

Rhizophora x mohanii*: A putative hybrid between *Rhizophora mucronata* and *Rhizophora stylosa* from mangroves of the Andaman and Nicobar Islands, India*Abstract**

Rhizophora x mohanii (family Rhizophoraceae), a new mangrove hybrid from the Andaman and Nicobar Islands, India, is described and illustrated. Determined to be F₁ hybrid between *R. mucronata* and *R. stylosa* based on the intermediate characters, the hybrid has thick ovate leaves, inflorescences with 2–8 flowers, long peduncle, an elongated style (0.4–0.5 cm), and an absence of reproductive stages.

Introduction

The genus *Rhizophora* is the largest in the family Rhizophoraceae worldwide, and is represented by six species (*R. apiculata*, *R. mucronata*, *R. stylosa*, *R. samoensis*, *R. mangle* and *R. racemosa*) and four natural hybrids (*R. x annamalayana*, *R. x lamarckii*, *R. x selala* and *R. x harrisonii* (Duke & Bunt, 1979; Duke, 1992; Duke *et al.*, 1998). Recently, Duke (2010) encountered *R. x tomlinsonii* a new hybrid between *R. apiculata* and *R. samoensis*, and Ng *et al.* (2013) recognized a possible hybrid between *R. mucronata* and *R. stylosa* through molecular studies. The Indo-West Pacific (IWP) region has four species *i.e.*, *R. apiculata*, *R. mucronata*, *R. stylosa*, and *R. samoensis*, and three natural hybrids *R. x lamarckii*, *R. x annamalayana* and *R. x selala* (Duke *et al.*, 2002). Except for *R. samoensis* and *R. x selala*, all others occur in India (Ragavan *et al.*, 2011).

Mangrove of Andaman and Nicobar Islands (ANI) is dense and diverse compared to others mangroves in India (Mandal & Naskar, 2008). According to the latest estimate by the Forest Survey of India (Anon., 2013), the total mangrove area is about 4,628 km² in India, of which, 604 km² occur in ANI with 38 species recorded. Three species (*R. apiculata*, *R. mucronata* and *R. stylosa*) and two natural hybrids (*R. x lamarckii* and *R. x annamalayana*) of genus *Rhizophora* have been reported from ANI (Ragavan *et al.*, 2011).

During a recent field excursion, we came across an interesting specimen of *Rhizophora* in mangrove forest of Burmanallah and Neil Island. The specimens were collected and critically studied. It was found that the specimens did not match any of the known species of the genus and hence have been described and illustrated here as a novelty. In addition, a key for *Rhizophora* species of ANI has been provided for identification.

Taxonomic Treatment***Rhizophora x mohanii* P. Ragavan, hybrid sp. nov.**

Type: South Andaman, Burmanallah (11° 33' 36.1" N, 92° 43' 38.2" E) and Neil Island (11° 50' 13.7" N, 93° 15' 15.1" E), India, 18 March 2014, P. Ragavan, PBL 30957 and 30958 (holotype: PBL).

Tree: columnar to spreading, up to 10 m tall, evergreen (Fig. 1A). **Bark:** dark brown to grey, rough, friable, fissured horizontally (Fig. 1B). **Roots:** both stilt roots and aerial roots growing from lower branches, stilt roots are highly conspicuous arching above ground to 2 m. **Leaves:** simple, opposite (Fig. 1E), oblong rounded (Fig. 1C), dark green and leathery, 0.1–0.15 cm thick, 8–14 by 6–9 cm, ratio of length to width 1.36, apex rounded (Fig. 1F) with pointed mucronate, to 0.3–0.4 cm long (Fig. 1G), base rounded, margin entire, laterally folded (Fig. 1D), leaves clustered at the end of branch; petiole green, 1.5–3.0 by 0.4–0.6 cm. **Inflorescences:** axillary, 2–8 flowered (Fig. 1H); bract prominent, either two lobed or single lobed (Fig. 1J); bracteoles prominent, two lobed (Fig. 1K); peduncle green, 2–5 by 0.3–0.4 cm, single lobed bract present before the first dichotomous branch (Fig. 1I); pedicel stout. **Mature flower buds:** yellowish green, ellipsoidal (Fig. 1K), four sided in cross section (Fig. 1L), 1.5–1.8 by 0.6–0.9 cm, ratio of length to width 2.21, apex obtuse, widest near the base; calyx lobes 4, yellowish white, apex acute; petals 4, white, lanceolate, hairy, folded, 1.2–1.3 by 0.3–0.4 cm (Fig. 1M); stamens 8, pale brown, 1.0 cm long (Fig. 1O); style bi-lobed, 0.4–0.5 cm long (Fig. 1N); ovary not prominent. **Fruits:** not observed.

