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Observations on the Floral Biology of Certain Mangroves

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The present study examined the floral biology in relation to pollinators in five mangrove plant species of the Godavary estuaries in Southern India. Pollen vectors were a necessity to *Caesalpinia nuga* and *Acanthus ilicifolius* flowers for their mating system. In *Aegiceras corniculatus* and *Lumnitzera racemosa*, flowers were pollinated autogamously and their pollen and nectar served as food resource for some insects. *Avicennia officinalis* reproduced through outcrossing while maintaining autogamy. Carpenter bees were the main pollinators for *C.nuga*, sunbirds for *A.ilicifolius*, flies for *A.officinalis*. The floral architecture was so designed to operate the pollination mechanism in each of these species. Retention of calyx in all but *C. nuga* was considered to be a protective role for the successful development of fertilised ovules into fruits.

Key Words: Floral biology, Mangroves, Autogamy, Carpenter bees, Sunbirds

Introduction

Studies on floral biology of mangroves are very few and those that have been investigated even are preliminary and incomplete. However, the mangroves have largely been studied of their reproductive biology in terms of viviparous seedling and dispersal. But, knowledge of reproductive biology must begin with a consideration of flower function in detail (Van Steenis 1958). A quite elaborate descriptions and presumptions are made on the floral biology of some mangrove Rhizophoraceae, of course, after preliminary observations in field (Tomlinson et al. 1979). Others that made fragmentary early records of members of the same family include Guppy (1906), Gehrmann (1911), Porsch (1924), Docters van Leeuwen (1927), Gill and Tomlinson (1969, 1971), Kress (1974) and Davey (1975). From such accounts, it can be concluded that Rhizophoraceae have a similar floral construction but exhibit a wide range of pollination mechanisms - Bruguieras had small and large flowered forms with pollination mechanism explosive and pollinated by day-time visitors; small flowered forms are pollinated by butterflies and large forms by birds. Explosive mechanism of *Ceriops tagal* is triggered by nocturnal moths; non-explosive flowers of *C. decandra* by small and short-tongued insects, *Kandelia candel* by large and longer-tongued insects. Rhizophoras are predominantly wind-pollinated. Piece-meal floral biology studies other than Rhizophoraceae include *Acanthus spinosus*, *A. longifolium* (Knuth 1909) and *A. mollis* (Knuth 1909, Schremmer 1960). *Acanthus* species have a fascinating flower pollination mechanism through which they are pollinated by legitimate animals. Such studies realise lack of information on other mangrove plant species, particularly on Indian flora. Hence, the present study was undertaken to investigate the basic information on floral biology of mangroves that are most abundant and widely distributed over the entire forest cover at the Godavary estuaries of Andhra Pradesh State, India.

Materials and Methods

The Godavary estuary region in Andhra Pradesh State, South India (Lat. 16°55'N, Long. 82°15'E) covered about four hundred hectares of land with mangrove forests. Access to the interiors of the forest is possible only during March-June; when the water level is low and rundown banks of estuaries and soil cover cracks open for it is well exposed to sunlight. This is the period for human activity in the forest and cut down the forest produce indiscriminately. About thirty plant species grow round the year. Of these, *Acanthus avicennia* L., *Aegiceras corniculatus* (L.) Blanco, *Av. officinalis* L., *Lumnitzera racemosa* Willd., and *Caesalpinia nuga* Ait. are the major components and their populations thrive well over the forest. *C. nuga* and *A. ilicifolius* populations are mostly confined to the banks of estuary, *A. corniculatus* and *L. racemosa* to the interiors along the tidal creeks and *A. officinalis* distributed throughtout the forest. With the commencement of flowering, regular field trips were undertaken during March-August 1985 and 1986. Flowering phenology, nature, morphology and orientation of the inflorescence and the individual flowers on them were keenly observed. The floral morphometrics were described and given in millimeters. Flower behaviour, estimation of pollen output, and pollen-ovule ratios were studied by methods of Cruden (1977) and Raju (1988). Flowering time of each inflorescence, anthesis, anther dehiscence, nectar secretion, relative positions of reproductive parts and natural fruiting behaviour were examined in detail. Reproductive behaviour was tested by hand pollinations for *A. ilicifolius* and Av. *officinalis*.

Flower visitors in the study area and for each plant species were recorded. Insects were collected and identified. Birds were observed and identified with the standard reference (Salim Ali 1988). Behaviour, forage objects and efficiency of pollen foraging were also noted as in previous studies (Raju 1988).

