Floral Biology and Pollination ecology of *Rhizophora mucronata* Lam in Pitchavaram, Tamil Nadu

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Abstract

Rhizophora mucronata, a blastocarpus mangrove species of Rhizophoraceae family, commonly known as red mangroves is considered as one of the keystone species in the mangrove ecosystem. However, floral biology in the taxon remains unexplored in Pitchavaram mangroves at Tamil Nadu (1°17'- 11°30'N; - 79°45'-79°50'E). Hence the study was conducted to understand the floral biology of R. mucronata. The present study hypothesised that "R. mucronata is a chasmogamous system in which anthesis time is independent of day light temperature rhythm". The study was also aimed to understand the correlation between the abiotic factors on the pollinator visitation. Result revealed that flowers are chasmogamous and exhibit protandry. Flower opening was independent of day light temperature and occurred throughout the day. However, the duration of anthesis is very slow (8-12 hrs). Diurnal flower visitation patterns of insects were negatively correlated to flower surface temperature (r = -0.92). It was also noticed that flowers of *R. mucronata* exhibit distinctive male and female phases during the floral life.

Mangroves are intertidal marine macrophytes distributed in the tropical and subtropical coastlines. These special groups of ecosystems are known for high productivity and for protecting the adjacent habitats from natural and anthropogenic calamities^{10,13}. Mangrove forest are considered as indispensable vegetation of the tropics as they function as dynamic link between terrestrial and aquatic carbon cycles and supports in carbon

sequestration in high level⁶. However, these critical ecosystems are threatened by deforestation, sea-level rise and the related climate change. On a global scale, mangrove loss continues to be 0.13% every year⁹. It is estimated that 90% of the total mangrove cover of the world are in the developing countries and are nearing extinction in 26 Countries⁸. India lost 44% and 26% of mangrove cover along the west and east coast respectively due





Fig 1. Map showing the study location Pitchavaram, Tamil Nadu



Figure 2. Morphological features of *Rhizophora mucronata* Lam. a - habit, b flowering twig, c - Leaf, d - flower close up view, e – pneumatophore.



Fig 3. Different floral stages considered in the study

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Figure 4 Diurnal Flower visitors of *R. mucronata*. a - *Solenonpsis* sps (ant), b -*Polyrachis* sps ant), c - bee, d - beetle, e - housefly, f - wasp



Figure 5. Graph explains the distinctive floral functions at different stage of the flower

to deforestation²⁵. According to IPCC 2013, global sea level are likely to rise between 0.28 and 0.98 m by 2100. However, mangroves are known to develop resilience to fluctuations in sea level²⁶. Planting and restoration of mangroves can be adopted as an option to prevent the implications of climate change²². However the basic understanding of floral morphology and functions is a precondition for the knowledge of reproductive capacity, which is essential for any conservation efforts. Phenology and reproduction are two important aspects of conservation science and aids in implementing effective conservation strategies. Generally, reproductive capacity depends on the local biotic and abiotic factors such as physical climate and pollinator resources. Several studies were conducted on the floral biology of mangroves^{1,11,16-18,20}, however studies on the role of abiotic factors on the flower functions were little known.

Rhizophora mucronata, a blastocarpus mangrove species of Rhizophoraceae family, commonly known as red mangroves is considered as one of the keystone species in the mangrove ecosystem. The taxon is considered as anemophilous species based on the characters such as high pollen ovule ratio, small and scentless flowers²³ however, and the stigmas are not featured capturing the pollen. Till date the pollination system of the species is debated. In the present study was conducted to meet the need of information on the floral biology and pollination ecology of R. mucronata in Pitcavaram. The study considered the following hypothesis "R. mucronata is a chasmogamous system in which anthesis time is independent of day light temperature rhythm". Understanding these basic aspects aids in finding the reproductive constraints and implementing effective conservation strategies of this key stone species.

