NBUJPS
NBU Journal of Plant Sciences

ISSN No. 0974-6927
Vol. 17 (2025), pp. 128-135

Research Article

Morphological and anatomical characteristics of seedlings of selected indigenous and introduced palms in West Bengal, India

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Abstract

Investigations on seedling morphology in vascular plants have increasingly emerged as a reliable taxonomic tool for both monographic and systematic studies. In the family Arecaceae (Palmae), two principal types of germination are commonly recognized, namely remote germination and adjacent germination, which provide significant diagnostic value. The present study deals with the morphological and anatomical characteristics of germination patterns in selected indigenous and introduced palm species representing six subfamilies. Special emphasis has been given to key seedling structures such as hyperphyll, cataphyll, eophyll, and primary root, which exhibit considerable variation among taxa. Detailed anatomical observations of the eophyll, petiole, stem, and root were carried out to understand internal structural differences and their taxonomic relevance. The study reveals that both external morphology and internal anatomy of seedlings offer stable and distinguishable characters that can be effectively utilized for early identification of palm taxa, even before the reproductive stage. The findings contribute to filling the existing gap in palm seedling studies and highlight the importance of integrating seedling morphology with anatomical data in taxonomic and evolutionary investigations of Arecaceae.

Article info

Received **13 February 2026**
Revised **5 May 2026**
Accepted **7 May 2026**

Keywords: Arecaceae (Palmae), Dissection, Juvenile stages, Taxonomic characters

DOI: ***https://doi.org/10.55734/nbujps.2025.v17i01.010***

Introduction

The family Arecaceae (Palmae) is one of the largest and most economically as well as ecologically significant families of monocotyledons. Recent estimates indicate that the family comprises about 184 genera and 2600 species distributed across tropical and subtropical regions of the world (Govaerts & Dransfield, 2005; Govaerts et al., 2011; Mondal, 2020). Members of this family exhibit remarkable diversity in habit, ranging from small understory palms to large canopy-forming species, and they play a crucial role in maintaining forest structure and biodiversity. In addition to their ecological importance, palms are widely utilized for food, construction, ornamentation, and traditional medicine. Seedlings represent the juvenile stage of plant development, and their morphological and anatomical characteristics are often genetically stable and less influenced by environmental variations. These features can therefore serve as reliable taxonomic markers, enabling early identification of taxa long before the onset of flowering (Paria, 2014; Mondal et al., 2016, 2021, 2025). Despite their significance, seedling studies in Arecaceae remain relatively scarce, particularly with

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respect to detailed anatomical investigations, and the available literature is fragmented and limited in scope. In recent years, there has been growing recognition of the importance of integrating seedling morphology with classical taxonomy to resolve taxonomic ambiguities and to understand phylogenetic relationships within the family. Furthermore, the study of early developmental stages provides valuable insights into evolutionary adaptations, germination strategies, and survival mechanisms of palms in different ecological conditions. Such information is especially relevant in regions like West Bengal, where both indigenous and introduced palm species coexist under varied environmental settings. In the present study, the seedling morphology and anatomy of the eophyll, petiole, stem, and root of 26 genera representing six subfamilies of palms have been investigated. Since most palms propagate through seeds, germination patterns constitute an important aspect of their biology and taxonomy. Detailed observations of morphological and anatomical features up to the eighth leaf stage are presented here, supported by photographs and illustrations, to provide a comprehensive understanding of early developmental traits and their taxonomic significance.

Materials and methods

Field collection

Plant materials (seeds and seedlings) representing all subfamilies of Arecaceae were collected from diverse sources to ensure adequate representation and variability. These sources included botanical gardens, private gardens, personal collections, and extensive field surveys conducted within the campus of the University of North Bengal and its adjoining regions (Darjeeling Himalaya, Trai & Duars region). Additional specimens were obtained from the Botanical Survey of India (BSI), Howrah; the Agri-Horticultural Society of India, Kolkata; and The Green Mall Nursery at Samukpota, South 24 Parganas. Field collections were also carried out from Suryasen Park, City Centre (Siliguri), covering both cultivated and semi-natural habitats. Seedlings were collected at the two-leaved stage along with attached seeds to ensure accurate identification and developmental assessment.

