8857	0.2152	3.5444	0.2786
Acanthus ilicifolius	3.3811	0.9718	4.4239	0.417
Aegiceras sp.	9.5279	2.4312	3.1699	0.3305

compared to the monsoon. As it has been experimentally proven that *Avicennia spp.* do exhibit diurnal variation in their photosynthetic activity with peaks during late morning and in the afternoon sessions, and a total photosynthetic shutdown during noon. C_3 plants do not function in high heat conditions as RuBisCO [chief photosynthetic enzyme] incorporates more oxygen to RuBP when temperature increases, leading to photorespiration [9]. This can also be the case with other mangroves during monsoon as perpetual cloud cover renders the temperature at a constant high. This coupled with low sunlight intensity might have caused a slack in the organic carbon accumulation [9],[8].

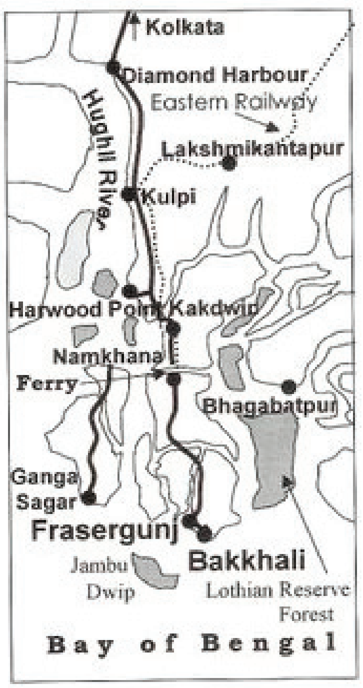

Fig. 1 Map of the stiudy area(Showing transportation route from Kolkata[Calcutta] to Namkhana[last bus stop at Sundarban] and onward).

Another very curious feature revealed from the charts was the apparently high rate of accumulation of organic carbon in the leaves of *Acanthus ilicifolius* second only to *A.marina.* Due to lack of enough evidence regarding enzymatic governance of photosynthesis in this plant, any comment on this result now would be premature, as it needs a detailed analysis. However, the habit in which these plants grow can shed some light on this. They normally grow in naturally occurring thickets under the shade of other large woody trees. Their general shrubby nature renders them greener compared to woody trees, hence higher photosynthesis and organic carbon accumulation [10]. Another reason for their high photosynthetic activity could be their high saline habitat. To maintain salt balance in their body and to excrete excess saline solution their rate of transpiration needs to be high which is directly related to photosynthesis [10].

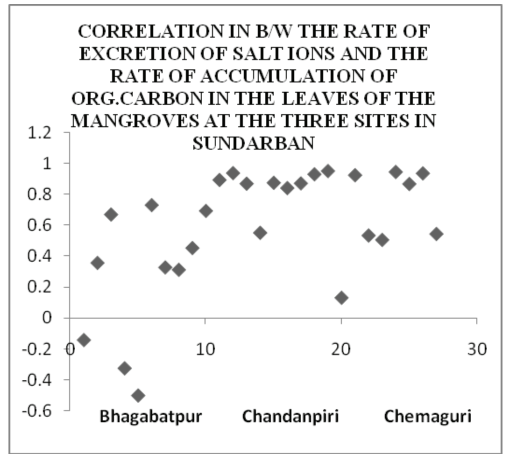

Fig. 2 Correlation plot between the rate of salt excretion and rate of orgC accumulation in Sundarban. (The diamonds represent the correlation value between orgC accumulation rate and Na, K, Cl excretion rate in premonsoon, monsoon and postmonsoon respectively; first three for premonsoon, middle three for monsoon and last three for postmonsoon at each station).

