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Standardization of the growth sustaining attributes of *Avicennia officinalis* L. for strategic afforestation protocols

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Abstract

Any afforestation / restoration initiatives on mangroves primarily require reliable information on the ecology, hydrology and sedimentology of the targeted mangrove species. The present investigation was carried out to evaluate the hydrogeochemical, sedimentological and climatological conditions ideal for the growth and establishment of the mangrove species *Avicennia officinalis* L. in pursuit of their afforestation practices.

Evaluation of the physicochemical characteristics of water and soil / sediment along with climatological attributes from three heterogeneous habitats falling in the coastal environments of Kerala was monitored monthly for a period of one year for deriving conclusions regarding the growth requirements of *A. officinalis*. Statistical analysis revealed the most vital attributes of water which influence the growth of *A. officinalis* are pH, total suspended solids, resistivity, alkalinity and nutrients like nitrogen, phosphorous and potassium. Similarly sedimentological parameters include pH, moisture percentage, organic carbon, nitrogen, potassium, sodium and relative percentage of sand, silt and clay. The study as a whole reported the capability of *A. officinalis* to cope up with different hydrological and sedimentological conditions in terms of tolerance or augmented range, which will form a basis for future afforestation initiatives.

Key words:*Avicennia officinalis, growth sustaining conditions, water quality, sediment quality, climatology.*

1. Introduction

Basically, any afforestation or restoration endeavor on mangroves primarily requires reliable information on ecology, hydrology and sedimentology that control the successful growth of the targeted mangrove species. Among all such vital attributes, water and sediment quality are known to have supreme influence on the growth of mangroves (Thom, 1967). In light of this, the present investigation was carried out with the objective of evaluating the hydrogeochemical, sedimentological and climatological conditions ideal for the growth and establishment of the mangrove species *Avicennia officinalis* L. in pursuit of their utilization for species specific afforestation practices.

2. Materials and Methods

Avicennia officinalis L. is a fast growing shrub / tree, mostly found in the lower intertidal estuarine zones. It is a shade intolerant species, grows on soft, recently consolidated mud banks. Three heterogeneous natural habitats confining to the coastal environments of Kerala (Fig. 1) have been fixed for assessing the growth sustaining conditions of the mangrove species *A. officinalis* L. (Table 1). Location 1 (Kumbalam) was falling in Ernakulam district. Location 2 (Kadalundi) of Malappuram District was 165 km far from Location 1 and Location 3 (Thekkumbad) was in Kannur district, which was 130 km from location 2.

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Fig. 1. Study Area

Table 1. Study Area

Sl. No:	Location	District	Latitude	Longitude
1	Kumbalam	Ernakulam	9°54'15.68"N	76°18'46.59"E
2	Kadalundi	Malappuram	11°07'42.49"N	75°49'53.31"E
3	Thekkumbad	Kannur	11°58'00.10"N	75°17'49.27"E

The study was carried out during 2013 to 2014. Monthly visits to these habitats were carried out and both water and sediment samples were collected. Estimation of the physicochemical characteristics of water and soil / sediments were worked out for deriving conclusions regarding their growth sustaining conditions along with the range of conditions to which they are adjusted to. Water quality parameters analyzed include pH (Systronics, MK IV), turbidity (Systronics, Model 341), TS, TDS, TSS (Gravimetric method), salinity, resistivity, conductivity (Eutech PCD, 650), acidity, alkalinity, total hardness, calcium, magnesium, chloride (Titrimetric method), sulphate (Turbidimetric method), sodium and potassium (Flame photometric method), total nitrogen (Kjeldahl Method) and phosphorous (Stannous chloride method) outlined in APHA (2005) and Trivedy et al. (1987). Similarly pH, moisture percentage, organic carbon, total nitrogen, total phosphorous, sodium and potassium content of sediment samples were worked out (Subramanyam and Sambamurthy, 2002; Trivedy et al., 1987 and Jackson, 1973). Also the textural percentages of sand, silt and clay associated with soil/sediment samples were worked out following International Pipette Method. The data concerning meteorological characteristics of the study area were obtained from India meteorological department. The results were then analyzed.