Study area and Target taxon :

The study was conducted in the Pitchavaram Reserve forest ($11^{\circ}17^{\circ}$ - $11^{\circ}30^{\circ}N$; - 79°45'-79°50'E) at Cuddalore District of Tamil Nadu, India (Fig. 1). It is one of the deltaic mangrove forest situated in the estuaries of the river Cauvery. Tides are semidiurnal, varying between 15 and 100 cm in amplitudes. The target taxon selected *R. mucronata* Lam (Fig. 2), is one of the keystone species of the mangrove ecosystem⁷.

Floral functions :

Floral functions were recorded from July 2019 to September 2021. Regular field visits were conducted to track the flowering seasons. 15 mature individual trees of R. mucronata Lam. were selected and 10 multidirectional flowering branches were tagged in each tree. Regular observations on the floral reproductive behaviour were made using the standard procedure²¹. Based on the preliminary observations, it is found that anthesis progression in R. mucronata is a slow process and flower functions will extend for more than a week hence, 7 floral stages (fig. 3) were identified in this study. Flower after anthesis in its fully opened form is considered as stage A, from mature bud to stage A were tagged as A-3 to A-1. Stages after A were tagged as A+1 to A+3. 25 mature buds were tagged as A-3 and observed for every three hours until the A+3 stage. Flower visitors were recorded in all the stages after anthesis. To understand the effect day temperature on the insect visitation, 10 flowers were tagged in stage A and their surface temperatures were recorded for every one hour using medical thermal scanner. Insect visitation on the tagged flowers were also observed for 12 hrs. To demonstrate the gender function, Stigma receptivity in different floral stages was verified using the Hydrogen peroxidise method²¹ and no. of pollen grains available was also counted on the same flower.

Data analysis :

Pearsons correlation test was conducted using SPSS software (version 25). Correlation between Flower surface temperature and flower visitors and correlation between Stigma receptivity and pollen availability at different stage of the flower were investigated.

Phenology :

R. mucronata is an ever green tree mangrove, reproductive events were occur throughout the year. Flowering to propagule dispersal period is 12 months. Flowering starts during July and continues till the end of October. The peak flowering was recorded during August. Propagule dispersal starts during August and continues till October, and it is in harmony with the southwest monsoon.

Floral Morphology :

Infloresence in *R. mucronata* is compound receme bearing 4 - 8 flowers. Mature buds are creamy yellow in colour. Flowers are perigynous, hermaphrodite, sepals - 4 leathery, petals - 4, hairy on the edges pale white in colour, anthers 6 - 12, ovary semiinferior, bilocular, ovules -4, two ovules per locule, stigma bifid, dry (0.21±0.5 length). Flowers are not showy and scented. Infloresence life spans between 20 – 30 days.

Anthesis and pollination :

Tropical trees mostly exhibit short and rapid flowering³, whereas most of the mangals such as, *Avicennia marina* it lasts for 2-5 days⁴, *Aegiceras corniculatum* 2-3 days. *R. mucronata* flowers remained functional for 5-6 days. This could be an adaptation towards the high humid environment as it flowers during summer. Flower opening occurs throughout the day independent of the day light temperature. This has been considered as an adaptation for anemophily¹⁹. In the present study, 55% of the observed flowers initiated during day time, this was in line with the findings from Gulf of Kutchchh, Gujarat¹⁶. The process of anthesis is a very slow process (8 -12 hrs).