Morphological and anatomical studies

Seedling morphology was examined through direct observation using a hand lens as well as an Olympus SZX7 binocular microscope for detailed structural analysis. For anatomical studies, standard procedures described by Martens and Uhl (1984) were followed. Transverse sections of lamina, petiole, stem, and root were prepared and examined under a Magnus light microscope. Different parts of the seedlings were subjected to double staining techniques or stained with safranin and light green to enhance tissue differentiation, following established protocols (Santra et al., 1989; Maji, 2004; Henderson, 2006). Photomicrographs and detailed observations were recorded to support comparative anatomical analysis.

Preservation and Identification

Collected specimens were carefully preserved and documented. Identification of plant materials was carried out using standard taxonomic literature, including Uhl and Dransfield (1987), Basu and Chakraverty (1994), and recent regional works by Mondal and Chowdhury (2018) and Mondal, Basu and Chowdhury (2019, 2020).

Result and Discussion

The present study records seedlings of twenty-six taxa of six different subfamilies along with tribes of the family Arecaceae (Palmae). From the above study, mainly two types of germination are noted: remote germination and adjacent germination. From the collected sample, 10 species have remote germination of tribes Coryphae, Phoeniceae and Caryoteae under the subfamilies Coryphoideae and Arecoideae, respectively, and 16 have adjacent germination of tribes Hyophorbeae, Caryoteae and Areceae under the subfamilies Ceroxyloideae and Arecoideae. Germination types depend on the length of hyperphyll. Palm seedlings have variable length (mm to cm) of hyperphylls, e.g., Phoenix sylvestris & Livistona jenkinsiana. Cataphylls are the most important character in the family Arecaceae. The number of cataphylls is related to eophyll shape. For example, seedlings with single cataphylls can be associated with entire eophylls, and seedlings with more than one cataphyll generally have bifid, palmate, or pinnate eophylls (Table 1).

The apex of eophyll may contain a needle-like projection (*Phoenix robelenii*) or a praemorse apex (*Caryota maxima*) or an acute apex (*Areca catechu*) or be irregularly toothed (*Licula grandis*). Eophyll shape is mainly lanceolate (*Dypsis lutescens*) or broadly lanceolate (*Livistona jenkinsiana*) or flattened (*Caryota urens*). Plication separates palms into two groups–reduplicate (L-shaped) folding and induplicate (V-shaped) folding. Some eophylls seem to be strongly plicate, such as some plants of Corypheae, while others do not show plication, like Caryoteae (Figure 1).