Results

The five plant species were found in flowering phase between March and August. *Aegiceras* and *Caesalpinia* initiated flowering at the same time in March; the former terminated the flowering in May and the latter in June. Both *Acanthus* and *Lumnitzera* began flowering in April and continued until the end of June. *Avicennia* flowered late in summer in May and extended through the middle of monsoon season in August. The mean number of flowering days and flower production in each inflorescence for each of the five species were presented in table 1.

The period of flower opening for a given species was between 0500 and 1900 hr. *Caesalpinia, Aegiceras* and *Lumnitzera* completed their anthesis before noon and the two others continued until dusk. Anther dehiscence just preceded anthesis in *Caesalpinia* and *Acanthus*; with anthesis in *Aegiceras* and *Lumnitzera* and three hours later in *Avicennia*. Nectar was produced in large quantity in *Acanthus*, small quantities in *Caesalpinia* and *Lumnitzera*, traces in *Avicennia* and no-nectar in *Aegiceras*. In *Avicennia*, the nectar was secreted by inner pale yellow surface of corolla tube and lobes. When solar radiation fell on it, the nectar surface area glittered which was then visible even to the naked eye.

Flowers of *Acanthus* and *Caesalpinia* were large and gullet shaped and were small and star-like in the others. The flowers of *Acanthus* and *Caesalpinia* were aromatic, *Lumnitzera* light scented and the others non-scented. Calyx colour was green in all but *Caesalpinia* which was greenish-yellow. Sepal number was five in all except *Acanthus* (four). Corolla colour in *Caesalpinia* and *Avicennia* was yellow, in *Aegiceras* and *Lumnitzera* white and in *Acanthus* blue with cartilaginous large corolla tube and bi-lipped. In *Aegiceras* corolla tube was not present and in others it was quite small. Petal number was four in *Avicennia* and five in the others. Stamens were ten in *Caesalpinia* five to ten in *Lumnitzera*, five in *Aegiceras* and four in the two

Table 1 *Floral phenological and morphological features of some mangrove plant species*

	C. nuga	*A. corniculatus*	*A.ilicifolius*	*L. racemosa*	*A. officinalis*
Habit	shrub	small tree	shrub	small tree	tree
Flowering season	March-June	March-May	April-June	April-June	May-August
Inflorescence	raceme	umbel	raceme	raceme	panicle
Flowering time of inflorescence (days)	9	7	9	4	20
Inflorescence mean flower production	15	20	36	9	42
daily mean flower production/day/ Inflorescence	2	3	4	2	2
Anthesis time (hr)	0600-1100	0500-1000	0600-1800	0700-1100	0500-1900
Flower size	large 17mm long & 10mm dia.	small 15mm long & 13mm dia.	large 50mm long & 32mm dia.	small 11mm long & 6mm dia	small 11mm long & 8mm dia.
Shape	gullet	star-like	gullet	star-like	star-like
Smell	scented	no smell	fragrantic	light scented	no smell
Calyx colour	greenish-yellow	green	green	green	green
No. of sepals	5	5	4	5	5
Corolla colour	yellow	white	blue	white	yellow
Tubular/non-tubular	small nectari-ferous tube	non-tubular	cartilaginous large nectari-ferous tube with villous throat	small nectari-ferous tube	small tube
No. of petals	5	5	bi-lipped	5	4
No. of stamens	10	5	4	5-10	4
Size (length)	12mm	4mm	29mm	4mm	3mm
Filaments	hairy	smooth	thick, hairy	smooth	smooth
Ovary	one carpel one locule	one carpel one locule	two carpels two locules	one carpel one locule	two carpels four imperfect locules
No. of ovule	1	1	4	3 (2-5)	4
Stigma	simple	simple	bi-fid	simple	bi-fid
Flower life span (days)	2	2-3	2	2 or 3	3
Anther dehiscence time	about anthesis	with anthesis	about anthesis	with anthesis	3 hr after anthesis
Nectar secretion	small quantity	no secretion	large quantity	small quantity	traces
Pollen colour	yellow	white	yellow	white	creamy
Pollen state (at anthesis)	sticky	powdery	powdery	powdery	sticky
Pollen output/flower	6350	9530	287350	1820	13480
Pollen-ovule ratio	6350 : 1	9530 : 1	71840 : 1	666 : 1	3370 : 1
Natural fruiting	few	all fruited	heavy	all fruited	heavy