Distribution: Present in two out of 47 sites surveyed, namely, Neil Island and Burmanallah.

Habitat and Ecology: In both sites, the hybrid was found at low inter-tidal zone along with *R. mucronata* and *R. stylosa*.

Phenology: Flowering occurs throughout the year. No other reproductive material was observed.

Etymology: Named in honour of Prof. P.M. Mohan (Department of Ocean Studies and Marine Biology, Pondicherry University, Port Blair, Andaman and Nicobar Islands) for his inspiration, and outstanding contribution to the field of Marine Biology in Andaman and Nicobar Islands.

Conservation status: *Rhizophora x mohanii* was collected only from the Burmanallah and Neil Island. In both sites, only one individual were observed and hence it is assumed to be rare. Therefore, the hybrid can be assessed as "Data Deficient" (DD), using the criteria of IUCN (2001).



Fig. 1 *Rhizophora x mohanii* P. Ragavan, hybrid sp. nov.

A: habitat, B: bark, C: leathery ovate leaf, D: laterally folded leaf with dark spots at the under surface, E: leafy rosette with flowers, F: rounded leaf shape, G: mucronate tip, H: inflorescences, I: single bract-like structure on peduncle before dichotomous branch, J: dichotomous branch with prominent bract, K: mature bud with prominent bracteoles, L: four-sided cross-section of mature bud, M: flower with hairy petals, N: elongated style, and O: stamens.

Discussion

The characters of *Rhizophora* species are very similar so that they can be easily confused when direct distinctions are made through measurements of phenotypic detail if the definitive characters are not present (Lo, 2003). The key distinguishing characters of *Rhizophora* spp. in ANI is given in Table 1. The identification of *R. apiculata* is not problematic because of the fundamental differences observed in many characters throughout its range, including lower position of inflorescences, apiculate leaves having mucronate tips, two flowered inflorescences with short peduncle, small style and swollen corky brown bract below the calyx. However, discontinuous pattern was reported on the dark spots in the underside of leaves. Dark spots are present in *R. apiculata* from India to Southeast Asia and northern Papuaia. However, in southern Papuaia and northern Australia, the spots are absent in *R. apiculata* (Duke *et al.*, 2002). Other notable difference reported earlier was differences in number of calyx lobes. Commonly calyx lobes are four in *R. apiculata* but in Australia the number of calyx lobes varied between 3–6. Generally, *Rhizophora* hybrids are recognized by intermediate morphology and absence of advanced reproductive stages. Both *R. x lamarckii* and *R. x annamalayana* are distinguished from *R. apiculata* by their smooth green bract, 2–4 flowered inflorescences within the leaf axis. *R. x annamalayana* is distinguished from *R. x lamarckii* by its dark green broad

leaves, ratio of length to width < 1.8, small style < 1.5 mm and occurrence of stamens in distinct whorls, while in *R. x lamarckii*, leaves are narrowly elliptic, ratio of length to width > 1.8, style > 1.5 mm, and 8–14 stamens in a single whorl. However, the occurrence of stamens in two distinct whorls is observed in *R. x lamarckii* too, but the frequency is lower than in *R. x annamalayana*.

