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Cover: A digital art of water birds of Noyyal River and its wetlands in Coimbatore District by Megha A. Kashyap.

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SHORT COMMUNICATION

Taxonomic significance of seeds and seedling morphology in the threatened Indian endemic palm genus *Bentinckia* (Arecaceae)

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Abstract: A comparative morphological study was carried out to evaluate the taxonomic significance of seed and seedling traits of *Bentinckia condapanna* and *B. nicobarica* (Arecaceae), the threatened endemic palm species. Both species are unique and have specific requirements for seedling recruitment. An effort was made to cultivate these species ex situ at the Botanical Survey of India's National Orchidarium and Experimental Garden (NOEG) in Yercaud, Tamil Nadu, and Dhanikhari Experimental Garden cum Arboretum (DEGCA), in Andaman & Nicobar Islands. The seeds and seedlings of the two species differ in the beak and ridges on the seed, endosperm colour and the shape of the eophyll.

Keywords: Disjunct distribution, fruit, hotspots, IUCN, Sahyadri, seed germination, taxonomic importance.

Bentinckia Berry ex Roxb. (Arecaceae) consists of two species, *B. condapanna* Berry ex Roxb. and *B. nicobarica* (Kurz) Becc., occurring in southern India and the Nicobar Islands. These tall palms are characterized by their stems ringed with conspicuous leaf scars, leaf sheath forming a distinct green cylindrical crown shaft, and inflorescence appearing from below the crown shaft. This genus is a prime example of disjunct distribution, with only two known species occupying different niches and ecosystems and separated by seawater. Both species were studied by the first author in their natural habitat, viz., *B. condapanna* at Chemunji hills in Agasthyamalai Biosphere Reserve, southern Western Ghats (Image 1A) and *B. nicobarica* at Trinket Island, Central Nicobar, Nicobar group of Islands (Image 1B).

Bentinckia condapanna trees are 6–12 m tall, with stems measuring 15–20 cm in diameter. The leaves are 1–1.5 m long, arching to spreading, becoming pendulous, forming a conspicuous crown shaft. The inflorescence is borne below the leaves, completely covered with two bracts, flowering branches pale red, male flowers scarlet, female flowers lilac (Image 1C). The fruits are globose to ovoid, deep scarlet red. The seeds are conspicuously grooved adaxially and laterally (Renuka & Sreekumar 2012; Sarkar 2012). The flowering is from April to June, and the fruiting period is June to September. This species is a narrow endemic and restricted in the tail end of southern Western Ghats, in Agasthyamalai Hills, Palni Hills, at around 760–1,830 m elevation (Sarkar 2012). This palm occupies the second-highest elevation niche among all palms in India (Kulkarni & Mulani 2004). It has

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been assigned with the IUCN Red List status 'Vulnerable' (Johnson 1998a). *B. condapanna* prefers and colonizes steep rocky slopes fully exposed to sunlight in the tropical wet evergreen forests of the Western Ghats. Major threats, such as habitat destruction by the gradual encroachment of *Ochlandra* reed brakes and vagrancy of dry months (Sarkar 2012), felling for terminal tender shoots by humans and elephants, and clearing forest areas for tea plantations, are the main reasons for its restricted distribution (Kulkarni & Mulani 2004). The other factors threatening the populations include the following: the inflorescences are harvested and used in religious ceremonies; the terminal buds and juvenile leaves are eaten by Kani tribes (Sarkar 2012); the fruits used for the treatment of asthma; the fruits are eaten by the Lion-tailed Macaques and elephants (Quattrocchi 2017), frugivorous birds such as Malabar Grey Hornbill, White-cheeked Barbet, Malabar Barbet, and Grey-fronted Green Pigeon, and mammals such as bats and Bonnet Macaques were observed feeding on the fruits of this palm (Murukesh & Ashokan 2018); and the shoot apices are relished by elephants (Kulkarni & Mulani 2004). Natural seed germination and survival percentage is about 10–20% (Gangaprasad & Matthew 2017), and it has been observed that this palm does not thrive well outside its natural habitat (Renuka et al. 1996). A need for ex situ conservation and the promotion of its cultivation as an ornamental has previously been suggested (Kulkarni & Mulani 2004; Sarkar 2012).

