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Germination and growth evaluation of tall-stilt mangrove (*Rhizophora apiculata*) propagules in tropical peninsular India.

Germination and growth evaluation of tall-stilt mangrove (Rhizophora apiculata) propagules in tropical peninsular India.

Mini Mohandas and Kurian Mathew Abraham*

Department of Aquatic Biology and Fisheries, University of Kerala, Kariavattom, Thiruvananthapuram, 695 581, Kerala, India

* Author for correspondence, email: kurianma@gmail.com

ABSTRACT

Mangrove forests are one among the most productive ecosystems and offer a wide range of resources and services including shoreline stabilization, habitat, nursery and breeding ground for many commercial fin and shell fish species and other fauna. In order to conserve and restore the fast diminishing mangroves patches along the coasts of tropical peninsular India, especially of Kerala due to anthropogenic developmental activities as well as pollution, holistic investigations must be carried out to find the reasons and suitable environmental factors that can support the germination and growth of propagules of different mangrove species. A preliminary attempt has been carried out to evaluate the germination and growth characteristics of tropical Tall-Stilt mangrove, *Rhizophora apiculata* Blume, propagules *in situ* along with water and sediment characteristics at a natural and private owned mangrove cum fish farm, 'Mangrove Isle', Kayamkulam, Alappuzha District of Kerala state (India). Monthly water and sediment samples were collected and physico-chemical parameters were analyzed following standard procedures and morphometric growth studies *in situ* of the mangrove during the three seasons, pre-monsoon, monsoon and post-monsoon were assessed for a year during 2017-2018. Water quality parameters like total dissolved solids, hardness and nitrate registered significant ($P<0.01$) difference and clay as well as silt content of sediment also showed significant ($P<0.05$) seasonal variation. A total of 11 morphometric parameters of plant were recorded to assess growth seasonally up to one year from the germination of propagules and the results were discussed in relation to water and sediment quality. Conservation, propagation and cultivation of indigenous mangrove species along the Kerala coast is the need of the hour to save the coast of Kerala from natural disasters like beach erosion, tsunami, flood and other anthropogenic hazards.

Keywords: Kaya-kandel, Mangrove Isle, Mangrove Water/Sediment Quality, Seasonal Variation, Mangrove morphometry.

RESUMEN

Los bosques de manglares son uno de los ecosistemas más productivos y ofrecen una amplia gama de recursos y servicios, incluida la estabilización de la costa, hábitat, cría y lugar de reproducción para muchas especies comerciales de peces, mariscos y otras especies de fauna. Para conservar y restaurar los parches de manglares en rápida disminución a lo largo de las costas de la India peninsular tropical, especialmente en Kerala, debido a las actividades de desarrollo antropogénicas y a la contaminación, se deben llevar a cabo investigaciones holísticas para encontrar las razones y los factores ambientales adecuados que puedan respaldar la Germinación y crecimiento de propágulos de diferentes especies de manglares. Se ha llevado a cabo un intento preliminar para evaluar las características de germinación y crecimiento de los propágulos del manglar tropical de zancos altos, *Rhizophora apiculata* Blume, in situ junto con las características del agua y los sedimentos en una granja de manglares y piscifactorías natural y privada, 'Mangrove Isle'. Kayamkulam, distrito de Alappuzha del estado de Kerala (India). Se recolectaron muestras mensuales de agua y sedimentos y se analizaron parámetros físico-químicos siguiendo procedimientos estándar y se evaluaron estudios morfométricos de crecimiento in situ del manglar durante las tres estaciones, premonzón, monzón y posmonzón durante un año durante 2017-2018. Los parámetros de calidad del agua como el total de sólidos disueltos, la dureza y el nitrato registraron diferencias significativas (P<0,01) y la arcilla y el contenido de limo del sedimento también mostraron una variación estacional significativa (P<0,05). Se registraron un total de 11 parámetros morfométricos de la planta para evaluar el crecimiento estacional hasta un año desde la germinación de los propágulos y los resultados se discutieron en relación con la calidad del agua y los sedimentos. La conservación, propagación y cultivo de especies autóctonas de manglares a lo largo de la costa de Kerala es la necesidad del momento para salvar la costa de Kerala de desastres naturales como la erosión de las playas, tsunamis, inundaciones y otros peligros antropogénicos.

