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Rhizopalmoxylon singulare sp. nov. - coralloid palm roots from the Late Cretaceous Deccan Intertrappean beds of Nawargaon, India

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ABSTRACT

Bonde SD, Chate SV & Gamre PG 2009. *Rhizopalmoxylon singulare* sp. nov. - coralloid palm roots from the Late Cretaceous Deccan Intertrappean beds of Nawargaon, India. The Palaeobotanist 58(1-3): 57-65.

Permineralized coralloid aerial palm roots forming a thick compact mantle have been described from the Deccan Intertrappean beds of Nawargaon, Maharashtra, India. A medium sized root exhibits rhizodermis, thick exodermis, thin outer and wide inner cortex; fibers in the inner cortex; air cavities in 3-7 concentric rings in the middle zone of inner cortex; polyarch stele with 12-15 xylem and phloem bundles and sclerenchymatous pith with 1-3 medullary bundles. Morpho-anatomical characters of the root suggest its affinity with coralloid roots probably of *Hyphaene dichotoma* (White) Furtado and *Phoenix sylvestris* (L.) Roxb. A combination of details of stelar and cortical region is found to be a better criterion to resolve the natural affinity of permineralized palm roots. Two new combinations of *Rhizopalmoxylon, R. angiorhizon* and *R. macrorhizon* are also suggested.

Key-words—*Rhizopalmoxylon*, Coralloid roots, Arecaceae, Evolution, Deccan Intertrappeans, Maastrichtian.

भारत में नवरगाँव के अंतिम क्रिटेशस दक्कन अंतःट्रेपी संस्तरों से प्राप्त *राइज़ोपामॉक्सीलॉन सिंगुलरी* नवजाति-प्रवालाभ ताड़ जड़ें

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सारांश

भारत में महाराष्ट्र के नवरगाँव के दक्कन अंतःट्रेपी संस्तरों से एक मोटी संहत प्रावार गठित करती हुई पर्मिनीकृत प्रवालाभ वायव ताड़ जड़ें वर्णित की गई है। एक मध्यम आकारी जड़ मूलत्वचा, मोटी बाह्यमूलत्वचा, तनु बाह्य व विस्तृत अंतः वल्कुट; अंतः वल्कुट में तंतु; अंतः वल्कुट के मध्य मंडल में 3-7 संकेन्द्री वलयों में वायु गुहिकाएं; 12-15 दारु (जाइलम) और पोषवाह बंडलों सहित बहु-आदिदारुक रंभ तथा 1-3 मज्जा बंडलों सहित दृढ़ोतक मज्जा प्रदर्शित करती है। जड़ के शारीरीय-आकार अभिलक्षण संभवतः *हाइफेने डिकोटोमा* (वाईट) फर्टेडो और *फीनिक्स सिलवेस्ट्रिज* (लिन.) रॉक्सब की प्रवालाभ जड़ों से बंधुता सुझाती है। तारकीय एवं वल्कुटी का संयोजन पर्मिनीकृत ताड़ जड़ों की प्राकृतिक बंधुता के विभेदन करने का बेहतर आधार पाया गया है। *राइज़ोपामॉक्सीलॉन, आर. एन्जियोराइजॉन* एवं *आर. मेक्रोराइज़ॉल* के दो नवीन संयोजन भी प्रस्तावित हैं।

संकेत-शब्द— *राइज़ोपामॉक्सीलॉन*, प्रवालाभ जड़ें, एरेकेसी, विकास, दक्कन अंतःट्रेपी, मास्ट्रीक्शियन।

INTRODUCTION

Rhizopalmoxylon was instituted by Felix in 1883 to refer the permineralized roots of palms. However, it remained a *Nomen nudum* as he neither provided description nor diagnosis. Gothan has (1942) validly published the name *Rhizopalmoxylon* along with diagnosis and descriptions of two species, *R. glaseli* and *R. bohlenianum* without assigning either of them as Lectotype, mandatory for taxonomic status as per ICBN. Accordingly as of now the taxonomic status of *Rhizopalmoxylon* remained invalid as per Article 42 of ICBN. In view of it the species delt here in this communication have nomenclatural and taxonomic significance.