Bentinckia nicobarica trees are much taller, growing up to 20 m, and their stems are significantly thicker, reaching up to 40 cm in diameter. The leaves are ascending or arching, about 2.5 m long, with a crown shaft of about 1 m long. The inflorescences are borne from below the leaves, and the flowering branches are greenish-yellow to ivory (Image 1D). The fruits are subglobose to ellipsoid and deep brown. The seeds are not as conspicuously grooved as in *B. condapanna* (Renuka & Sreekumar 2012). This species is endemic and restricted to Andaman & Nicobar Islands at 10–150 m altitude. It has been assessed as 'Endangered' under the IUCN Red List Criteria & Category (Johnson 1998b). The grasslands of the Nancowry Islands are its natural habitat, and they are found growing abundantly in the tropical evergreen forest patches along the fringes of savannah-like grass-heath. The main threats for this species are habitat alteration, including wildfire and illegal felling. This species is sensitive to insulating shade, and altering the shaded, humid habitats could lead to its extinction. The local inhabitants widely use this palm to construct huts and fences (Sreekumar & Coomar 1999). It is a fast-growing tree in cultivation and sets fruits in abundance, but the fresh seeds take 55–60 days to germinate, and their natural germination under the mother tree is rare (Basu 1984). Similarly, the natural regeneration of *B. condapanna* seeds under the mother tree has been reported to be low (Renuka et al. 1996). Due to its habitat specificity and several other threats faced by its populations, immediate conservation measures are required for *B. nicobarica* (Sreekumar & Coomar 1999).

Rationale and Methods

Since almost all palms are propagated by seeds, the subject of germination is pivotal, and the present study attempts a survey of germination and seedlings in the genus *Bentinckia* in India and the possibility of their taxonomic significance. In general, there are three types of germination in palms: adjacent ligular, remote ligular, and remote tubular (Henderson 2006). In *B. condapanna*, the type of germination is unknown. In the previous experiments, the seeds either did not germinate or the germination percentage was low. Moreover, the seedlings of *B. condapanna,* a high-altitude plant, do not establish well in low altitudes (Renuka et al. 1996). Basu (1984) noted that *B. nicobarica* is cross-pollinated and fruit setting is abundant; the first sheath of the seedling is achlorophyllous, the second sheath is tubular and truncate at the rim, and the third sheath is slightly greenish and obliquely truncate; the eophyll is bifid, each lobe ca 20 × 5 cm, acuminate and toothed. The morphological characterization of seeds and seedling germination was attempted to find characters of taxonomic relevance.

Fruits of *B. condapanna* were collected from plants growing in the National Orchidarium and Experimental Garden (NOEG), Botanical Survey of India (BSI), Yercaud, Tamil Nadu and those of *B. nicobarica* from the plants growing in the BSI, Andaman Nicobar Regional Centre, Port Blair. The freshly fallen fruits were used to study the morphological characteristics of fruits and seeds. After the study, the seeds were cleaned by removing the fleshy fibrous pericarp and washed in running tap water in the laboratory. The seeds were germinated using sand and soil mix (2:1) as germination medium. Seedlings of both species were studied at different stages of development. The quantitative and qualitative morphological features of the collected and germinated seeds were studied by direct observation using a hand lens. Measurements were taken using graph papers and scale. Images were processed in Adobe Photoshop.