Palabras clave: Kaya-kandel, Isla de los Manglares, Calidad del agua/sedimentos de los manglares, Variación estacional, Morfometría de los manglares.

INTRODUCTION

Mangrove vegetation form unique ecosystem of tropical and subtropical marine intertidal zones, which play pivotal ecological role along coastline providing many economic and social values to mankind. Mangrove forests of peninsular India, especially of west coast of India represented by the state of Kerala has been reduced manifold, which once occupied to an extent of 700km^2, have dwindled to 17 km^2 (Ramachandran, *et al*., 1986) and still reduced to 663.09 Ha (ENVIS Hub, 2021) due to unscrupulous anthropogenic developmental activities, population growth, coastal erosion and environmental pollution/ degradation (Silva and Amarasinghe, 2021). The importance of mangroves has been clearly recognized even by the layman or coastal people through the protection offered by mangrove patches along Kerala coast during the Indian Ocean Earthquake and Tsunami in December, 2004. Since then several research, conservation and propagation activities by both, governmental and non-governmental organizations fostered to increase mangrove patches along coastline of Kerala, however no much mangrove afforestation were observed till date (ENVIS Hub, 2021).

The mangrove diversity of peninsular India, especially of West coast of Kerala state is mainly represented by nine true mangrove species including *Rhizophora apiculata* and *Avicennia ilicifolicus*, and mangrove associates (Mohandas *et al*., 2012; Pillai and Harilal, 2018). The estuarine creeks along coastal lines were affected by human intrusion for various purposes including aquaculture activities, which either destroyed the natural habitat or altered the ecosystem properties through saline intrusions etc, which resulted in mangrove abundance diminution. The afforestation of mangrove patches by governmental and non-governmental agencies were not fully successful due to various reasons including the reproductive behavior of mangroves. Parida and Jha (2010) extensively reviewed the salt tolerance mechanisms in mangroves. Viviparous hypocotyl, seedlings and/or saplings are important stages in the growth and succession of mangrove population. The establishment and early growth of mangrove seedlings are influenced by a number of abiotic and biotic factors - light availability, soil characteristics, tidal current, salinity, animal predation, propagule size, propagule dispersal properties, inter-specific competitions *etc*. Thus quantifying the dynamics of the early stages in the life cycle of mangroves is essential to predict the distribution, species composition and structure of mangrove forests, their maintenance and recovery from perturbations. The growth and phenology of different mangrove species along east coast of India including *R. apiculata* was reported by Upadhyay and Mishra (2010) and Manju *et al.* (2012). A comparative restoration efficiency of two mangrove species including *R. apiculata* was described from Sri Lanka by Madarasinghe *et al*. (2014).

Germination and early development peculiarities of mangrove plants especially of *R. apiculata* were not reported in relation to environmental parameters from tropical peninsular India, which is very much essential to the nursery rearing, propagation and conservational activities. Growth of mangrove seedlings in the intertidal area of Vellar estuary along south east coast has been reported (Kathiresan *et al*., 1996) from India. Relationship between sediment conditions and mangrove *R. apiculata* seedling growth and nutrient status was reported by Duarle *et al*. (1998). The effects of seed predators on the recruitment of mangroves were reported by Clarke and Kerrigan (2002), where as early growth of seven mangrove species planted at different elevations in a Thai estuary was reported by Kitaya *et al*. (2002). The germination and growth of Tall stilt mangrove propagules were evaluated and reported and nursery rearing and propagations were investigated for conservation and afforestation purposes. The development of *R. apiculata* in a mangrove nursery was described from Banten, Indonesia (Mustika *et al*., 2014). The growth responses in terms of morphometric evaluations of *R. apiculata* in different soil and sediment conditions at Indonesia were described by Amaliyah *et al*. (2018). Different aspects of growth, development, distribution and application of different mangroves including *Rhizophora* was discussed and reported (Husin *et al*., 2019) from Malasia. Even though several studies reported the growth and germination of seedlings of *R. apiculata*, the same was not reported from Kerala, especially in relation to the environmental parameters. In order to restore and conserve the mangroves which once abundant along the coasts of Kerala, reasons and suitable environmental factors that can support the germination and growth of propagules of different mangrove species are to be explored and protocols for nursery rearing should be proposed for which the baseline information on germination and growth of *R. apiculata* propagules along Kerala coast is investigated in the present study.