others. The stamen filaments in *Acanthus* flowers were very strong and hairy, hairy in *Caesalpinia* and smooth in the others. Stigmas were bifid in *Acanthus* and *Avicennia* and simple in the others. Pollen colour was white in *Aegiceras* and *Lumnitzera*, yellow in *Caesalpinia* and *Acanthus* and creamy in *Avicennia*. Pollen grains were powdery at anthesis in *Aegiceras*, *Lumnitzera* and *Acanthus* and sticky in the other two. The pollen production in relation to ovules was very high in *Acanthus* and very low in *Lumnitzera*. The centrally seated pistil was roofed over by the anthers in *Aegiceras* and *Lumnitzera*. In *Avicennia*, the receptive pistil bent to the corolla throat and remained so for three hours after anthesis, which then gradually grew 1mm long and later became slightly straight to have seated between two lateral stamens below and close to the anthers. The pistil in *Caesalpinia* was seated with stamens close to the lower petals but beyond the anthers. In the bi-lipped *Acanthus* flowers, the upper lip was poorly developed and the lower lip broad, thick and strong acting as landing base for foragers. The pistil and stamens were adjacent to the upper lip and the bifid stigma exerted 2mm beyond the upper lip and situated on the outer surface of the anthers. The anthers were contiguous and mutually appressed. One of the two locules of each antheres was fertile and appressed into the sterile lobe of the facing anther. The flower life span was three days in *Avicennia*, two to three days in *Aegiceras* and *Lumnitzera* and two days each in the others. Except for *Caesalpinia*, where the calyx dropped off along with other floral parts, the other four species retained their calyces and sheltered fertilised ovules for fruit formation and crowned the apex of fruits.

Very few flowers were fruited in nature indicating that their stigmas were self-incompatible but cross-pollinated in *Caesalpinia*. *Acanthus* flowers too were cross-compatible and were tested through hand pollinations. Both self and cross compatibilities were revealed in *Avicennia* (table 2). Each flower produced on *Aegiceras* and *Lumnitzera* were usually fruited.

Table 2 *Results of the breeding experiments for* ***Acanthus ilicifolius*** *and* ***Avicennia officinalis***

Treatment	*No. of flowers pollinated*	*No. of flowers fruited*	*Fruit set (%)*
A. ilicifolius			
Autogamy	50	0	0
Geitonogamy	50	29	58
Xenogamy	50	50	100
A. officinalis			
Autogamy	20	18	90
Geitonogamy	25	25	100
Xenogamy	25	25	100

Flower Visitors and Their Behaviour in Relation to Pollination

Altogether fifteen flower visitors were recorded during the entire blooming period of the five species (table 3). Of these, two were sunbirds and they confined their visits to the blue flowers of *Acanthus* for nectar. Other visitors included nine species of bees, two fly species, one each ant and wasp species. Fly visits were limited to *Avicennia* flowers for pollen and nectar traces, wasp to *Acanthus* and *Lumnitzera* for nectar. Bee species *Apis cerana var. indica* and *A. florea* foraged for pollen and nectar of *Lumnitzera*, *Trigona* for pollen of *Aegiceras* and *Avicennia*, *Pseudapis* for pollen of *Aegiceras* and pollen or nectar of *Caesalpinia* and *Lumnitzera*, and *Megachile* only for nectar of *Caesalpinia*. All these foragers were day active from dawn to dusk, but their foraging activity rate varied with the time of the day. The number of flower foraging visits were usually very high during forenoon hours and then on gradually their visits were low until they became inactive at dusk.

Caesalpinia flowers were mainly visited and pollinated by *Xylocopa*. It foraged for nectar sternotribically as directed by nectar guides on the upper petal and the essential organs placed near the lower part of the corolla. After the foraging visit, it returned with a plenty of pollen on the sternum and legs. The individuals of *Xylocopa* were less in number and they visited the flowers

Table 3 *Flower visitors and their forage objects on some mangrove plant species*