Table 1. Morphological features of palm seedlings

Specie names	LS (cm)	BS (cm)	TG	SL (cm)	LPR (cm)	LH (cm)	LCS (cm)	LC		LE (cm)
								1st (cm)	2nd (cm)	
Adonidia merrillii (Becc.) Becc.	2.8	1.5	Adjacent	36.5	11.7	-	-	2.5	5.3	25
Archontophoenix alexandrae (Muell). Wendl. & Drude	2.5	1	Adjacent	35	11.2	-	-	1.3	4.8	18.8
Areca catechu L.	2	1.5	Adjacent	32	11	-	-	1	5	27.4
Areca trianda Roxb.	2.8	1.3	Adjacent	23.5	4	-	-	2.5	2.9	14.1
Arenga pinnata (Wurmb) Merr.	1.5	1.1	Adjacent	24.8	4	Short	Elongated	4.5	-	22
Bentinckia nicobarica (Kurz) Becc.	0.9	0.8	Adjacent	16.1	2.4	-	-	0.8	2.1	11.6
Carpentaria acuminate Becc.	1.6	1.1	Adjacent	23.2	4.5	-	-	1.9	4.8	18.7
Caryota maxima Blume ex Mart.	1.5	1.7	Remote	17.5	8	1.2	2.4	4.5	-	9.5
Caryota mitis Lour.	1.6	1.4	Remote	25.9	2	1.5	1.7	4.8	-	24.4
Caryota urens L.	1.3	1.7	Remote	22.5	5	1.4	4.7	5.4	-	16
Chamaedorea cataractarum Mart.	1.8	1.3	Adjacent	27	8.8	-	-	2.2	6	17.5
Cyphophoenix fulcita (Brongn.) Hook.f. ex-Salomon	2	1.5	Adjacent	30.5	11.4	-	-	1	6.7	8.8
Dypsis decaryi (Jum.) Beentje & Dransf.	2	1.7	Adjacent	20	7	-	-	1	5	12.5
Dypsis fibrosa (Wright) Beentje & Dransf.	1.9	1.6	Adjacent	31.5	12.2	-	-	2.2	4	13.6
Dypsis lanceolata (Becc.) Beentje & Dransf.	2.1	1.9	Adjacent	35.2	11.3	-	-	1.9	4.8	18.5
Dypsis lutescence (Wendl.) Beentje & Dransf.	1.9	1.6	Adjacent	22	5.5	-	-	1.1	2.2	16.5
Licula grandis Wendl.	0.9	0.9	Remote	24	2.5	2	1.1	6.3	_	21.3
Livistona jenkinsiana Griff.	1.7	1.1	Remote	24.5	4.4	4.5	1.3	8	-	22.2
Livistona speciosa Kurz	0.9	0.9	Remote	32	5.8	2	2.7	6.6	-	23.5
Phoenix acaulis Buch-Ham. ex Roxb.	2	0.9	Remote	29.5	6	0.9	1.1	1.9	-	25
Phoenix dactylifera L.	1.96	0.72	Remote	25	9.2	1.6	2.7	8.4	-	14.8
Phoenix robelenii O'Brien	1		Remote	25.5	7	1.1	1.6	1.9	-	21.3
Phoenix sylvestris Roxb.	2.2	0.9	Remote	51	12	0.5	3.2	8.7	-	36
Ptychosperma macarthurii (Wendl.) Nichols.	1	0.7	Adjacent	25.2	8	-	-	0.7	1.8	16
Roystonea regia (H.B.K.) Cook.	1.14	0.84	Adjacent	26	5	Short	-	2.4	5	21
Wodyetia bifurcate A. K. Irvine	5.9	3.2	Adjacent	44.5	23	-	-	3.5	5.8	9.3

[**LS**: Length of seed; **BS**: Breadth of seed; **TG**: Type of germination; **SL**: Seedling Length; **LPR**: Length of primary root; **LH**: Length of hyperphy-ll; **LCS**: Length of cotyledonary sheath; **LC**: Length of cataphyll; **LE**: Length of eophyll].

