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Reproductive Fitness and Success in Mangroves: Implication on Conservation

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ABSTRACT

Studies on phenology, floral biology, pollination and reproductive success were carried out *Rhizophora apiculata, R.mucronata, Bruguiera cylindrica* and *Ceriops decandra* belonging to Rhizophoraceae. Observations were made for three consecutive years in the study site Pitchavaram, India. Each of the species exhibited unique phenology and reproductive behaviour. Flowers are bisexual, protandrous, white in colour and do not require any specialist pollinator. Opened flowers last 3-10 days and produce large amounts of pollen. *Bruguiera* and *Ceriops* exhibit entomophilous floral adaptations while *Rhizophora* shared anemophilous features. Low flower to fruit, seed to ovule ratios and reproductive success was common to all species. In *Bruguiera* seedlings developed immediately after fruit set while *Ceriops* exhibited a dormant phase. Implication of reproduction and conservation in the said species is discussed in detail.

Key words: Bruguiera, Ceriops, Mangrove, Propagule, Rhizophora, Reproductive success.

INTRODUCTION

Mangroves are unique marine wetland ecosystems found in the inter-tidal coastal regions of tropics and subtropics. They are not only among the most productive but most threatened ecosystems in the world due to natural and demographic pressures (Kathiresan 2002, Roy and Krishnan 2005, Proffitt et al. 2006). The global mangrove cover is estimated to be about 200,000 km^2 (Spalding *et al*, 1997). Owing to natural calamities, climatic change and anthropogenic pressure over the past twenty years approximately 35% of the world's total mangrove area has been lost (Valiela et al. 2001).

Mangrove vegetations constitute approximately eighty species belonging to twenty families (Duke, 1992). The better known taxa are the members of Rhizophoraceae namely *Rhizophora, Bruguiera, Ceriops* and *Kandelia*. These are listed under various IUCN threat categories that require conservation programs (Rao et al. 1994). Among tropical ecosystems mangroves remain poorly understood in terms of life history traits (Tomlinson et al. 1979). Quantifying levels of reproduction is a prerequisite to effective genetic resource management (Congdon and Herbohn 1993, Aronson et al. 1994). As mangroves propagate only through sexual reproduction their maintenance and recovery depends on propagule production, dispersal and establishment (Tomlinson, 1986).

Although habitat fragmentation and over exploitation are the more apparent causal factors, failure of reproductive processes to cope with environmental changes could also be the fundamental reason for species loss (Moza and Bhatnagar, 2007). In the recent past only a few studies have been conducted on reproduction of mangroves (Duke, 1990, Clarke and Myerscough 1991, Sun et al. 1998, Drexler 2001, Coupland et al. 2005, Coupland et al. 2006, Raju et al. 2006). In this work we have attempted in quantifying the following aspects in natural populations of *Rhizophora apiculata, R.mucronata Bruguiera cylindrica and Ceriops decandra*:

- Phenology
- Floral Biology
- Pollination biology
- Reproductive success

MATERIALS AND METHODS

Study site

The Study site, Pitchavaram is located between the Vellar River in north, Coleroon River in the south and Uppanar in the west (Chidambaram 2005) (Table 1)**.** The part near the Coleroon estuary is pre-dominated with mangrove vegetation, while the northern part near the Vellar estuary is dominated by mud flats. The tides are semi-diurnal and varying in amplitude from about 15 to 100 cm in different regions during different seasons, reaching a maximum during monsoon and post monsoon and a minimum in summer (Kathiresan 2002). The rise and fall of the tidal waters is through a direct connection with the sea at the Chinnavaikkal mouth and also through the two adjacent estuaries and the depth in water channels range from about 0.3 to 3 m (Kathirasen 2002).

Target species

The species *Rhizophora mucronata*, *R.apiculata*, *Bruguiera cylindrica* and *Ceriops decandra* belong

to the family Rhizophoraceae. These are referred to as true mangrove species and are viviparous in nature.

Phenology

Studies were carried out in forty individuals in each of the said species in different islets. Ten branches in each of the plants were tagged for observing bud initiation, flower production and fruit set.

Floral Biology

Time and duration of anthesis, flower life and pollen output was quantified according to methods described by Dafni (1992). Flower from the period of opening to drying up of the stigma tip was recorded.

Pollen fertility

Pollen was collected from different flower positions for testing fertility using differential staining method (Alexander 1969). Pollens were smeared with a drop of stain and left undisturbed over night. Pollen with pink stained cytoplasm will be scored as viable while those with green stained cytoplasm will be treated as aborted. Standard procedures were used to analyze pollen grains morphology. (Radford et al. 1974)

Pollen Ovule ratio

P/O ratio = Number of pollen grains in a flower/ Number of ovules in a flower was calculated using procedures developed by Cruden (1977).

