RHEEDEA
Journal of the Indian Association for Angiosperm Taxonomy

RESEARCH ARTICLE

Vol. 34(2): 118–123 (2024)
ISSN: 0971-2313 (Print edition)
ISSN: 2582-2438 (Online edition)
https://dx.doi.org/10.22244/rheedea.2024.34.02.03

Significance of carpology in the taxonomy of the family Myristicaceae from the Western Ghats, India

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Abstract: The fruit, aril, and seed morphology of all the Myristicaceae members of the Western Ghats were systematically examined and discussed. The morphological analyses unveiled distinctive carpological features among both endemic and exotic species. Consequently, fruit characteristics play a significant role in the delineation, identification, and classification of taxa within the Western Ghats. A key developed based on aril characteristics will adequately facilitate the identification of Myristicaceae species in the Western Ghats.

Keywords: Aril, Fruit, India, Morphology, Western Ghats.

Introduction

Myristicaceae Brown the pantropical nutmeg family, comprises 21 genera and 520 species (Christenhusz & Byng, 2016). In the Western Ghats, the family thrives in dense evergreen forests, represented by eight species under three genera. *Gymnacranthera* (A.DC.) Warb. is represented by only one species *G. canarica* (Bedd. ex King) Warb., *Knema* Lour. by two species *K. attenuata* (Wall. ex Hook.f. & Thomson) Warb. and *K. flavostamina* M.G.Govind & Dan, whereas *Myristica* Gronov. by five species *viz. M. beddomei, M. magnifica, M. malabarica, M. pushpangadaniana* and *M. trobogarii* (Nayar *et al.*, 2014; Banik *et al.*, 2017; Govind *et al.*, 2020; Govind & Dan, 2020, 2022). Three more species were introduced and grown in the Western Ghats region: *Endocomia macrocoma* and *M. andamanica* from the Andaman Islands, and *M. fragrans*, the famous spice 'nutmeg' – from the Mollucas Islands.

The carpological features of Myristicaceae species growing in the Western Ghats have not yet been studied comprehensively, and the detailed data on the morphology of the fruit, aril and seed of these trees are insufficient. Therefore, the main objective of this study was to examine and describe the significant carpological features of Myristicaceae members in the Western Ghats and to reveal those characteristics important for the taxonomic delimitation of the species. The morphology of fruit, aril and seed of all eleven species growing in the Western Ghats, including eight endemics, are investigated and discussed.

Material and Methods

Extensive exploration trips and other reported localities were conducted to the type locality. Fresh mature fruits were collected, and detailed taxonomic data were generated through the investigation of type specimens, illustrations, and relevant literature (King, 1891; Sinclair, 1961; Wilde, 1997; Banik *et al.*, 2017) along with the comparison with the authentic specimens in various Indian Herbaria. Out of the eleven species studied, eight species were from natural populations, two conserved at the JNTBGRI campus and one (*Myristica fragrans*) from the plantations.

Received: 16.08.2023; *Revised & Accepted*: 04.02.2024
Published Online: 30.06.2024