MATERIALS AND METHODS

Study location and setup: 'Mangrove Isle' is a private owned mangrove cum aquaculture farm at Puthuppally (Kayamkulam; 9°147661'N and 76°476531'E), Alappuzha district of Kerala State, India (Fig.1). Tidal effect from Kayamkulam lake, en-route of National Water Way No. 3 through Kuttanad Kole wet lands, washes the farm and mangrove patches along the belt adjoining to Arabian Sea. The farm holds seven shallow earthen ponds (0.3 – 1.0 m depth) for aquaculture practices bordered with thick mangrove vegetation dominated with *Rhizophora apiculata* Blume. An experiment was set up *in situ* to assess the germination and growth through morphometric assessment of *R. apiculata* along with environmental parameters evaluation during February 2017 to January 2018 in which, monthly data were pooled seasons wise as pre-monsoon (February to May), monsoon (June to September) and post-monsoon (October to January) for statistical evaluations.

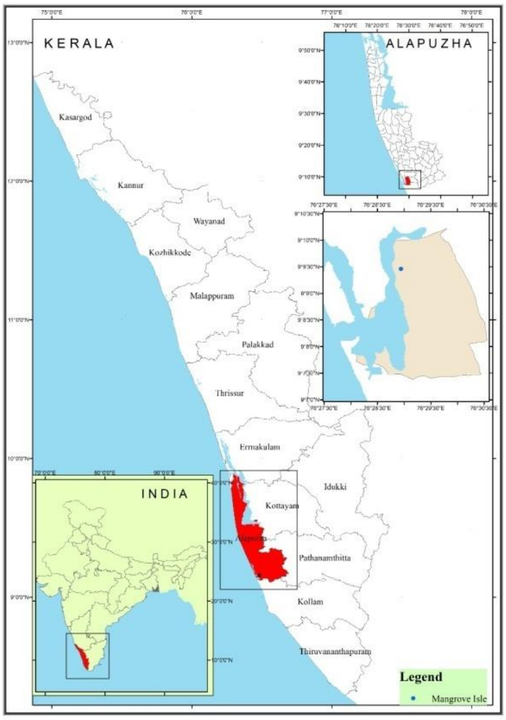

Fig.1. Location map of Kayamkulam kayal and the study site, Mangrove Isle farm

Water and sediment analysis: Water and sediment were sampled monthly during early morning hours of the day for analyses. A total of seven physico-chemical parameters (pH, salinity, total dissolved solids, total hardness, nitrite, phosphate and sulphate) of water (APHA, 2017) and three parameters (temperature, pH, and texture) of sediment (Carver, 1971) were analyzed using standard procedures.

Germination and growth assessment: Healthy and matured propagules (seeds) of *R. apiculata* were collected from site were used for growth studies. A total of 63 uniform sized propagules (23.0 $\pm$ 0.5 cm; 22.0 $\pm$ 0.5 gm), 9 each were planted (1 feet apart) in pre-marked seven square areas/earthen troughs of 1 m^2 with adequate sunshine and tidal flushing. Growth parameters were assessed through eleven morphometric (plant length, stem perimeter, leaf length, leaf breadth, leaf area), different weight (wet) parameters (total plant weight, root weight, leaf weight, shoot weight) and counts like number of leaves and nodes of the plant. Lengths were measured using a digital vernier caliper gauge micrometer and

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standard meter scale towards end of experiment in nearest centimeter with +0.01cm accuracy where as weight (Electronic Balance) was taken in gram (+0.01 accuracy) except for root weight, which was measured in milligrams (Zhang *et al*., 2007). Growth experiment continued for one year taking all measurements at 0 day (initial), 7 day, 30 day, 120 day, 240 day and 360 day by sampling and sacrificing one plant each from seven earthen troughs per observation day.