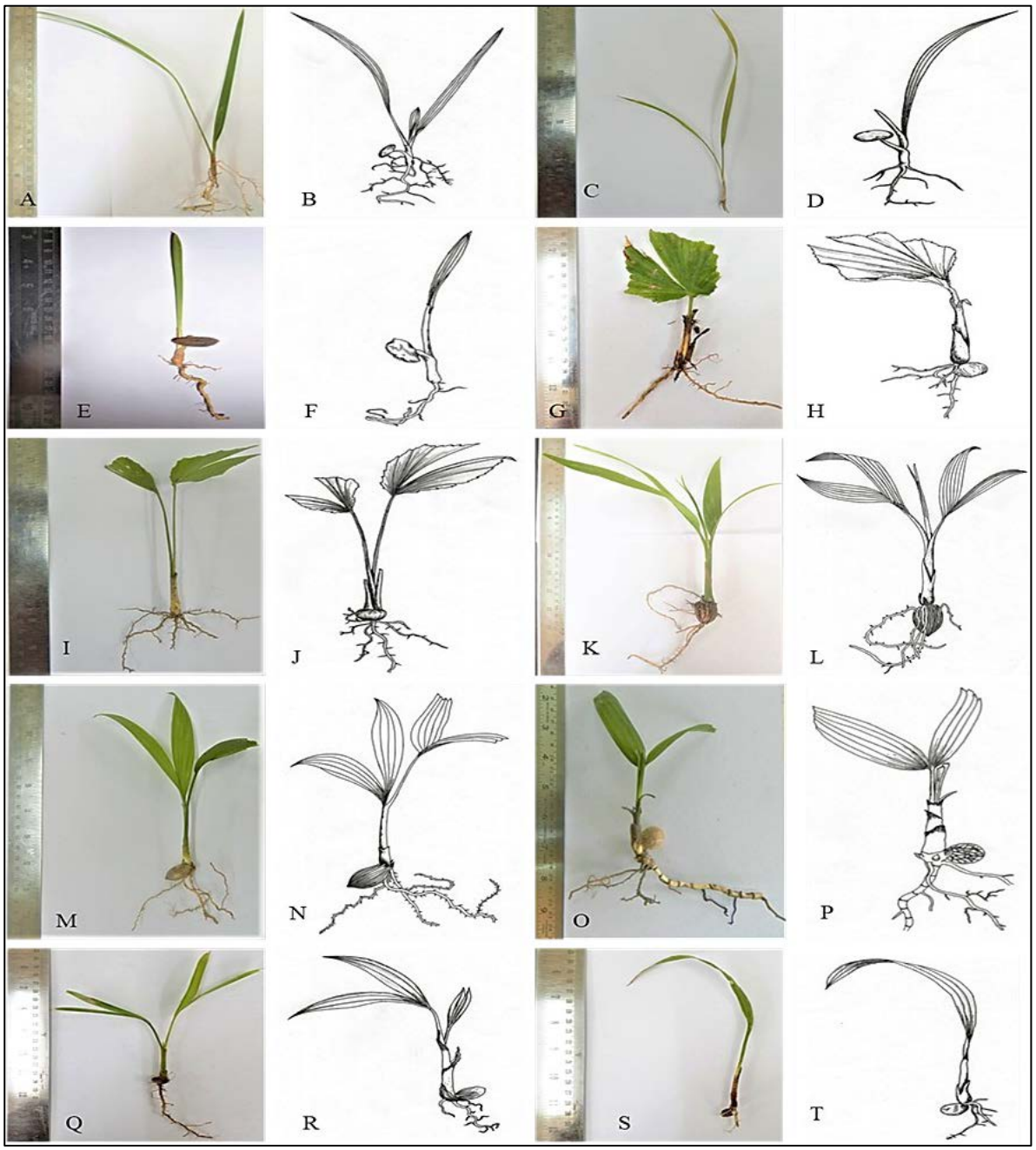

Figure 1. Live photo and hand-drawing photo of different seedlings; A-B. *Phoenix acaulis* Buch-Ham. ex Roxb.; C-D. *Phoenix robelenii* O'Brien; E-F. *Phoenix dactylifera* L.; G-H. *Caryota maxima* Blume ex Mart.; I-J. *Caryota urens* L.; K-L. *Areca catechu* Linn. M-N. *Areca trianda* Roxb.; O-P. *Dypsis decaryi* (Jum.) Beentje & J. Dransf; Q-R. *Dypsis lutescens* (H. Wendl.) Beentje & J. Dransf.; S-T. *Roystonea rigia* (H.B.K.) Cook.

The mesophyll layers are differentiated into palisade and spongy parenchyma. The vascular bundles are generally protected by a sclerotic layer, which is a protective inner sheath (IS) adjacent to the vascular tissue. Vascular bundles are of three categories – major, median, and minor. Major veins are attached to the hypodermal layers at the adaxial and abaxial ends. Median veins are the intermediate type between major and minor veins (Figure 2).

Minor veins are equidistant from the abaxial and adaxial layers. The number of phloem strands may be single or double. Vascular bundles with three phloem strands may fuse into a single one, and vascular bundles with four strands may fuse into two strands (Table 2). Cell inclusions (ideoblasts) are common in most eophylls. The most common shapes are spherical, ellipsoid, and hat-shaped; the last shape is present in a few tribes of Caryoteae, Iriarteeae, Hyophorbeae, some Cocoeae, and Areceae.