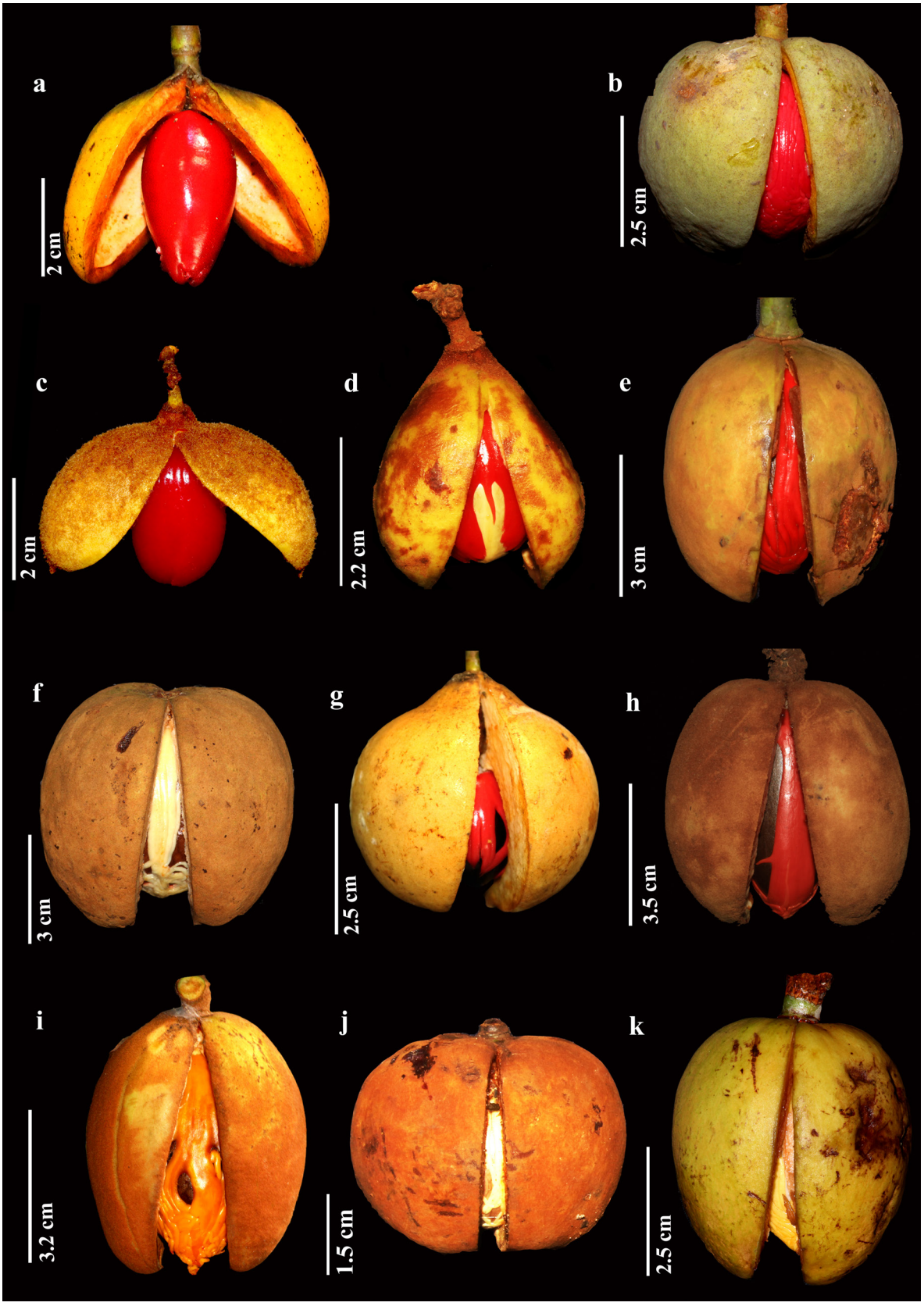

Fig. 1. Fruits. **a**. *Endocomia macrocoma* W.J.de Wilde; **b**. *Gymnacranthera canarica* (Bedd. ex King) Warb.; **c**. *Knema attenuata* (Wall. ex Hook.f. & Thomson) Warb.; **d**. *Knema flavostamina* M.G.Govind & Dan; **e**. *Myristica andamanica* Hook.f.; **f**. *M. beddomei* King; **g**. *M. fragrans* Houtt.; **h**. *M. magnifica* Bedd.; **i**. *M. malabarica* Lam.; **j**. *M. pushpangadaniana* M.G.Govind & Dan ex Kottaim.; **k**. *M. trobogarii* M.G.Govind & Dan.