High saline condition was also found to play a key role as in case of *A. alba and Aegiceras sp.* The depressions in rate of accumulation of organic carbon that was observed in those plants might be attributed to a reduction in stomatal opening due to salinity stress. The likely sequence of events could have been increased salinity, water stress, stomatal closure, decrease in intercellular carbon di-oxide and decrease in photosynthesis [11]. This interpretation of reduction of photosynthesis through restricting access of CO_2 via stomatal closure is also supported by linear proportionality of organic carbon accumulation and salt excretion curves, a feature vindicated by earlier studies on different mangroves at other mangrove ecosystems [12].

As far as rates of excretion of salt ions are concerned, the plants exhibited a more or less similar pattern in case of Cl excretion with that of organic carbon accumulation in leaves of the mangroves studied where the two highest rates were reflected from *A. marina and A. ilicifolius.* This also somehow highlights the relationship b/w photosynthesis and salt excretion. Few exceptions were also observed during monsoon as high degree of dilution of salt in ambient soil and water media almost render the excretion rate equal in general at Bhagabatpur (Table I) and Chandanpiri (Table II). It has been proven that during monsoon seasons the salt excretory mangrove plants do tend to store more salt ions than their surroundings to maintain the transpiration pool and osmotic balance [13]. However, at Chemaguri, the chloride ion excretion profile shows values lower in comparison with others and typical salinity in the region is also lower compared to the other sites studied, as a profound discharge of freshwater takes place in the creeks and rivers of this region the year round getting higher during monsoon. Hence, there will always be a tendency among the plants here to store excess salt ions in their cells as compared to the same plant species growing in areas of higher salinity regime. So, the rate of excretion of chloride ions also reflects a lower value [13], [14].

An apparent relationship b/w photosynthetic activity (organic carbon accumulation) and excretion of salt ions from the leaves was also observed in case of sodium ions. The rate seemed to be high in case of low rate of accumulation of organic carbon and vice versa, although the chart showed similar topography for both the curves. These two facts suggest two things: 1. the photosynthetic activity actually governs the rate of excretion of ions such as sodium and at the same time 2. Higher photosynthetic activity in evidenced by lower rate of sodium excretion from the leaves as obviously sodium plays a significant role in maintenance of photosynthetic/ metabolic pathways and transmembrane transportation of ions [7]. However, once again the glitch in the prevalent trend was observed in the monsoon season at the chosen study sites as values of excreted amount of sodium seems to be higher than others. As in case of chloride ion excretion, the values were lowest in monsoon, which is somewhat contradictory to Na excretion values. This could be because a general cloud cover dims the intensity of sunlight and theoretically should affect the speed of photosynthesis leading to less utilization and consequently more excretion of Na ions [12],[13]. Another point worthy feature for the Na ion excretion profile at the three study sites was the lack of similarity among the species. As the charts show (Table I, II & III) the highest and second highest rates were observed in *Avicennia marina and Aegiceras sp.* which makes it even more interesting as the plants are of completely dissimilar habits and also habitats in terms of salinity wit *A. marina* thriving at the soil water interface zone compared to the relatively inward position of the *Aegiceras* thickets. From the present study it would be premature to narrow in on the possible explanations, as more studies of this sort need to be done. On an assumptive ground though, it can be said that in a steady state condition the rate of salt entering the roots equals that excreted by the leaf and the latter fraction must be very small in case of genera like *Avicennia, Aegialitis* and *Aegiceras* and during monsoon the rate of salt ions entering the roots increases drastically as the freshwater input dilutes the saline concentration [15],[16].

For potassium ion excretion, the observations were more or less similar to the profile of Na ion excretion during the three seasons at the three sites. The first mentionable feature is the apparent equal rate of excretion rate of potassium ions in all the plant species. This could be because all the six salt excretory plant species might utilize potassium in a more or less similar way and there is very little variation in that pattern of utilization with respect to the change in seasons. Here too *A. marina* and *A. ilicifolius* (Table I, II & III) exhibited relatively higher values of excretion in pre- and postmonsoon seasons but the amount was far less than the other two given its low concentration in seawater. But during monsoon, the K excretion curve only followed the Na excretion curve as the plants as micronutrients utilize both these ions; any deviation in the pattern of uptake and exclusion is likely to produce similar excretion patterns (the change in uptake of salt owes to the dilution by fresh water). Both the Na and K excretion curves are quite inclined to the organic carbon accumulation curve, a fact that can suggest their utilization during photosynthesis and lack of it during periods of lower accumulation of organic carbon with simultaneous higher egress of these ions from the leaves of the mangroves [15],[17],[18],[7].