Mature buds are creamy yellow in colour. The strong protandrous system allows the anther to mature inside the flower even before it opens. Anthers are found enclosed within the petals. Anther dehiscence and flower opening are simultaneous. Anthers split open vertically towards the flower axis and the pollen dispersal happens. This can be referred as the male phase of the flower function it exist almost a day (A-A+1). Pollen availability decreases as the flower gets older. High pollen availability was recorded in A-3 and A-2 stages. At his stage stigma receptivity will be very low which prevents the selfpollination. R. stylosa was also recorded to exhibit the same floral mechanism⁵. When the flower fully opens (stage A), anthers would

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		Frequency of	r value (correlation	Peak visiting
S. No	Flower visitors	visit/flower/hour	to flower surface	time
			temperature)	
1	Tephritidea	0.22	-0.72	07.30 - 10.30
2	Polyrachis	0.23	-0.91	06.30 - 10.30
3	Camponotus	0.42	-0.75	06.30 - 10.30
4	Solenopsis	0.07	-0.94	06.30 - 10.30
5	Apis	0.05	-0.90	06.30 - 09.30
6	Hymenoptera	0.06	-0.96	06.30 - 09.30
7	Beetle	0.01	-0.64	06.30 - 09.30

Table 1. Detail of flower visitors in R. mucronata

have dispersed the entire pollens in the flower and fallen. Meanwhile, the petals will also fall. The female phase of the flower function (Stigma receptivity) starts during A-1 however, peak time of stigma receptivity was found during A+2 stage when pollen availability was almost nil (Fig 5).

Negative correlation between the percentages of pollen availability and stigma receptivity (r = -0.63) this explains that the flower functions (male and female) in R. mucronata is temporally separated. This allow the species to be strong protandrous and tailoring the mating system complex, Probably this would aid in mating with the co-occurring species R. apiculata and producing putative hybrid R. annamalayana published by¹². Female phase of the flower exist for more than 2 days. Most of the flower visitors were active during this phase, however they feed exudate from the fallen anther and petals. Coupland et al,⁵ also reported such a visitation in R. stylosa. Bees, ants, wasps and beetles were found visiting the flower during day time (Fig 4) among them ants were the major visitors and they were also found approaching the stigma. Intra floral mites were also noticed in the study however their role in pollination unlikely.

As the peak flowering phenophase occurs during the summer (August) the external abiotic factors such as temperature impact the flower function. Diurnal flower visitation patterns were negatively correlated with the flower surface temperature. The r values were varied from -0.96 to -0.64 (Table. 1). It indicates that the flower surface temperature has the impact on the insect visitation. Features such as leathery calyx, long flower life could be resilience to the high humidity of the outer environment.

Among the flower visitor wasp had the maximum negative correlation with flower surface temperature it could be because of the sensitivity of wasp to the temperature changes. Ants such as Polyrachis sps and Camponotus sps were the most frequent visitors. Kondo *et al.*, also recorded the visitation of Camponotus sp in *R. mucronata* flowers. Although ants are considered as pollen thieves and they are assumed to negatively impact the pollination by disturbing the other effective pollinator²⁶ they can be an effective pollen vectors between flowers. Ant visitation is likely be encouraged as it prevents the herbivore². Insect visitation was maximum during 06.30 - 11.00 hrs and 14.00 - 18.00 hrs. No significant pattern was observed in nocturnal.

R. mucronata is considered as wind pollinated species although their flowers have some anemophillous feature like high pollen to ovule ratio and hairy petal margins featured for slow release of pollen²⁵. Their stigmas are not featured to capture the air borne pollen. Based the observations of the present study it can be assumed that, *R. mucronata* could be pollinated by ants, atleast in this case. Further breeding system studies would bring a clear information on the legitimate pollinator. Kavitha and Kathiresan¹⁴ reported nectar secretion on the stigma region of the *R. mucronata* flowers whereas it was not recorded during the present study.

Post flowering behaviour :

After fertilization, the stigma turns in to black and calyx become brown and thicker. Fruits are brown in colour. Hypocotyl will develop from the mature fruit. The calyx persists until the propagule dispersal.

R. mucronata flowers are long lived and opens very slowly at any time of the day independent of day light. Flower life is consist of distinct, temporally separated male and female functions. Bees, wasps, ants and beetles were found actively visiting flowers during day time. Ants could be a possible pollen vectors in *R. mucronata* atleast in Pitchavaram mangroves. Identifying the legitimate pollinator and breeding system of this species is important of the hour.

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