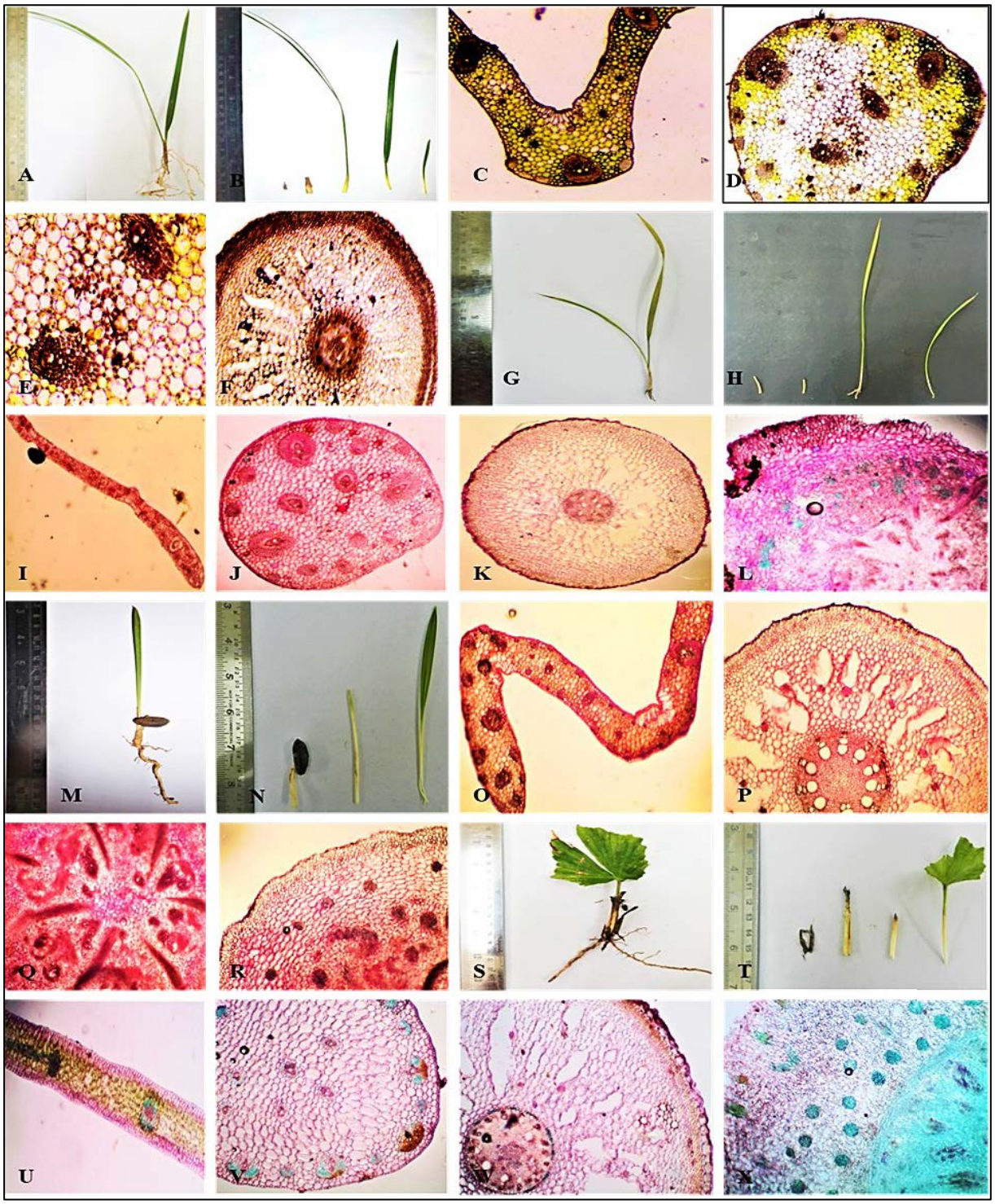

Figure 2. A-B. *Phoenix acaulis* Buch-Ham. ex Roxb. Habit of seedling; C. T.S. of eophyll; D. T.S. of petiole; E. Vascular bundle in petiole; F. T.S. of root; G-H. *Phoenix robelenii* O'Brien Habit of seedling I. T.S. of eophyll; J. T.S. of petiole; K. T.S. of root; L. T.S. of stem. M-N. *Phoenix dactylifera* L. Habit of seedling; O. T.S. of eophyll; P. T.S. of root; Q. T.S. of stem (middle portion); R. T.S. of stem (outer portion). *Caryota maxima* Blume ex Mart.; S-T. Habit of seedling; U. T.S. of eophyll; V. T.S. of petiole; W. T.S. of root; X. T.S. of stem.