From the correlation chart (Fig. 2), it has become clear that the rate of excretion of salt ions (Na, K & Cl) from the mangrove leaves share a fairly high degree of positive correlation [r-values at or above 0.5 in general] with the rate of accumulation of organic carbon in Sundarban. This also underlines that photosynthesis and salt excretion are two very different but physiologically interrelated processes and the only exception was found at Bhagabatpur which could be a case of aging of leaves or some other metabolic malfunction of the plant individual resulting in negative correlation. The chart also states a fact very boldly that the observations made from the earlier profiles for monsoon seasons regarding the possible depression in photosynthetic activity might not hold much of a significance on an overall basis as it if well documented that for some mangroves such as *A. officinalis,* low light and heat intensity might cause a higher degree of photosynthesis (functioning of RuBisCO), showing a dual nature reaching optimum at 32-39ºC [19]. A higher rate of photosynthesis could also trigger a higher rate of transpiration resulting in enhanced rate of salt ion excretion from the leaves. However, to ascertain these facts, further studies on enzymatic activities of Sundarban salt secreting mangroves as a response to changes in physicochemical parameters need to be conducted.

IV. Conclusion

The study was conducted to re-evaluate the relationship between organic carbon accumulation and salt ion excretion by salt excretory mangrove species of the Sundarban mangrove forest. The six species considered for the present study showed variations in their individual rates of accumulation of organic carbon and excretion of salt from leaves as well as overall variations in general as a response to changes in salinity (due to changes in sites receiving different tidal inflow and changes in seasons). The study revealed a high degree of positive correlation in between the two physiological aspects taken into consideration, which makes it interesting as it sheds light on the interrelated processes of a mangrove ecosystem and its fragile nature. Premonsoon and postmonsoon findings were more or less similar to each other as in general a similar physico-chemical condition prevails at the estuarine forests. The deviation was observed during monsoon as freshwater inflow dilutes the ambient salt content and plants change their rate of metabolic activities viz. photosynthesis and transpiration to cope with it.

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References

1. Savage, T. (1972): Florida mangroves as shoreline stabilizers. Florida Department of Natural Research, Prop. Paper No. 19, pp. 46.
2. Stambler, N. and Dubinsky, Z. (1996): Eutrophication, marine pollution and coral reefs. *Global Change Biol.,* 2:511-526.
3. Hernandez, J. A., A. Jimenz, P. Mullineaux and F. Sevilla, (2000): Tolerance of Pisum sativum to long-term salt stress is associated with induction of antioxidant defenses. *Plant Cell Environ.,* 23: 853-862.
4. Tomlinson, P. B., (1986): The botany of mangroves. Cambridge University Press. Cambridge.
5. Lugo, Ariel. E. (1973): “The Role of Mangrove Ecosystems: Diurnal Rates of Photosynthesis, Respiration and Transpiration in Mangrove Forests of south Florida”.
6. Scholander PF, Hammel HT, Hemmimgsen EA, Garey W (1962) Salt balance in mangrove. *Plant Physiol.* 37:722-729.
7. Saravanavel, R., R. Ranganathan and P. Anantharaman, (2011): Effect of sodium chloride on photosynthetic pigments and photosynthetic characteristics of Avicennia officinalis seedlings. Recent Research in Science and Technology, 3(4): 177-180.
8. Kathiresan, K. and B. L. Bingham (2001): Biology of Mangroves and Mangrove Ecosystems. *Advances in Marine Biology,* Vol 40: 81-251.