Among the *Rhizophora* spp., taxonomical distinction between *R. mucronata* and *R. stylosa* is often problematic and style is the key feature to differentiate these taxa. It has long been unclear whether the two are sibling species or just variants of one species (Duke *et al.*, 2002). The occurrence of undefined intermediate individuals between *R. mucronata* and *R. stylosa* causes the uncertainty to distinguish them. The question is whether the intermediates are mixed genotypes between variants of one species or they are hybrids between genetically distinct sibling species. Duke *et al.* (2002) noted that if *R. stylosa* and *R. mucronata* are different species, intermediate hybrids might be present as in other *Rhizophora* spp. Recent observation of a possible hybrid between *R. mucronata* and *R. stylosa* through molecular evidence by Ng *et al.* (2013) and Ng & Szmidt (2015) shows that undefined intermediate individuals might be products of hybridization and is not restricted the F₁ stage. So it is pertinent to mention here that *R. stylosa* and *R. mucronata* are distinct species with close affinities. Moreover, Lo *et al.* (2010) also mentioned that *R. stylosa* and *R. mucronata* are well discriminated based on ISSR data and are likely to have diverged recently. A study carried out by Ragavan *et al.* (2011) in Havelock Island based on style length indicates that in *R. mucronata* style is sessile and ovary is raised similar to *R. apiculata* whereas in *R. stylosa* style is long and ovary is obscure. Apart from style length, *R. stylosa* is distinguished from *R. mucronata* by its prominent two lobed bract and bracteoles, small bud size, obovate leaves, small fruits and short propagules.

Generally, individuals that are morphologically intermediates might have arisen by hybridization. The hybrid *R. x mohanii* resembles *R. mucronata* by its broad leaves, and resembles *R. stylosa* by its long style (0.5 cm) and differs from *R. stylosa* and *R. mucronata* by its ovate leaves with rounded leaf apex, leathery texture, conspicuous bract and bracteoles with one or two lobes, large dimension of mature buds (1.7 x 0.7 cm) and lack of propagules. The complete absence of advance reproductive parts, intermediate floral morphology and aberration in stamen morphology support the idea that this taxon would be F₁ hybrid between *R. mucronata* and *R. stylosa*. A key for the species of the genus *Rhizophora* in Andaman and Nicobar Islands is given below to facilitate identification.

Molecular evidence provided by Ng & Szmidt (2015) assured the existence of hybrids between *R. mucronata* and *R. stylosa*. Hybridization between closely related or rapidly radiating species is most likely to produce viable offspring (Chapman & Burke, 2007). Thus hybrids between *R. mucronata* and *R. stylosa* are likely to be fertile. Ng & Szmidt (2015) also mentioned that hybrids between *R. mucronata* and *R. stylosa* are may be fertile and further noted the occurrence of advanced hybridization and introgression with two parent species based on structure and new hybrid analysis. If hybridization occurs between two species, F₁ individuals are likely to be sterile or partially fertile due to improper chromosome pairing. These initial hybrids frequently undergo spontaneous chromosome doubling (allopolyploidy), which stabilizes the genome, or, if partially fertile, may backcross to one of the parental species (introgression). Thus the sterility of *R. x mohanii* supports its F₁ stage of hybridization between *R. stylosa* and *R. mucronata*. Ng & Szmidt (2015) did not collect taxonomical information of the specimens as without taxonomical identity, the results are not translated in the field for conservation and management of this sensitive ecosystem. Thus, the present observation of hybrid intermediate between *R. stylosa* and *R. mucronata* (*R. x mohanii*) may provide better understanding of hybridization and speciation in *Rhizophora* species.

Key to *Rhizophora* of Andaman & Nicobar Islands

1. Peduncle shorter than petiole 2
1. Peduncle as long as petiole or greater than petiole 4
2. Mature flower bud and fruits below the leaves in leaf shoot, two flowers per inflorescences, bract corky brown, hypocotyl present..... ***R. apiculata***
2. Mature flower buds within the leaves in leaf shoot, 2–4 flowers per inflorescence, bract smooth green, hypocotyls absent 3
3. Leaves broadly elliptic, style 0.08–0.12 cm, stamens occur in two distinct whorls, inner smaller, mature bud four sided in cross section, outer long stamens ***R. x annamalayana***
3. Leaves narrowly elliptic, style 0.2–0.3 cm long, stamens 8–12 occur in single whorl, mature bud rounded in cross section ***R. x lamarckii***
4. Mature bud < 1.5 cm long, hypocotyls present 5
4. Mature bud > 1.5 cm long, hypocotyls absent, bract and bracteoles prominent, single or two lobed, leaves oblong ovate, leathery, apex rounded, style 0.3–0.4 cm ***R. x mohanii***
5. Bract and bracteoles minute, style 0.1 cm, seated on raised ovary, hypocotyls 50–80 cm ***R. mucronata***
5. Bract and bracteoles prominent, form two lobed cup-like structures, style 0.3–0.4 cm, ovary not distinct, hypocotyls 20–40 cm long ***R. stylosa***