Palms have a considerable long geological history. Their fossil remains are known in the form of permineralizations, impressions, compressions and casts of almost all organs assigned to number of organ genera (Daghlian, 1981; Muller, 1981; Harley, 2006). The palms (Family-Arecaceae) constitute a large assemblage of woody monocotyledons distributed naturally in the Oceanic Islands and coastal areas in the tropics between 44º North and South of the equator. They have a very long geological history right from the early Mesozoic era. *Sanmiguelia lewisii* Brown (1956) from the Triassic of Colorado, U.S.A. and *Propalmophyllum liasianum* Lignier (1895) from the Lower Jurassic of France are the doubtful records. *S. lewisii* is a simple large pleated leaf but it lacks a definite midrib and cross veins (Read & Hickey, 1972; Doyle, 1973). Besides Arecaceae, its affinities are suggested with Liliaceae (Tidwell *et al*., 1977) and Cycadophytes (Read & Hickey, 1972). Cornet (1986, 1989) considers *Sanmiguelia* to be a primitive angiosperm that shares features of monocotyledons and dicotyledons and at the same time Martin *et al.* (1993) accept *Sanmiguelia* as an angiosperm ancestor. Scott *et al*. (1960) suggested the affinity of *Propalmophyllum liasianum* with the Cycadophytes. However, Read and Hickey (1972) did not assign it to any plant group as it is of a fragment. *Sabalites carolineusis* Berry (1914) from late Coniacian – Early Santonian of South Carolina, U.S.A., *S. longirhachis* (Unger) Kvacek and Herman (2004) from the Lower Campanian of Austria, *Palmoxylon andegavense* Crie (1892) and *P. ligerinum* Crie (1892) from Turonian of France, *P. cliffwoodensis* Berry (1916) from Coniacian- Santonian of New Jersey, U.S.A. are some of the earliest and definite records of Arecaceae. However, the palm remains occur abundantly in the Maastrichtian of southern continental sedimentary basins.

MATERIAL AND METHOD

The present work is based on two permineralized chert pieces collected from Deccan Intertrappean beds at Nawargaon- Maragsur area (21°01' N, 78°35' E), District, Wardha, Maharashtra, India, from where quite many angiosperm remains as well as a mangrove fern *Acrostichum* have been reported (Bonde, 2005; Bonde & Kumaran, 2002, 2005). Specimen N 225/98 is 26 cm long and 13.0 x 8.0 cm wide and the other specimen, N 226/98 is 17.5 cm long and 11.5 x 5.5 cm wide. They comprise a large number of well preserved small to medium sized, irregularly oriented roots. Sections of specimens show details of the roots lying in various planes, and consequently cut in different angles. The sections were prepared following the usual ground thin section method employed for silicified material and studied using a Nikon Labophot-2 microscope attached with Fx-35 DX Camera and Leica S6D Microscope along with Canon Powershot S45 Digital Camera.

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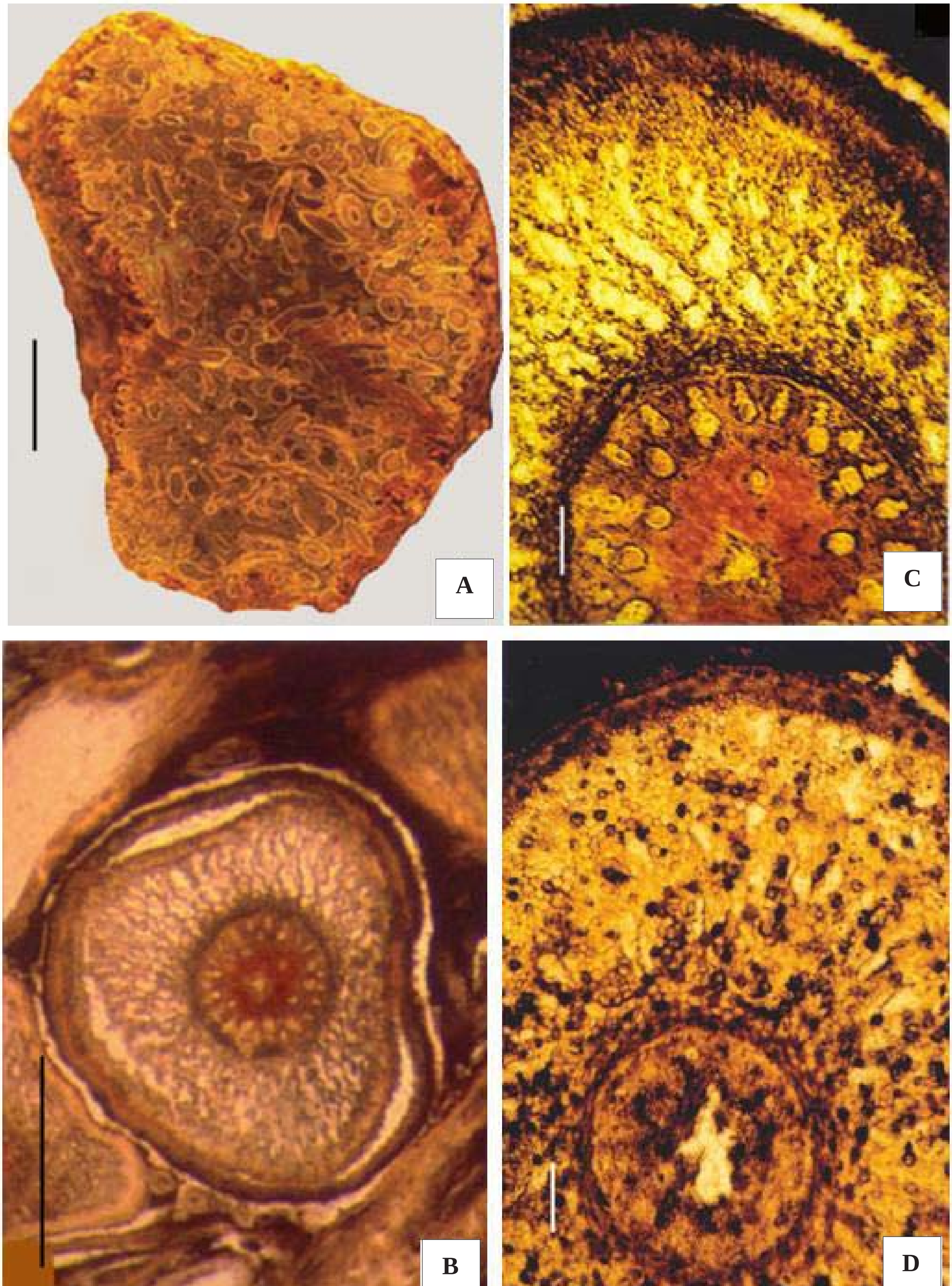
Fig. 1—*Rhizopalmoxylon singulare* sp. nov. **A.** Polished cut surface of Holotype showing root mantle with haphazardly running small & medium sized roots. Scale bar = 2 cm. **B.** Transverse section of medium sized root with exodermis, wide cortex and central stele. Scale bar = 2 mm. **C.** Transverse section enlarged showing thin outer and wide inner cortex with air cavities in rings in middle zone. Stele with alternate xylem and phloem bundles in a ring and central pith with two medullary bundles. Scale bar = 300 mm. **D.** Transverse section of small sized root showing round air canals in rings and dispersed fiber cells in the cortex and poorly developed stele in the centre. Scale bar = 150 mm .