Forager species	*C. nuga*	*A. corniculatus*	*A. ilicifolius*	*L. racemosa*	*A. officinalis*
HYMENOPTERA					
Bees					
Apis cerana var. indica				p, n	
A. florea				p, n	
Trigona sp.		p			p
Xylocopa latipes	n		n		
X. pubescens	n		n		
Pseudapis oxybeloides	p, n	p		p, n	
Ceratina sp.				p, n	
Amegilla sp.				p, n	
Megachile sp.	n				
Ant					
Camponotus sp.	n				
Wasp					
Rhynchium metallicum			n	n	
Flies					
Chrysomya megacephala					p, n
Musca domestica					p, n
Aves (Sunbirds)					
Nectarinia asiatica			n		
N. zeylonica			n		

p, pollen; *n*, nectar

infrequently. However, the flowers foraged were many in each foraging bout. *Megachile* and *Pseudapis* infrequently foraged on these flowers for nectar similarly as *Xylocopa*. *Pseudapis* foraged for pollen with head directed outwards and moving towards anthers. *Camponotus* frequently foraged for nectar illegitimately from lateral side. *Aegiceras* flowers offered only pollen for foragers. *Trigona* and *Pseudapis* foraged for the pollen and brushed the stamens and stigma with their ventral side.

The five animal species visiting *Acanthus* flowers fed on nectar only. *Xylocopa* and *Rhynchium* probed the flowers after landing on the lower corolla lip and *Nectarinia* sitting on the lower flowers. The contiguous anthers were then separated and pollen was deposited on the stigma and on the back of the animal resulting in nototribic pollination. After the visit, the anthers returned to their original position and released no pollen when firmly held by filaments. Except *Rhynchium*, all the others were frequent in their visits to the flowers. Heavy pollen loads were observed on the backs or beaks of the bees and sunbirds.

The foraging insects of *Lumnitzera* except *Rhynchium* which foraged for only nectar were directed to both pollen and nectar collection. *Avicennia* flowers were frequently, regularly and consistently foraged and pollinated by *Chrysomya* and *Musca*. The two species when foraged for pollen contacted the stamens and stigma; they did not contact the stamens and stigma when foraged for trace nectar on the inner surface of petals. The pollen feeder *Trigona* also brushed the stamens and stigma and resulted in loading the stigmas with pollen.

Discussion

The five plant species examined show that flowering phase is assoiated with gradual rise in temperature and fall in relative humidity immediately after winter. *Aegiceras* terminates flowering while in summer as an indication that it completes the flowering phase before the onset of monsoon season. The other plant species continued to bloom in monsoon period which usually causes intensive flowering in them.

Each flower produced on *Aegiceras* plants normally sets fruit by virtue of its ability to pollinate autogamously. The autogamy is effective as a result of the powdery viable pollen reaching the surface of the stigmas located under the anthers. It does not require an external agent for its pollen movement and hence nectar is not secreted. However, bee foraging activity for its pollen causes pollen flow between individual plants. The floral pollination mechanism in *Lumnitzera* is as similar as in *Aegiceras*. Although it produces fruits from each borne flower, it secretes nectar in traces, which is not clearly understood. Its pollen and nectar is foraged by bees and a wasp and hence transmits pollen from one flower to another that eventually enhances outcrossing.

Natural fruiting in *Caesalpinia* is highly limited and each flower does not fruit, and shows that autogamy is not operative as reflected in its floral features such as large sized, gullet-shaped flower with scent accompanied by nectar guide on the upper most petal and essential organs on the lower petals and stigma over the anthers. Further, a coincidence between bee foraging activity period and blooming process by anthesis, anther dehiscence and nectar secretion timings makes it obvious that floral mechanism is so designed for insect pollination. The ant in its behaviour at the flower is a nectar robber. Small-sized *Pseudapis* pollinates through sternotribic behaviour when forages for pollen or nectar. *Megachile* and *Xylocopa* are also similar in their foraging behaviour as *Pseudapis* but they forage for only nectar. These two species are the actual pollinators, however, their visits are infrequent and small in number. The *Xylocopas* are usually nototribic pollinators and their flowers with stamens and stigma near the upper petal lobes (Faegri & Pijl 1979, Reddi & Subba Reddi 1983, Frankie et al. 1983, Raju 1987) and their behaviour at the flowers is always the same. Here, the sternotribic behaviour of *Xylocopa* is because of the stamens and stigma on the lower petal lobes. The natural fruiting is an attribute to the flowers that have been pollinated by insects, and therefore *Caesalpinia* is entirely dependent on insects for its pollination.