3. Results

Many ecological factors strongly influence the growth and development of mangroves (Kjerfve et al., l999); among them, water and sediment quality are known to have supreme influence (Thom, 1967). The mean values of water, sediment and climatological parameters together with their standard deviation from habitats containing *A. officinalis* are estimated.

The estimated percentages of sand, silt and clay were used to determine the textural class of the soil. This was achieved through the triangular textural diagram, proposed by the United States Department of Agriculture (USDA). Based on the physical composition, the textural classes of sediments noticed along the habitats of *A. officinalis* were sandy clay loam, sandy loam and loamy sand (Fig. 2).

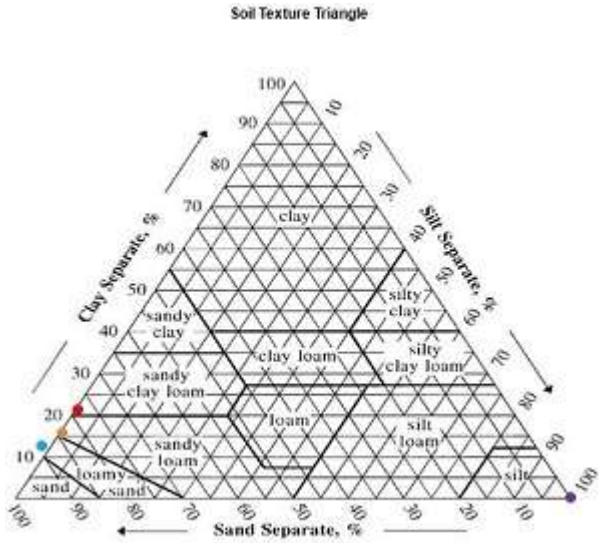

Fig. 2. Sediment class preference of the mangrove species *A. officinalis*

Data pertaining to climatological attributes like atmospheric maximum – minimum temperature (°C), Total Rainfall (MMS) and Relative Humidity

(%) with respect to all the locations under study has been collected and reported.

Upon compiling all the results, it can be stated that, even though the mangroves are growing in a wider range of environmental conditions, each species has its own range of tolerance to different hydrogeochemical, sedimentological and climatological attributes along their natural habitats. In the present investigation, the range of environmental attributes influencing the growth of selected mangrove species has been categorized into tolerance range and augmented range. **Tolerance range** is the ideal range, at which a particular species can flourish well along their natural environmental settings and the **augmented range** is the range that is acquired by adapting to an uncertain environmental condition. The ranges of various environmental attributes influencing the growth of *A. officinalis* are depicted in Table 2.

Table 2. Range of environmental attributes influencing the growth of *A. officinalis.*