The initial growth parameters were measured for the popagule (Fig. 2a) and the later measurements were measured for seedling (Fig. 2b) without considering the propagule measurements except for weight. The stem height was defined as the length between the top of the propagule where the stem emerged to the bottom of the most distal opened pairs of leaves on the stem, while the stem diameter was determined at the midpoint of the bottom-most inter-node. The height was averaged for all the plants in the pond, and the leaf areas were averaged for 2 to 4 leaves of the same stage and calculated by tracing the outline of the leaf onto a graph paper and counting the number of squares covered by assuming 1 square unit as 1 cm^2. The number of leaves emerged from the leaf primordial and unfolded completely was counted (Fig.2c). Each portion was washed and wet weight was recorded after removing wash water. The hypocotyl was excluded, because the weight of hypocotyl would not change during the exposure and partly because its heavy weight would affect the accuracy of the stem biomass measurement (Ye *et al*., 2003).

Data Analysis: The hydrographical and growth parameters data were compared for seasons with Analysis of variance (One Way ANOVA) along with post hoc analysis, Duncan's Multiple Range (DMR) test using R software (R Core Team, 2021). For all statistical evaluations, probability < 0.05 considered significant.

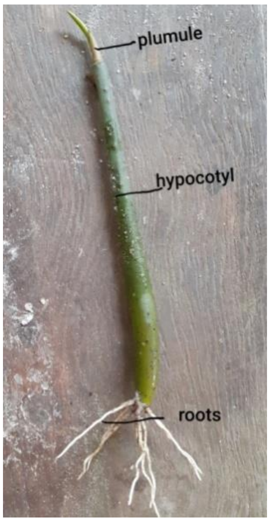

Fig 2a. Propagule

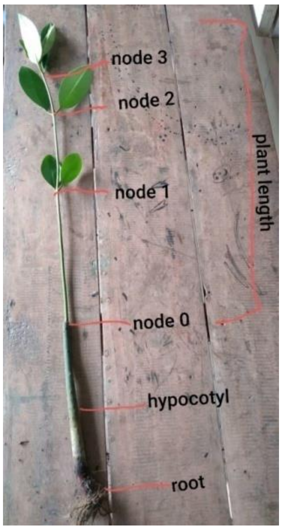

Fig 2b. Seedling

Fig 2c. Leaves

RESULTS AND DISCUSSION

Water and sediment quality monitoring of the *in situ* experimental set up was measured monthly, pooled seasonally and the results of the seven physico-chemical characteristics including nutrients of water and three sediment quality parameters including texture are presented in table 1. The pH of the farm site were within neutral range throughout the study period with slightly on alkaline side with maximum of 7.50 ± 0.08 during the monsoon and minimum of 7.29 ± 0.17 during premonsoon season. pH did not varied significantly between seasons (P>0.05), which may be due to daily influx of estuarine tidal water washings. Aquatic organisms including flora are affected by pH because most of their metabolic activities are pH dependent (Wang *et al.*, 2002). The optimal pH range for sustainable aquatic life forms are reported to be 6.5 - 8.2 and normal growth of flora and fauna occurs in either normal or slightly alkaline pH ranges (Murdoch *et al.*, 2001). Another important and fluctuating variable, which governs growth and metabolic activities of mangrove is none other than salinity of the water. The annual mean of salinity recorded during present study was 15.02 ± 1.09, in which highest was during the premonsoon and lowest during the monsoon season, both of them were in mesohaline range optimal for mangrove growth (Kitaya *et al*., 2002; Amaliyah *et al*., 2018; Auni *et al*., 2020). This trend was attributed to the freshwater influx during the monsoon and high evaporation rates during the premonsoon and similar conditions were reported in many of the previous reports (Senthilkumar *et al*., 2002; Manju *et al*., 2012). Since the mangrove under consideration is a euryhaline species, which can tolerate a wide range of salinity from 1 ppt to seawater salinity of 35 ppt and a medium salinity around 15 was optimal for germination and growth (Do *et al*., 2015). Majority of the studies of the *R. apiculata* were carried out in salinities less than 5 ppt (Amaliyah *et al*., 2018; Auni *et al*., 2020) but the present study results and earlier study (Kathiresan *et al*., 1996) reveals that mesohaline salinities around 15 ppt or more with some fluctuations due to tidal effect may more suited to germination and propagation of mangroves in tropical conditions. Silva and Amarasinghe (2021) reported germination and growth of the mangroves shows a strong relationship with salinity in which germination *R. apiculata* propagule registered a negative relationship with salinity, whereas Do *et al*. (2015) described the effect of salinity on nursery growth of *R. apiculata* propagules and reported that salinity has no significant effect as seven salinity treatment starting from 0 ppt to 30 ppt, showed same pattern of propagule growth at coastal areas of Central Vietnam, but proposed 10 ppt saline water watering fostered nursery rearing of propagules.