Plant pollinator interaction

Pollinator behaviour in plants and their effectiveness in pollination were studied according to standard procedures described by Dafni (1992).

Table 1. Details of the study site

Name of the location	Pitchavaram, Tamil Nadu, India
Geographical position	11º 24'N, 79º 47'E
Total mangrove area	1,100 ha.
Annual mean range temperature	20°C - 37°C
Vegetation type	Estuarine Mangrove
Floral composition	*Rhizophora apiculata, R. mucronata, Bruguiera cylindrica, Ceriops decandra, Sonneratia apetala, Avicennia marina, A, officinalis, , Aegiceras corniculatum, Suaeda maritime, S.nudiflora, Arthrocnemum*

Table 2. Phenology and floral biology characteristics in the four Rhizophoraceae taxa present in Pitchavaram Mangroves.

	B. cylindrica	*C.decandra*	*R.mucronata*	*R.apiculata*
Flowering period	March - April	April-May	October -December	September - November
Flower type	Entomophilous	Entomophilous	Anemophilous(?)	Anemophilous(?)
Colour	White	White	White	White
Symmetry	Actinomorphic	Zygomorphic	Actinomorphic	Actinomorphic
Odour	Present	Mild	Present	Absent
Nectar	Present	Present	Absent	Absent
Anthers/ Flower	16	10	8	8
Pollens/Anther	1690	24,000	50,000	NA
Ovules/ flower	4 -6	6	4	4
Pollen size (µm)	14 - 16	18-20	16-22	16-28
Pollen fertility	80%	65%	81%	79%
Pollen type	Spherical, smooth walled, tricolpate	Spherical, smooth walled ,tricolpate	Spherical, smooth walled , tricolpate	Spherical, smooth walled, tricolpate
Stigma type	Wet, Bifid	Wet, Bifid	Bifid	Bifid
Pollen/ovule ratio	1:6750	1:40, 000	1:1,00,000	NA

Table 3. Reproductive Success in different Rhizophoraceae taxa found in Pitchavaram mangroves

Species	Flower/fruit ratio	Seed / ovule ratio	PERS*
B.cylindrica	0.30	0.25	0.07
C.decandra	0.16	0.16	0.025
R.apiculata	0.25	0.25	0.06
R.mucronata	0.12	0.25	0.03

* - Based on Wiens *et.al.,* (1984)

Reproductive success

Pre-emergent Reproductive Success (*PERS*) was derived from fruit to flower ratio and seed to ovule ratio using the following formula (Wiens et al 1987)
P*ERS = Fruit/flower ratio* X *Seed/ovule ratio*

RESULTS

Phenology

Among the four species *B.cylindrica* was the earliest to flower and fastest to mature fruits within a period of 12 weeks. *C.decandra* flowered one month latter to *B,cylindrica* which was followed by Rhizophoras (Table 2).

Inflorescence architecture and Flowering behaviour

Inflorescences are cymes borne opposite in axils of the second and third immediate nodes proximal to cymes bear 2 flowers in *R.apiculata*, 3 flowers in *B.cylindrica*, 4 flowers in *C.decandra* and *R.mucronata*. A reproductive shoot contains 12-18 flowers in *B.cylindrica,* 16-24 flowers in *C.decandra* and 12–16 flowers in case of *R.apiculata* and *R.mucronata*. Flowers within an inflorescence or in a reproductive shoot do not bloom simultaneously.

Floral biology

Flowers were in shades of white, not showy and not found adapted to any kind of specialist pollinator syndrome. They are bisexual, protandrous and produce enormous amounts of pollen (Table 2). *B.cylindrica* had the least duration of flower life (3-4 days), followed by *C.decandra* (6-8 days) and *Rhizophora* (8-10 days). The dichogamous are strongly protandrous with pollen dispatches for about a day in *Bruguiera* and for more than 2 -3 days in *Ceriops.* In *Rhizophora* pollen is dispatched over 3-4 days as anthers open continuously. The stigma is receptive on the second day in *Bruguiera*, day three in *Ceriops* and beyond 4 days in Rhizophora. Well hydrated stigmas within completely dehydrate anther mass is common sight among Rhizophoraceae taxa.

Pollen biology

Flowers produced plenty of pollen also the pollen to ovule ratio was also very high among species (Table 2). Pollen fertility varied considerably among species (Table 2). Infertile pollen was smaller in size as well.