Table 2. Anatomical features of palm seedlings

Name of species	T.S. of Lamina	T.S. of Petiole	T.S. of stem	T.S. of root
Areca catechu L.	Dorsiventral; EC non-sinuous, HC single layer. Non-vascular fibres almost absent. Phloem divided into two strands. Midrib adaxially prominent.	CVB metaxylem vessel and phloem divided into strands.	VB two. Phloem strand undivided.	Fibres thick-walled; scattered in outer cortex. Stele cylindrical with central cavity in medulla.
Areca trianda Roxb.	Dorsiventral; EC non-sinuous, hexagonal. HC single layer. Veins in abaxial mesophyll, small veins independent of surface layer. Phloem divided into two strands.	CVB with one wide metaxylem vessel and phloem divided into two strands.	VB with two inconspicuous, wide vessels.	Fibres with slightly thick walls; scattered in outer cortex. Stele cylindrical with central cavity in medulla.
Caryota maxima Blume ex Mart.	Dorsiventral; EC spindle-shaped, usually longitudinally extended, hypodermis single layer. Largest veins in contact with abaxial epidermal layer, small veins independent of surface layer.	Peripheral vascular bundles are congested, forming a sclerotic cylinder.	VB with narrow protoxylem vessels. Phloem strand undivided.	Fibres with thick walls; Stele cylindrical with a central cavity in the medulla.
Caryota urens L.	Dorsiventral; EC spindle-shaped, longitudinally extended. HP single layer. Large veins with abaxial epidermal layer, small veins with independent surface layer.	Peripheral vascular bundles are congested, forming a sclerotic cylinder.	VB narrow protoxylem vessels.	Fibres with thick walls; stele cylindrical.
Dypsis decaryi(Jum.) Beentje & J. Dransf.	Dorsiventral; EC non-sinuous, hexagonal. HP single layer. Fibres few. Large veins in the abaxial epidermal layer, small veins in the independent surface layer.	CVB with one wide metaxylem vessel and phloem divided into two strands.	VB narrow protoxylem vessels.	Fibres with slightly thickened walls. Stele cylindrical, centre of stele with fibrous ground tissue.
Dypsis lutescence (H. Wendl.) Beentje & J. Dransf.	Dorsiventral; ECP non-sinuous, hexagonal. Hypodermis single layer. Large veins with abaxial epidermal layer, small veins independent surface layer.	Central vascular bundles with metaxylem vessel and phloem divided into two strands.	VB narrow protoxylem vessels.	Fibres with slightly thick walls. Stele cylindrical, centre of stele with fibrous ground tissue.
Phoenix acaulis Buch-Ham. *ex* Roxb.	Isolateral; CW sinuous, rectangular. Hypodermis one layer. Fibres in strands. Small veins independent of surface layer, large veins attached to each hypodermis with layers of colourless cells.	CVB with two wide metaxylem vessels and with a single phloem strand.	VB with narrow protoxylem vessels,	Fibres with thick walls, stele cylindrical; medulla completely fibrous.
Phoenix dactylifera L.	Isolateral; CW sinuous, narrow, rectangular. Hypodermis single layer. Small veins independent of surface layer, large veins attached to each hypodermis by colourless cells.	CVB two wide metaxylem vessels and a single phloem strand.	VB narrow protoxylem vessels.	Fibres thick-walled, stele cylindrical; medulla completely fibrous.

Phoenix robelenii Brien.	Isolateral; CW sinuous, rectangular. Hypodermis single layer. Small veins independent of surface layer, large veins attached to each hypodermis by colourless cells.	CVB with two wide metaxylem vessels and a single phloem strand.	VB with narrow protoxylem vessels.	Fibres with thick walls; stele cylindrical; medulla completely fibrous.
Roystonea regia (H.B.K.) Cook.	Dorsiventral; CW non-sinuous, HC single layer. Large veins in the abaxial epidermal layer, small veins in the independent surface layer. Phloem sclerotic.	CVB mostly with one wide metaxylem vessel and phloem	VB with narrow protoxylem vessels.	Fibres absent. Stele cylindrical; centre of stele with fibrous ground tissue.