Sl.No.	Parameters	Tolerance range	Augmented range
Hydrological attributes			
1.	**pH**	**6.84–7.61**	3.86-8.16
2.	**Turbidity (NTU)**	**8.64– 7.41**	0.7-29.9
3.	**TS (mg/l)**	**10,733.33 – 25,444.44**	200-44,400
4.	**TDS (ppt)**	**9.9–22.92**	0.2-42.0
5.	**TSS (mg/l)**	**833.33– 5111.11**	0-41,200
6.	**Acidity (mg/l)**	**22.55– 35.69**	1.32-88.0
7.	**Alkalinity (mg/l)**	**132.08– 164.44**	50-340
8.	**Hardness (mg/l)**	**1,786.17– 3,490.75**	26-7,620
9.	**Calcium (mg/l)**	**151.09– 308.963**	6.4-801
10.	**Magnesium (mg/l)**	**343.02– 690.693**	0.49-1582.5
11.	**Chloride (mg/l)**	**8,001.7– 15,257.9**	255.6-40,186
12.	**Sulphate (mg/l)**	**37.375– 51.21**	2.0-126
13.	**Sodium (ppt)**	**5.677– 17.85**	0.02-54.6
14.	**Nitrogen (mg/l)**	**56.42 – 68.33**	20-196
15.	**Phosphorous (mg/l)**	**22.0– 36.4**	5.0-60.0
16.	**Potassium (mg/l)**	**910.42– 3,252.73**	0-27800
17.	**Salinity (ppt)**	**8.693– 19.677**	0.05-38.05
18.	**Resistivity (Ω)**	**131.12– 2,017.66**	17.71-10790
19.	**Conductivity**	**13.77– 29.37**	0.091-55.23
Sedimentological attributes			
20	**pH**	**6.63–7.71**	4.08-8.33
21	**Moisture %**	**9.40– 13.22**	4.97-20.15
22	**Organic carbon (g/kg)**	**17.9– 34.75**	1.0-96
23	**Total nitrogen (mg/kg)**	**2,269.16– 5,610.83**	1050-18840
24	**Total phosphorous (mg/kg)**	**9.7–23.1**	7-38.5
25	**Potassium (mg/kg)**	**55.55– 76.33**	3.4-240
26	**Sodium (ppt)**	**0.34– 1.055**	0.0775-1.884
27	**Sand %**	**78.45– 87.29**	51.4-99
28	**Silt %**	**0.26– 0.475**	0.1-1.2
29	**Clay %**	**12.44– 21.075**	0.8-47.7
Climatological attributes			
30.	**Atm.Max.Temp (^{o}C)**	**31.79– 32.52**	28-35.5
31.	**Atm.Min.Temp (^{o}C)**	**23.275– 24.36**	21.6-26.9
32.	**Total rainfall (MMS)**	**222.25– 249.533**	0-565.3
33.	**R.H % at 0830 hrs**	**80.75– 82.42**	65-93
34.	**R.H % at 1730 hrs**	**68.92– 74.833**	55-94

Physico chemical attributes of both water and sediment along selected habitats were further analyzed statistically to find out the discrepancy among different sites and seasons. Seasonal and site specific mean values of each parameters were subjected to two way ANOVA and found out the variations among the locations as well as the seasons. Such variations in each parameter with respect to sites and seasons were considered towards elucidating each of their influence on the growth of mangrove species. Accordingly, the most vital physico chemical attributes of water and sediment that are likely to influence the growth of each mangrove species can be enumerated. Since a uniform pattern of climatological conditions has been experienced along all the locations under

study, statistical analysis for elucidating each of their influence on mangrove growth was not attempted.

The study as a whole revealed no significant variation in water quality attributes like pH, total suspended solids, resistivity, alkalinity, nitrogen, phosphorous and potassium and also with respect to sedimentological attributes like pH, moisture %, organic carbon, nitrogen, potassium, sodium, sand, silt and clay % between different sites and seasons. The physico-chemical attributes of both water and sediment that showed no significant variations between sites and seasons can be confirmed as the growth promoting factors for the mangrove species under study. Thus, the study as a whole reports the capability of the mangrove species to cope up with different hydrogeochemical and sedimentological conditions in terms of **tolerance range** or **augmented range**.

4. Discussion

The present study evaluated the hydrogeochemical, sedimentological and climatological conditions ideal for the growth and establishment of the mangrove species *A. officinalis* L. in pursuit of their utilization for species specific afforestation practices. The most vital physico chemical attributes of water and sediment that are likely to influence the growth of the mangrove species can be enumerated using variation analysis. Comparison of the results with earlier reports was carried out to derive strategic conclusions.

The present study reported the tolerance and augmented range of pH of water as 6.842 to 7.612 and 3.86-8.16 respectively. Paramasivam and Kannan, 2005, in their studies on the Muthupettai mangrove ecosystem, showed the range of hydrological pH in mangrove area as 7.1-8.7 and in 2012, Manju et al., studied the entire mangrove ecosystems of Kerala and reported the pH of water as 7.1 – 8.05. The study also reported the tolerance range of the species to alkalinity as 132.08 - 164.44 mg/l, and their augmented range as 50 - 340 mg/l. Shilna et al., (2016) also reported the annual range of alkalinity of the mangrove area with the selected mangrove species as 100.79 mg/l.