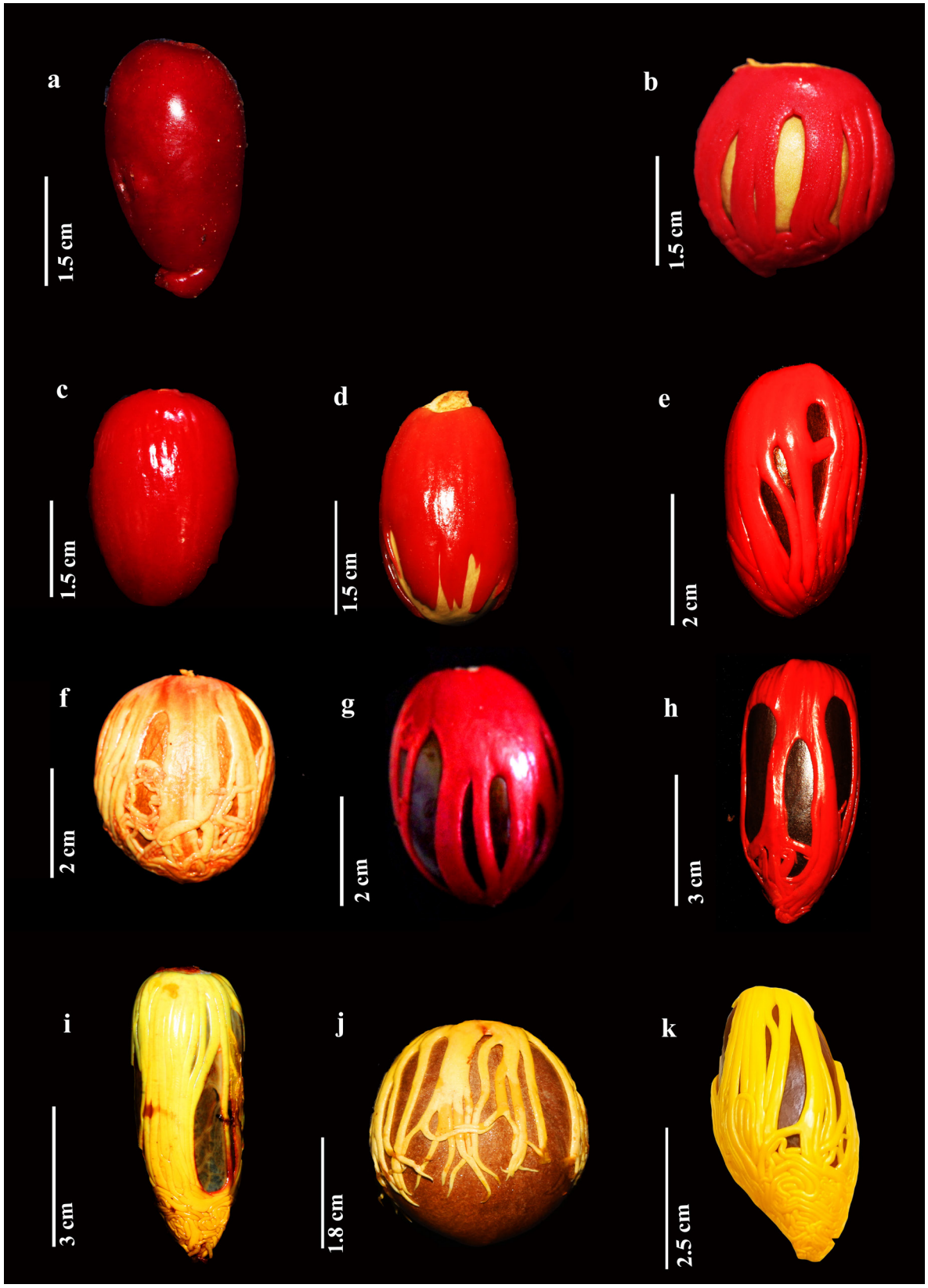

Fig. 2. Seeds with aril. **a**. *Endocomia macrocoma* W.J.de Wilde; **b**. *Gymnacranthera canarica* (Bedd. ex King) Warb.; **c**. *Knema attenuata* (Wall. ex Hook.f. & Thomson) Warb.; **d**. *Knema flavostamina* M.G.Govind & Dan; **e**. *Myristica andamanica* Hook.f.; **f**. *M. beddomei* King; **g**. *M. fragrans* Houtt.; **h**. *M. magnifica* Bedd.; **i**. *M. malabarica* Lam.; **j**. *M. pushpangadaniana* M.G.Govind & Dan ex Kottaim.; **k**. *M. trobogarii* M.G.Govind & Dan.

The Fruit, aril, and seed of each taxon were collected from the established trees for morphological characterization. Based on the flowering and fruiting season of each species, flowers were collected at the peak flowering period, and fruits were collected at the maturity stage when it dehisces to expose arils and seeds. Taxonomic investigation and confirming the identity of specimens with flowers/ fruits were carried out using various Floras and protologues. Photographs were taken and documented using a Canon 700D DSLR camera. The macro characters were examined using a hand lens and micro morphological characters were observed using Olympus Stereo Microscope SZ2-ILST equipped with a camera. An artificial key was prepared using the morphological features of arils.

Results

1. **Endocomia macrocom*a*** W.J.de Wilde **Figs. 1a & 2a**

Fruits dehiscent, usually in 4–5 groups, rarely solitary, 3–5 × 2–3 cm, ovoid, apex acute, base rounded, longitudinal suture on both sides, glabrous; pericarp fleshy, soft, 1–1.5 cm thick, yellow; seed 2.5–4 × 2–3.5 cm, oblong, black; aril bright red, entire.

2. **Gymnacranthera canarica** (Bedd. ex King) Warb. **Figs. 1b & 2b**