Table 1. Analytical results of the physico-chemical characteristics of water and sediment samples

Water Quality									
Parameters	Premonsoon		Monsoon		Postmonsoon		Annual		F- value
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	
pH	07.29	0.17	07.50	0.08	07.39	0.17	07.39	0.16	01.18
Salinity (ppt)	16.31	1.75	10.50	0.71	12.25	0.50	14.02	1.09	00.62
Total Dissolved Solids (mg/L)	08.20	5.02	01.15	0.37	24.53	4.29	11.29	1.79	38.19***

Total Hardness (mg/L)	23.50	5.80	03.50	0.58	28.00	6.58	18.30	2.03	17.64***
Nitrite (µg/L)	02.16	0.14	01.00	0.63	02.89	0.67	02.01	0.95	09.03**
Phosphate (µg/L)	23.43	0.44	22.92	6.02	23.59	2.68	23.32	3.47	00.80
Sulphate (mg/L)	21.77	0.54	14.12	7.04	26.91	6.23	20.94	3.20	03.55*
Sediment Quality									
Sediment Temperature (°C)	29.60	1.70	30.50	1.30	29.60	1.50	29.90	0.40	0.48
Sediment pH	07.30	0.10	07.50	0.10	07.30	0.20	07.40	0.10	1.79
Sand (%)	65.00	9.61	52.63	9.12	57.45	9.82	58.36	9.69	3.50
Clay (%)	13.10	5.10	10.30	0.00	10.60	0.40	11.30	1.30	5.54*
Silt (%)	21.90	8.40	37.08	9.12	32.00	9.33	30.33	9.97	6.44*

* P < 0.05; ** P < 0.01

Total dissolved solids (TDS) of water is also an important factor which contributes to turbidity and density of the water, which in turn affect the growth of the mangroves. TDS registered a maximum value of 24.53 ± 4.29 mg/l during the post monsoon and minimum during the monsoon season (1.15 ± 0.37 mg/l). The estuarine environment under tidal effect, freshwater and saline influx, wave actions etc, usually have high turbidity and suspension of particles from sediments (Sadhuram *et al.*, 2005). TDS affect metabolism and physiology of fish and other aquatic organisms as well as mangroves especially the germination and growth of propagules, more over the TDS affect the ion transport across the root cell membranes by blocking the pneumatophores as well as altering the osmotic pressure. The maximum amount of total hardness was recorded during the post monsoon season (28.00 ± 6.58 mg/l) and minimum during the monsoon season (3.5 ± 0.58 mg/l), registering a highly significant difference (P<0.001) among seasons with least in monsoon, which may be due to the dilution by the precipitation water during monsoon season. Hardness of water increases due to industrial discharge of effluents containing salts of calcium and magnesium and also due to run off fertilizers from agricultural lands. Hassan (2006) reported management of private mangrove plantation with respect to charcoal production at Thailand and reported relationship of sediment and water quality with *R. apiculata* growth, where hardness of water has important relationship with mangrove growth as calcium and magnesium ions that make water hard has an effect on root and stem tissues of mangroves.