In *Acanthus* too, the correlation between blooming process and insect and bird foraging activities is evident. It does not reproduce autogamously and hence not all flowers are fruited. The pollen flow between flowers is essential as realised through hand pollinations. The carpenter bees, wasp and sunbirds transmit pollen within and between plants when they forage for nectar. The three lobed lower corolla lip serves as a convenient landing base for the forager. The upper corolla lip shelters the stamens and stigma. The stamen filaments are strong enough and hold the sterile and fertile anther locules together with fringed hairs. The development and orientation is such that the fertile anther lobes are locked in the sterile locule of the facing anther; the pollen receptacle is thus kept firmly closed and can only be separated by large bodied bees or birds. During the foray by these visitors, the contiguous anthers appressed to each other gets separated and the stigma and the back of thorax or beak of the forager is sprinkled with pollen as the forager's strong proboscis or beak inserts between the appressed stamens. As soon as the forager leaves the flower, the separated stamens under tension come back to their original position preventing wastage or removal of the powdery and light pollen by the wind. Similar pollination mechanism has been described for *C. spinosus*, *A. longifolium* and *A. mollis* by Knuth (1909) and Schremmer (1960). It seems that this floral mechanism is basical in the genus *Acanthus*.

Fruiting in *Avicennia* is usually high. Its flowers open continuously during day light hours, delay anther dehiscence for three hours after anthesis, receptive pistil lie close to the corolla throat for a certain period and nectar secrete on the inner surface of corolla tube and lobes. The nectar bearing surface glitters in sun light and directs the flies to probe the flower and acts as a substitute for nectar guides. When the flowers with stigma bent to one side of the corolla throat are visited by flies, the stigmas get cross-pollinated because the anthers within the flower are not dehisced. In the course of flower life time, the bent stigma begins to stand erect by growing 1mm above and come close to the over-arched anthers to have pollinated autogamously, if the flower is not previously pollinated. The autogamy here, is a function of pollen shedding from the over-arched anthers and reaching the stigma below.

The autogamy in *Aegiceras* and *Lumnitzera* associates with small flower forms and close juxtaposition of stigma and anthers (Ornduff 1969, Cruden 1977). The *Avicennia* prefers to be cross pollinated and employs autogamy in the final stage of flower life span. The *Caesalpinia* and *Acanthus* fruit only when cross pollinated.

Cruden (1977) predicts that pollen-ovule ratios (P/O) correlate with breeding system and reflect the likelihood of sufficient pollen grains reaching each stigma to result in maximum seed set. It is nearly true with *Caumnitzera*. In Acanthus, the higher P/O ratio is presumed to be a compensation for the pollen loss during the forays of carpenter bees and sunbirds and in *Aegiceras* to overcome the pollen loss from the voracious pollen feeders.

Birds are known to be flower colour specific and prefer red colour flowers (Raven 1972). The sunbirds foraging on blue and nectariferous *Acanthus* flowers is inevitable since they have no other nectar source in that season.

The *Caesalpinia* drops the calyx soon after pollination leaving the ovary exposed to sun light. This feature may have been limiting the fruit set after pollination. In the other four taxa, the calyx retains and protects the ovary from the direct effects of solar radiation and eventually crowns the apex of the fruit (Grant 1950, Pijl 1972).

The summer causes many flower species to shed leaves and remain until the monsoon season is returned in the study area. The dry period triggers flowering in the five plant species which otherwise feed some insects and sunbirds. Butterflies do not show up during March-August, although they are evident in the remaining period. What makes them to disappear is not known. A more elaborate study on the community ecology of each mangrove plant species would yield interesting results.

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Maximum floral density was observed in the month of April June in male plants and May June in female plants. Male flowers are borne on loose panicle and yellowish green in colour, while female flower are greenish white and arranged in axillary crowded spikes.Â by stigmatic receptivity between h. Pollen viability was highest in the month of April. Unicellular trichomes were seen on the dorsal and ventral surface of tepals and ovarian surface. Pollen grains are 30 Âµm in diameter and are triporate and suboblate. Number of pollen/flower 36, and number of pollen/anther is 7, There is one ovule per ovary and pollen ovule ratio is 36,553: 1. Pollination is anemophilous and fruit-set percentage is 16.6% and seed-set is 100%. Observations on the Floral Biology of Certain Mangroves. View. Show abstract.Â Mangrove forests are wetland resources in coastal areas that important role in supporting of life. However, in recent decades, many mangrove forests have been degraded or lost, mainly due to the conversion of mangroves into ponds. Mangrove restoration activities on ex-pond lands have begun in recent years on the eastern coast of North Sumatra. This study aimed to measure the recovery of mangrove [Show full abstract] species through restoration activities on ex-pond lands and to know the composition of the restored mangrove forests at the eastern coast of North Sumatra.