Fruits usually solitary, rarely in pairs, 4.5–5 × 3.5–5 cm, globose, green with white exudate, apex and base round, dehiscent, longitudinal suture on both sides, glabrous; pericarp fleshy scented, soft, 0.3 mm thick, green; seeds 4–5 × 3–4 cm, globose, black; aril bright red lacerated.

3. **Knema attenuata** (Wall. ex Hook.f. & Thomson) Warb. **Figs. 1c & 2c**

Fruits usually solitary, rarely in pairs, dehiscent, 3–5 × 2–4 cm, ovoid to ovate, brown, apex obtuse, base round, longitudinal suture on both sides, scurfy pubescent; fruit wall fleshy, soft, 0.7–1.5 cm thick, brown; seeds 2.5–5 cm, oblong, black; aril red, completely covering seeds.

4. **Knema flavostamina** M.G. Govind & Dan **Figs. 1d & 2d**

Fruits dehiscent, usually solitary, rarely in pairs, 3.0–4.0 × 1.5–2.5 cm, oblong, brown, apex acute, base slightly oblique, longitudinal suture prominent on one side, pubescent; pericarp 6.0–8.0 mm thick, brown outside, seeds 1.5–2.5 × 1.2–1.8 cm, oblong, black; aril bright red, almost covering the seed with an irregular, partially open at apex.

5. **Myristica andamanica** Hook.f **Figs. 1e & 2e**

Fruits dehiscent, usually in pairs, rarely solitary, 5–7 × 4.5–6 cm, ovoid, apex round, base cordate, longitudinal suture on both sides, floccose; pericarp fleshy, soft, 2–2.4 cm thick, orange-brown; seeds 4.5–6 × 3–4 cm, oblong, black; aril bright red, lacerated.

6. **Myristica beddomei** King **Figs. 1f & 2f**

Fruits usually solitary, rarely in pairs, dehiscent, 4–6 × 3.5–4 cm, ovoid to subglobose brown, apex obtuse, base round, longitudinal suture on both sides, scurfy pubescent; fruit wall fleshy, soft, 7–10 mm thick, brown; seeds 3–4.5 × 2.5–4 cm, oblong, black, arillate; aril yellow, turns to orange-red, lacerated.