Nutrients of sediment as well as water paly an important role in the germination and growth of the propagules. The amount of estuarine nitrite ranged between 2.89 ± 0.67 µg/l during postmonsoon and 1.0 ± 0.63 µg/l during monsoon season with a significant (P<0.01) difference. The reduction during monsoon period may be due to the utilisation of nitrites by the thick mangrove vegetation during premonsoon as well as monsoon period and monsoonal wash off enriched the nutrient during postmonsson period along the farm as the farm area is less when compared to the estuary (Reef *et al.*, 2010). Phosphate registered a minimum value of 22.92 ± 6.02 µg/l during the monsoon season and maximum value of 23.59 ± 2.68 µg/l during the postmonsoon season, showing the same pattern of that of nitrite but with out significant difference (P>0.05). The high phosphate level in the estuarine farm during the monsoon season may be due to the inflow of freshwater and the discharge of fertilizers from the nearby paddy fields. Kitaya (2002) also reported high phosphate content during the studies of early growth of seven mangrove species planted at different elevations in a Thai estuary. The addition of super phosphate applied in the agricultural fields as fertilizers and alkyl phosphates used in households, as detergents can be other sources of inorganic phosphates (Bragadeeswaran *et al*., 2007). Sulphate content also showed a significant seasonal difference with a maximum of 26.91 ± 6.23 mg/l during the post monsoon season and monsoon season recorded the minimum value 14.12 ± 7.04 mg/l. Duarle *et al.* (1998) and Husin *et al*. (2019) reported growth characteristics of *Rhizophora* and influencing nutrient and other chemical parameters of estuarine water.

Sediment qualities of the estuarine farm were also monitored for the seasonal fluctuations and provided in table 1. Sediment temperature, pH and texture were statistically evaluated for seasonal fluctuations. Clay and silt content (%) showed significant (P<0.05) difference between seasons. The clay and silt difference may be due to the rain water wash off and settlement during monsoon and post monsoon period, which may affect the growth characteristics of mangroves (Duarle, *et al*., 1998). Amaliyah *et al*. (2018) also reported growth responses of *Rhizophora apiculata* in different soil and sediment conditions in which reported sediment thickness and texture had a significant influence on the growth of mangroves. Few researchers have explained the negative influence of sediment characteristics on mangrove germination and growth (Thampanya *et al*., 2002; Parent *et al*., 2008).

Upon comparing water quality, marked differences in the results were noticed between the three seasons. Total dissolved solids, total hardness and the nutrients, nitrate, phosphate and sulphate were high in the post-monsoon season. In the monsoon season all the parameters analyzed were less compared to the other seasons. These may be due to the rainfall received during the monsoon season followed by mass dilution of water. Similar observations were made by several researchers in similar and/or nearby locations (Manju *et al*., 2012; Toriman, *et al*., 2013; Mariappan *et al*., 2016; Guntur *et al*., 2018; Abraham and Sivan, 2021; Sari and Soeprobowati, 2021). Since these fluctuations are natural, mangrove growth also water quality dependent and follow natural growth. Among various characteristics of sediment samples studied, sediment temperature, sediment pH and sand percentage were high in the monsoon season. The highest clay percentage was observed during the pre-monsoon whereas silt percentage was highest during the monsoon. Sediment quality governs as mangrove growth as the major nutrient supplier of plant growth being the soil (Krauss *et al*., 2008; Bakshi *et al*., 2019; Sarker *et al*., 2020; Sulochanan *et al*., 2022).