Table 1 Diagnostic morphological attributes of *Rhizophora* species and hybrids in the Andaman and Nicobar Islands, India

| Component | Attribute | <i>R. apiculata</i> | <i>R. mucronata</i> | <i>R. stylosa</i> |
|----------------|--------------------|---|--------------------------|---|
| Leaves | Leaf shape | apiculate | ovate broader at base | narrowly obovate, broader at apex |
| | Leaf apex | acute | acute | obtuse |
| | Leaf base | cuneate | Broadly acute to rounded | cuneate |
| | Leaf tip | mucronate | mucronate | mucronate |
| Inflorescences | Leaf shoot | matures below | matures within | matures within |
| | No of flowers | 2 | 2–8 | 2–8 |
| | Branching number | 2 | 2 | 2 |
| | Juncture number | 1 | 1–3 | 1–3 |
| | Bract condition | corky | smooth, obscure | smooth, conspicuous |
| Mature buds | Bud length | 1–1.6 | 1.2–1.6 | 0.7–1.2 |
| | Bud width | 0.9–1.0 | 0.8–1.0 | 0.3–0.6 |
| | Bud x-section | rounded | rounded | rounded |
| | Length/width ratio | 1.20 | 1.81 | 2.39 |
| | Petal x-section | flat | encloses stamens | encloses stamens |
| | Petal margin | glabrous | hairy | hairy |
| | Style length | 0.08–0.12 mm | 0.09–0.12 mm | 0.3–0.4 mm |
| | Stamen number | 9–14 | 8 | 8 |
| Fruits | Expended fruit | cork-like, length almost equal to width | pear-like | pear-like, length almost equal to width |
| Hypocotyls | Hypocotyl length | 20–40 cm | 50–80 cm | 21–35 cm |
| | Hypocotyl colour | green | green | green |
| | Hypocotyl tip | bluntly pointed | narrowly pointed | narrowly pointed |

| Component | Attribute | <i>R. x annamalayana</i> | <i>R. x lamarckii</i> | <i>R. x mohanii</i> |
|----------------|--------------------|--------------------------|-----------------------|----------------------------------|
| Leaves | Leaf shape | broadly elliptic | narrowly elliptic | oblong rounded, laterally folded |
| | Leaf apex | acute | acute | rounded |
| | Leaf base | cuneate | attenuate to cuneate | rounded |
| | Leaf tip | mucronate | mucronate | mucronate |
| Inflorescences | Leaf shoot | matures within | matures within | matures within |
| | No of flowers | 2–4 | 2–4 | 2–8 |
| | Branching number | 2 | 2 | 2 |
| | Juncture number | 1–2 | 1–2 | 1–2 |
| | Bract condition | swollen smooth | swollen smooth | smooth, conspicuous |
| Mature buds | Bud length | 1.4–1.6 | 1.5–1.7 | 1.5–1.8 |
| | Bud width | 0.8–1.1 | 0.7–0.8 | 0.6–0.9 |
| | Bud x-section | four-sided | slightly four-sided | slightly four-sided |
| | Length/width ratio | 1.68 | 2.06 | 2.21 |
| | Petal x-section | curved | curved | encloses stamens |
| | Petal margin | slightly hairy | slightly hairy | hairy |
| | Style length | 0.08–0.12 mm | 0.2–0.4 mm | 0.4–0.5 mm |
| | Stamen number | up to 16, in 2 whorls | 8–16, in 2 whorls | 8 |
| Fruits | Expended fruit | | | |
| Hypocotyls | Hypocotyl length | | | |
| | Hypocotyl colour | | | |
| | Hypocotyl tip | | | |

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