7. **Myristica fragrans** Houtt. **Figs. 1g & 2g**

Fruits usually solitary, rarely in pairs, dehiscent, 4.5–6 × 4–5.5 cm, subglobose to ovoid, yellow, apex and base round, longitudinal suture on both sides, glabrous; fruit wall fleshy, soft, 1–1.5 cm thick, yellow; seeds 2.5–3 × 2–3 cm, subglobose to ellipsoid, black, arillate; aril bright red, lacerated.

8. **Myristica magnifica** Bedd. **Figs. 1h & 2h**

Fruits usually solitary, rarely in pairs, dehiscent, 4.5–6 × 3.5–5 cm, ovoid, brown, apex obtuse, base round, longitudinal suture on both sides, scurfy pubescent; fruit wall fleshy, soft, 0.7–1.5 cm thick, brown; seeds 4–6 × 3–3.5 cm, oblong, black; aril orange-red, lacerated.

9. **Myristica malabarica** Lam. **Figs. 1i & 2i**

Fruits usually solitary, rarely in pairs, dehiscent, 4.5–7 × 3.5–6 cm, ovoid, brown, apex obtuse, base

round, longitudinal suture on both sides, densely pubescent; pericarp fleshy, soft, 1.5 cm thick, brown; seed 4–6 × 3–3.5 cm, oblong, black; aril orange-red, lacerated.

10. **Myristica pushpangadaniana** M.G.Govind & Dan ex Kottaim. **Figs. 1j & 2j**

Fruits usually solitary, rarely in pairs, dehiscent, 2.5–4.0 × 3.5–5.0 cm, subglobose to globose, brown, apex obtuse, base round, longitudinal suture on both sides, scurfy pubescent; pericarp 7–10 mm thick, brown; seeds 2.0–3.6 × 2.5–4.0 cm, oblong, black; aril partially covering the seed, yellow, turning orange-red, lacerated.

11. **Myristica trobogarii** M.G.Govind & Dan **Figs. 1k & 2k**

Fruits usually in pairs, rarely solitary, dehiscent, 6–8 × 4.5–6 cm, ovoid, pale yellow turning orange-yellow on maturity, apex mucronate, base cordate, longitudinal suture on one side, glabrous; pericarp fleshy, soft, 2–2.4 cm thick, orange-yellow; seeds 4–5 × 3–3.5 cm, oblong, black; aril yellow, lacerated.

Discussion

The features of *Myristica* fruits are specific and distinct, with a crucial role in identifying species. The fruits of all the species were drupe which dehiscent on maturity. The fruits were either solitary or in pairs except in *E. macrocoma*, in which they form the infrutescences of 4–5. The dimension of the fruit's ranges from 4–9 cm in length and 2–6 cm in diameter. The smallest fruits were that of *K. attenuata* (3–5 × 2–4 cm), and the largest was of *M. magnifica* (7–8 × 5–6 cm). The fruits of *K. attenuata, K. flavostamina, M. beddomei, M. malabarica, M. magnifica* and *M. pushpangadaniana* were brown in colour. *M. fragrans* and *E. macrocoma* possess yellow fruits, *M. andamanica* has orange-brown fruits, while the fruits of *G. canarica* are green. The recently described species *M. trobogarii* had yellowish green fruits turning orange-yellow on maturity (Fig. 1k). The fruits of *G. canarica* and *M. pushpangadaniana* were globose, while all others were ovoid in shape. The base of fruits was cordate–subcordate in *G. canarica, M. beddomei, M. magnifica, M. malabarica, M. pushpangadaniana* and *M. trobogarii* while in *K. attenuata,* and *M. fragrans* the base was round (Fig. 1). The longitudinal suture was visible both on the dorsal and ventral sides of the fruits in *G. canarica, K. attenuata, M. fragrans* and *M. pushpangadaniana* (Fig. 1). But for all the other species, it was prominent only on one side. Another demarcating feature was the texture of the fruits. *M. malabarica, K. attenuata* and *K. flavostamina* had densely tomentose fruit wall, while *M. andamanica, M. magnifica, M. beddomei* and *M. pushpangadaniana* were with scurfy pubescent pericarp. Glabrous pericarpwall was observed in *E. macrocoma, G. canarica, M. trobogarii* and *M. fragrans* (Fig. 1). The pericarps of all species were fleshy, soft, 2–20 mm thick. The *Myristica* fruits possess thicker pericarp of 1.5–2 cm.