Plant Pollinators

In *B.cylindrica* large number of thrips were found within flowers. Seldom visits by wasps and solitary bees was also recorded. In case of *C.decandra* the pollen vector started visiting 08.00 – 18.00 hours. Wild solitary bees were the major visitor group. No social bees could be recorded. Occasionally large pollinators like *Xylocopa* were also recorded. Forage timing of bees varied from 3-5 seconds.

Vivipary and seedling development

Development of viviparous seedling followed immediately after fruit set in *Bruguiera* and *Rhizophora*. However, in *C.decandra* after a dormancy period of 16-18 weeks fruits started maturing in to propagules.

Reproductive success

Flower to fruit ratio varied among species, in terms of reproductive success *B.cylindrica* showed the highest and the lowest was of *R.apiculata* (Table 3).

DISCUSSION

In the past studies on mangrove reproductive phenology have indicated latitudinal effect on flowering (Duke 1990a and 1990b). Pitchavaram mangroves are among the southern most latitudes in India, Rajendran and Sanjeevi (2004) have recorded that flowering phenology in Pitchavaram is highly seasonal and unique from rest of the mangrove locations in the country.

Clarke and Myerscough (1991) found reproductive events in mangroves were relatively synchronous among trees at particular latitude and this was constant among years. However, the reproductive status of individual trees highly varied between years. Individual trees and clusters did switch synchronously from reproductive to a non - reproductive state across years. A similar

phenological trend was observed in the present study. Such patchy flowering may promote out breeding or simply reflect change in sediment resources availability (Clarke and Myerscough 1991). It was observed that in Pitchavaram every species had its own reproductive niche. Such distinct reproductive behaviour among species within an ecosystem reduces competition in sharing pollinators, nutrients and substrate for propagules to establish.

Inflorescence architecture is unique in Rhizophoraceae; they are borne sub-terminally wherein reproductive shoots develop only in the second and third nodes immediate to the meristamatic tips of vegetative branches. There is a clear spatial and temporal separation of sexual phases within and among flowers in an inflorescence. Even though the Rhizophoraceae taxa investigated in this study reveal entomophily, characteristics such as production of small sized pollen in large quantities and high pollen to ovule ratio reflect anemophilous breeding system.

The pollen fertility observed in *Bruguiera, Ceriops* and *Rhizophora* is comparatively lower to the values reported in other out breeding woody perennials (Nagarajan et al. 1998, Nagarajan et al. 2006). This could be due to the possibilities of inbreeding depression. In terms of pollinators all the three species showed different group of insect visitors. *Bruguiera cylindrica* flowers were pollinated by thrips while *Ceriops decandra* was visited by diverse taxa of insect visitors belonging to *Hymenoptera and Lepidoptera*. In case of *Rhizophora* even though occasional bee and wasp visits were noted their pollination accomplishment remains unclear.

It is interesting to note that despite having multiple ovule system (4-6) only one ovule succeeds in developing in to a propagule. Allen and Duke (2006) noted that *B. gymnorhiza* had very long reproductive maturation period of 1-2 years from flower emergence to dispersal of mature hypocotyls. In this study it was found that propagules in *Rhizhophora* mature over a period of 8-10 months to develop on mother plants, whereas in *B.cylindrica* and *C.decandra* it was 3-6 months.

In *Ceriops decandra* after fruit set they remain dormant for the next 3-4 months. A similar reproductive behaviour was reported in *Ceriops australis* (Coupland et al. 2006). However, Raju et al. (2006) reported that in *C.decandra* populations found in Coringa, India develop propagules immediately after fruit set.

Diverse floral features, high pollen out put, very high pollen to ovule ratio and low reproductive success noticed in *Bruguiera, Ceriops and Rhizophora* places them amongst highly out crossing woody perennials. Based on entomphilous adaptations and moderate reproductive success it can be well inferred that *C.decandra* propagules are outcrossed products. On the contrary, *B.cylindrica* pollinated by thrips, an intra floral pollinator could promote geitonogamy. In *Rhizophora* no conclusive evidences could be drawn. In human assisted regeneration programs of Pitchavaram it is recommended that *B.cylindrica* propagules should not be sampled from a few individuals as it could lead to selecting genetically related individuals. Instead if sampling is done from various clusters in different Islets, genetically diverse material can be obtained. In case of *C.decandra* one or more individuals within a cluster can be sampled for plantation purposes. However, recent studies on genetic markers contrarily indicate high levels of genetic relatedness within and among populations of *Ceriops* (Sun et al. 1998). At this stage it can only be inferred that this could be due to bi-parental inbreeding or perhaps due to short distance travel by the propagules. Further studies are required on these lines.

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