Nitrogen, Phosphorous and Potassium are the major nutrients in sediments reported from various natural mangrove habitats of Kerala. In the present study, the tolerance and augmented range of *A. officinalis* towards N, P, K are reported to be 56.417 to 68.333 (20 to 196) mg/l, 22.0 to 36.4 (0.5 to 60) mg/l and 910.42 to 3252.73 (0 to 27800) mg/l respectively. Likewise, in 2012, Manju et al. reported the annual average values of N, P and K of mangrove ecosystems of Kerala as 88.35 µM, 9.61 µM and 105.38 mg/l respectively.

With respect to sediments, the study reported a range of tolerance and augmented values towards pH, moisture percentage and organic carbon as 6.633 to 7.713 (4.08-8.33), 9.40–13.22 % (4.97-20.15 %) and 1.793 to 3.475 (1.0 to 96) g/kg respectively. Saravanakumar et al. (2008) reported the range of organic carbon from the mangrove ecosystem of Kachchh - Gujarat as 2.9 to 25.6 g/kg. The distribution of total organic carbon closely followed the distribution of sediment type i.e., as sediment is low in clay content, the total organic carbon content is also low and as the clay content increased, the total organic carbon content also increased (Reddy and Hariharan, 1986). Various studies have also reported that, soil organic carbon and pH are the major factors having most significant influence on the growth and establishment of mangroves (Clough, l984 and Yang et al., 2013).

As far as the present study concerned, the tolerance and augmented range of the species to sediment NPK is 2269.16 to 5610.83 (1050 to 18840) mg/kg, 9.7 to 23.1 (7 to 38.5) mg/kg and 55.558 to 76.333 (3.4 to 240) mg /kg respectively. A recent study carried out in the mangrove ecosystem of Ayiramthengu, Kerala possessing these mangrove species reported a range of P and K as 29.5 to 57.9 Kg/ha and 231 to 440 Kg/ha respectively. The species has a tolerance range of 78.45 to 87.29%, 0.267 to 0.475 % and 12.442 to 21.075 % towards sand %, silt % and clay % respectively. More or less similar results have been reported by Saravanakumar et al. (2008). The study reported ranges of sediment textures in terms of % of sand, clay and silt as 0.26-19.2, 7.6-47 and 47-87.4 % respectively. Studies using textural triangles revealed that the nature of soil / sediment in all the locations studied were silty loam, silty clay and silty clay loam.

In general, mangroves are inimitable intertidal ecosystems with unique features, having own adaptations to cope up with extreme environmental conditions. A prior assessment of the area with respect to the tolerance / augmented range of various growth sustaining conditions of the mangrove species (*A. officinalis*) will help in the futuristic assessment of the feasibility of the area with regard to the inntroduction of *A. officinalis.*

5. Conclusion

Afforestation of mangroves seems to be a promising solution for the restoration of lost coastal ecosystems. Successful restoration/afforestation practices of mangroves require reliable information

on their growth sustaining conditions. The present study has been carried out to evaluate the environmental factors (water, soil / sediment and climate) determining the growth of the mangrove species *A. officinalis* along heterogeneous habitats of Kerala.

The results as a whole revealed that between different sites and seasons, no significant variations have been noticed in water quality attributes like pH, total suspended solids, resistivity, alkalinity, nitrogen, phosphorous, potassium and sedimentological attributes like pH, moisture %, organic carbon, nitrogen, potassium, sodium and percentages of sand, silt and clay content of sites having *A. officinalis*.

From the above results, it can be concluded that each mangrove species have their own growth sustaining conditions along different habitats. The physico-chemical attributes of both water and sediments that showed no significant variations between sites and seasons can be confirmed as the growth promoting factors for that species. The study as a whole reports the capability of the mangrove species *A. officinalis* to cope up with different hydrological and sedimentological conditions in terms their **tolerance range** or **augmented range**. Results of the textural characterization of sediments revealed Sandy Clay Loam, Sandy Loam and Loamy Sand as ideal environments for the growth of *A. officinalis.*

Thus the study proposed that the 'tolerance range' of a species with respect to the site is a mandatory requirement towards including them in afforestation purposes, whereas 'augmented range' is not a natural one as it is acquired by the species after acclimatization in the new area. In conclusion, the study emphasized that all the afforestation/ restoration practices of mangroves must be either species or site specific.

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