Image 1. A & C—*Bentinckia condapanna* | B & D—*B. nicobarica* | A & B—habit | C & D—inflorescence, crown shaft. © M.Y. Kamble

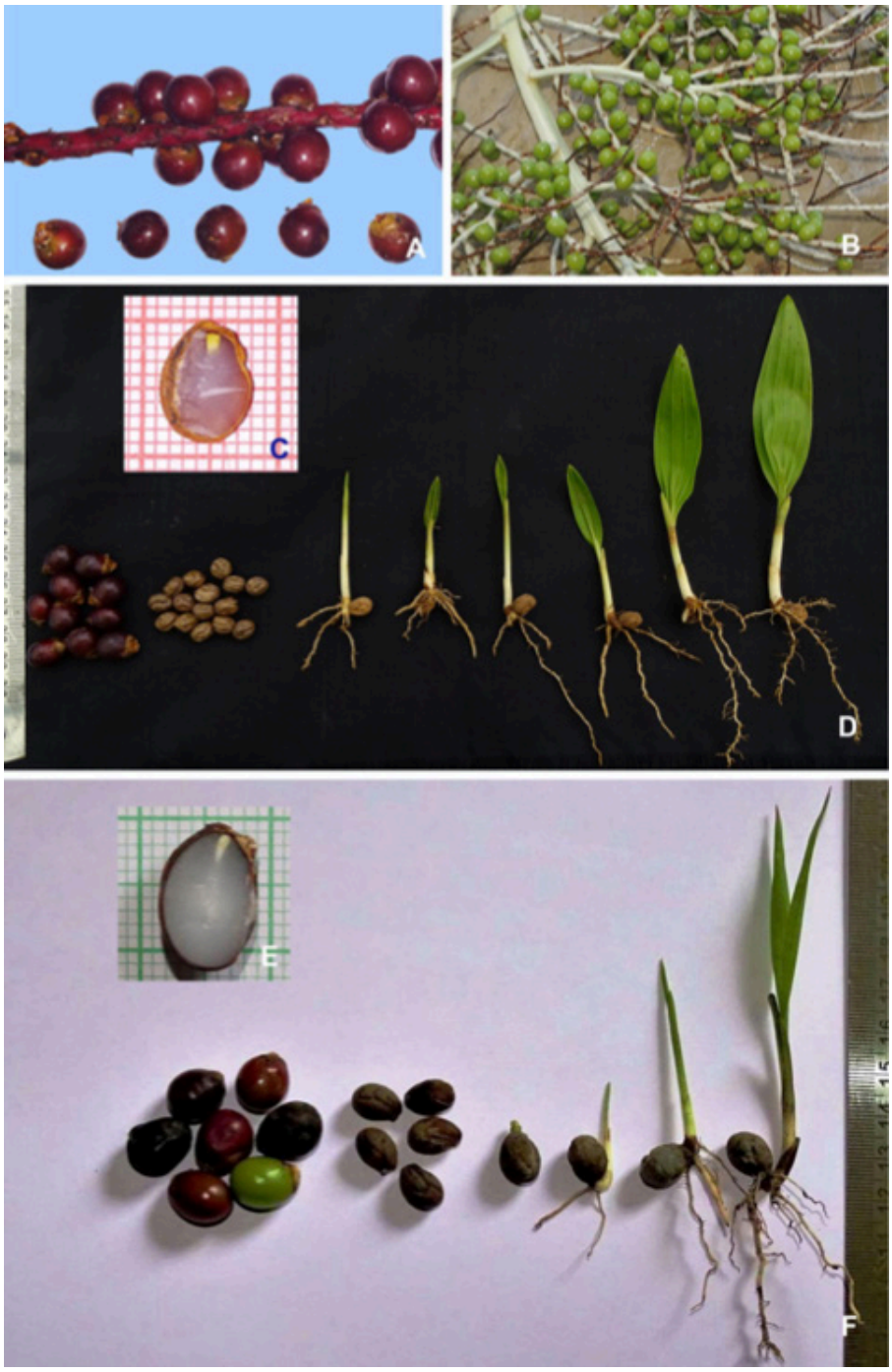

Image 2. C & D—*Bentinckia condapanna* | B,E & F—*B. nicobarica* | A&B—young fruits | C & E—V.S. of seeds showing embryo and endosperm | D & F—mature fruits, seeds & seedlings. © (A–D)—M.Y. Kamble, (E–F)—C.P. Vivek.