The most important and attractive part of fruits is aril which has an inevitable role in the identification of species. Based on the observations on the arils of different species included in the present study, an artificial key was prepared and presented here, which clearly demarcated the 11 taxa investigated. The aril of *M. fragrans* is the source of world-famous spice 'Mace'. In the taxa investigated, *M. beddomei, M. malabarica, M. trobogarii* and *M. pushpangadaniana* had yellow arils while all other species had red arils (Fig. 2). Very exceptionally in a cultivar of *M. fragrans* yellow aril was observed. The arils were lacerated in all the species of *Myristica* and *Gymnacranthera* but were entire in *Knema* and *Endocomia.* In all the species of Myristicaceae, the arils were extended up to the tip of the seeds except in *M. pushpangadaniana* which had the shortest (2–2.5 cm) and thinnest aril (0.8 mm) that covers only up to half of the seed (Fig. 2). The longest aril was observed in *M. malabarica* (up to 10 cm) and the thickest aril was that of *M. magnifica* (1.5 mm).

The seeds of all Myristicaceae members studied were oblong, having a dimension of 3–7 × 2–4 cm,

except for that of *M. pushpangadaniana* (2.0–3.6 × 2.5–4 cm) and *G. canarica* (4–5 × 3–4 cm) with almost globose seeds. The testa of mature seeds of *Myristica* and *Knema* members were black while striated brown in *Endocomia.* But in *G. canarica,* seeds were brownish green.

Conclusion

The present study reports the taxonomical significance of the carpological features of Myristicaceae members in the Western Ghats (both endemic and introduced). The detailed carpological studies of the fresh specimens collected from the type and other reported localities resulted in constructing an artificial key solely based on the characters of aril, which will be sufficient for species delimitation.

Taxonomic key based on the characters of arils

1. Arils entire 2

1. Aril lacerated 4

2. With a beak-like mass at the tip of aril .....*E. macrocoma*

2. Without a beak-like mass at the tip of aril..... 3

3. Arils fully covering seed ..... *K. attenuata*

3. Arils partially covering seed..... *K. flavostamina*

4. Aril length < 3.5 cm 5

4. Aril length > 3.5 cm 6

5. Aril red and extends up to the tip of seed ....*G. canarica*

5. Aril yellow and not extending up to the tip of seed..... *M. pushpangadaniana*

6. Aril yellow 7

6. Aril red 9

7. Aril tip not exceeding seed ..... *M. beddomei*

7. Aril tip exceeding seed 8

8. Aril length > 5 cm ..... *M. malabarica*

8. Aril length < 5 cm ..... *M. trobogarii*

9. Aril spicy .....*M. fragrans*

9. Aril not spicy 10

10. Aril tip exceeding seed ..... *M. magnifica*

10. Aril tip up to seed .....*M. andamanica*

Acknowledgments

The authors are thankful to the Director, JNTBGRI for providing facilities and the Department of Forests and Wildlife, Government of Kerala, Tamil Nadu and Karnataka for forest entry permission. The first author is thankful to the University of Kerala, Thiruvananthapuram for Junior Research Fellowship.

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