[EC-Epidermal Cell; CVB-Central Vascular Bundle; VB-Vascular Bundle]

Conclusion

Palms are the most important plant species for their valuable uses like landscaping, beautification, and daily life uses. It is one of the important raw materials for small and large industries in West Bengal as well as India. The present study shows that palm seedlings (juvenile stages) have variable lengths of hyperphylls, which can extend to various angles from the seed, from a few millimeters to several centimeters (Figure 3). The number of cataphylls appears to be distinct for every tribe and is related to eophyll structure. In the tribes Caryoteae and Borasseae, the mesophyll layers are infrequently well differentiated into spongy and palisade parenchyma. The external and internal architecture of 26 seedlings of the family Arecaceae showed two types of germination, viz. remote and adjacent. The morphological features such as eophyll, cataphyll, placation, etc. were considered for their study.

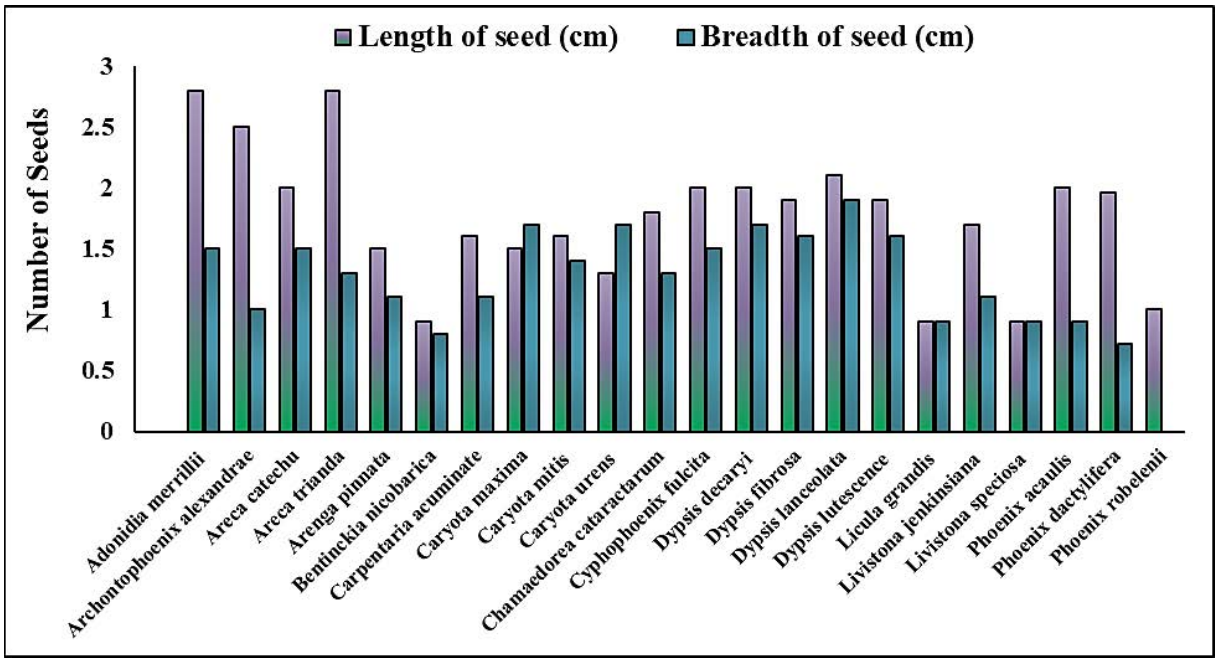

Figure 3. Length and breadth (cm) of the Indigenous and Introduced Palm seeds.

Acknowledgements

The authors were grateful to the authority of The Green Mall Nursery, Samukpota, 24 Pgs (S) and The Agri Horticultural Society of India, Kolkata, who granted us all necessary permits for collecting the palm seedlings. The first author would like to convey his heartiest thanks to the authority of NBU for financial support.

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