Results and Discussion

The genus *Bentinckia* is endemic to India and holds considerable taxonomical and phytogeographical importance. The genus is represented by only two species, and both are strict endemics to their respective habitats, viz., *B. condapanna* to the Western Ghats and *B. nicobarica* to the Andaman & Nicobar Islands. These two species are geographically disjunct, with a gap of more than 1,500 km between them. They also have different habitat specificities: *B. condapanna* prefers steep rocky cliffs at an altitude of above 700 m, while *B. nicobarica* prefers savannah-like grasslands at a maximum altitude of 150 m. There are remarkable differences in their growth patterns in natural habitats

Table 1. Common traits in fruits, seeds, and seedlings of both species of *Bentinckia*.

Character	*B. condapanna*	*B. nicobarica*
Crown shaft	Cinereous tinged with light maroon	Pale green
Inflorescence colour	Maroon	Ivory
Fruit colour when young	Maroon	Green
Fruit colour at maturity	Dark maroon	Maroon or greenish-brown to dark brown
Shape of mature fruit	Globose	Ovoid
Seed colour	Pale brown	Dark brown
Ridges on the seed surface	Distinct	Not prominent
Fruit Length	1.2–1.6 cm	1.4–1.6 cm
Fruit Breadth	1.1–1.4 cm	1.1–1.3 cm
Seed length	7–9 mm	7–12 mm
Seed breadth	6–7 mm	5–7 mm
Seed germination type	Adjacent ligular	Adjacent ligular
Seed beak	Away from embryo	Near embryo
Endosperm	Purplish-white	Greyish-white
Embryo	1–1.2 mm, dark yellow	About 2 mm, ivory
Eophyll (first leaf)	Simple	Bifid

as well as ex situ conservation. According to the IUCN Red List Category and Criteria, both species are assessed as 'Threatened.' The decline in their natural populations can be attributed to both human-imposed as well as natural factors. Thus, the present paper recommends in-situ conservation of their natural populations. The propagation of both species occurs through seeds, highlighting the importance of seed germination and seedling survival in conservation efforts.

The present study observed the differences between *B. condapanna* and *B. nicobarica,* which share similar vegetative characteristics. Both species are distinguished by their reproductive characteristics (Table 1). The distinguishing features include the fruit colour, which is maroon vs. green when young (Image 2A,B) and dark maroon to scarlet red vs. greenish-brown or dark brown to maroon when ripe (Image 2D,F), the shape of the fruit (globose vs. ovoid), seed colour (pale brown vs. dark brown), and ridges on seed surface (well developed vs. indistinct). The fruit and seed sizes between the two species are quite similar. Also, both species exhibit 'adjacent ligular' type germination. This is the first report for *B. condapanna.* The notable difference was observed in the position of the seed beak (Image 2C,E), which was away from the embryo in *B. condapanna* and nearer to the embryo in *B. nicobarica.* The endosperm is purplish-white in *B. condapanna* and greyish-white in *B. nicobarica* (Image 2C,E). In this study, the eophylls (Image 2D,F) were observed to be simple in *B. condapanna,* whereas they are bifid in *B. nicobarica* (Basu 1984). Therefore, apart from the fruit colour, seed ridges and endosperm colour, the eophyll shape in seedlings can also be used to differentiate the two species. Ex-situ conservation of both species has been effectively carried out in the National Orchidarium and Experimental Garden (NOEG), Botanical Survey of India (BSI), Yercaud, Tamil Nadu and in the Experimental Garden cum Arboretum of BSI, Andaman Nicobar Regional Centre, Port Blair.

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