Results of the germination studies of *R. apiculata* for the three seasons are represented in the table 2. A total of 11 propagule and/or sapling parameters were recorded for one year of growth of which propagule parameters were recorded only for the initial day (0 day). The plant total length and weight were increased manifold with 208% and 47.2% respectively which registered significant (P<0.001) increment between days of observation. The results were in tune with the reports of Hastuti and Hastuti (2018). Morphometric parameters of sapling emerging from propagule, like stem perimeter, root and shoot weight along with different leaf parameters were also observed and registered significant (P<0.01) increment between observations in a year. Several reports have been cited similar pattern of growth in other species (Gill and Tomlinson, 1971; Basyuni *et al*., 2018; Juwari *et al*., 2020) and in growth of *R. apiculata* (Kathiresan and Rajendran, 2002). Stem perimeter, number of nodes and shoot weight was assessed and registered gradual increment in time. Stem perimeter reached 4.20 cm in one year of time and the number of nodes has been increased from one at one month to 20 at one year, which showed good growth pattern when compared to other species like *R. mucronata* (Hastuti and Budihastuti, 2016). Results of different leaf parameters like number of leaves, leaf length, breadth, weight and area were also following the normal growth of the species, which were comparable with earlier studies from tropical estuaries (Kathiresan *et al*., 1996; Kathiresan and Rajendran, 2002) as well as from other species (Ellison and Farnsworth, 1993; Kathiresan *et al*., 1995; Koch, 1997). The number of leaves has been reached to 40 in one year, leaf length to 10.90cm, breadth to 6.20cm and area to 62 cm^2. Even though the growth of any mangrove is water quality as well as sediment quality along with climatic factors dependent, the growth of *R. apiculata* in tropical conditions of Kerala registered standard growth comparable with other species (Fan and Chen, 1993; Manju *et al*., 2012). The reasons for the differential growth of mangrove propagule can be attributed to the sediment characteristics of the region together with the presence of salinity and associated parameters in optimum dosages supporting the growth of mangrove propagules (Shilna, *et al*., 2017). Even though the present study flash light on the germination and growth characteristics of *R. apiculata* in response to the environmental conditions, more research on these line are warranted to have a comprehensive information on the mangrove species. The conservation and propagation of mangroves warrants species specific baseline data to either conserve the existing patches as well as to propagate through establishment of hatcheries and/or nurseries for which the mangrove patches are to be considered as natural naval protectors of the coastal environment.

Table 2. Analysis of variance (One Way ANOVA) comparing observations for germination and growth parameters of *R. apiculata*.

Mangrove Growth Parameters	0 Day (Propagule)		7 Day		30 Day		120 Day		240 Day		360 Day		F- value
	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	
Plant length (cm)	29.90	3.67	12.10	1.50	17.15	2.50	45.00	3.18	55.50	2.52	62.30	2.78	17.59**
Total weight (g)	27.50	0.02	27.55	0.05	30.48	0.60	33.02	0.58	36.06	0.55	40.48	0.88	29.72**
Shoot weight (g)	00.00	0.00	00.01	0.00	02.36	0.04	02.54	0.08	02.85	0.05	03.60	0.12	19.45**
Stem perimeter (cm)	00.03	0.01	00.02	0.04	02.00	0.04	02.90	0.07	03.80	0.25	04.20	0.12	33.13**
Number of nodes	00.00	0.00	00.00	0.00	01.00	0.00	05.00	1.00	13.00	2.00	20.00	2.00	42.8**
Root weight (mg)	00.00	0.00	00.01	0.00	00.70	0.12	01.50	0.21	02.20	0.21	02.90	0.10	31.48**
Leaf Parameters													
Number of leaves	00.00	0.00	00.00	0.00	02.00	0.00	10.00	1.00	26.00	4.00	40.00	4.00	46.56**
Leaf length (cm)	00.00	0.00	00.00	0.00	06.00	0.30	07.50	0.21	09.20	0.31	10.90	0.40	29.64**
Leaf breadth (cm)	00.00	0.00	00.00	0.00	02.90	0.10	04.60	0.07	05.50	0.10	06.20	0.38	21.56**

Leaf weight (g)	00.00	0.00	00.00	0.00	00.02	0.04	00.10	0.02	00.14	0.01	00.16	0.01	15.57**
Leaf area (cm^2)	00.00	0.00	00.00	0.00	12.50	1.20	23.50	0.57	42.00	6.18	62.00	5.30	56.79**

* P < 0.05; ** P < 0.01

SUMMARY

Growth parameters analyzed varies in the three seasons and can be attributed to the different water/ sediment characteristics and the nutrients available during the three seasons. Generally we can conclude that the water/ sediment samples enhance the early growth of *Rhizophora apiculata* Blume. Data and information on growth characteristics of the species is essential for its conservation and propagation along tropical conditions.

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