A
C
B
D

Looking at the arbitrary use of anatomical terminologies by different workers hitherto engaged in the study of palm roots both extant and extinct we have adopted here a combined system of terminologies used by Mahabale and Udwadia (1960) for the stelar region and Seubert (1997) for the extrastellar region as it is based on ontogenetical and phylogenetical considerations. It will be the most feasible method to resolve fossil palm roots to their natural taxa on the morpho-anatomical characters. The specimens and micropreparations are deposited at the Department of Palaeobiology, Agharkar Research Institute, Pune, India.

SYSTEMATICS

Order—ARECALES

Family—ARECACEAE Schultz-Schultzenstein

Genus—RHIZOPALMOXYLON Gothan (1942)

Rhizopalmoxylon singulare sp. nov.

(Fig. 1A-D; Fig. 2A-E)

Diagnosis—Roots adventitious, aerial, coralloid, compact forming a mantle. Rhizodermis unicellular. Exodermis, 3-5 layered. Cortex divisible in three regions; outer 3-7 layered, sclerenchymatous; inner wide in three distinct zones, outer thin, compact, middle wide with air cavities in 3-7 circles, inner thin forming concentric rings. Endodermis unicellular, pericycle 1-3 layered. Fibre cells present. Stele with 12-15 separate xylem and phloem bundles. Pith sclerenchymatous. Medullary bundles 1-3.

Holotype—N 225/98 (Slide Nos. 1-6). Department of Palaeobiology, Agharkar Research Institute, Pune.

Paratype—N 226/98. Department of Palaeobiology, Agharkar Research Institute, Pune.

Horizon —Deccan Intertrappean beds of India.

Locality—Nawargaon, District Wardha, Maharashtra, India.

Age—Upper Cretaceous (Maastrichtian).

Etymology—The specific epithet "singulare" is after the coral- like appearance of the roots forming a compact mantle.

Description—The root mantle embodies adventitious coralloid roots embedded in the chert matrix. They are circular, small to medium sized, 3.0-9.0 mm in diameter (Fig. 1A). Rhizodermis is single layered devoid of root hairs, made up of rectangular, suberized, 17 x 14 – 31 x 17 µm cells. Exodermis is 3-5 layered, made up of polyhedric or hexagonal cells with truncate radial walls. Outer cortex is single -zoned, 3-7 layered (225-300 mm thick) with polygonal, thick walled, 27 x 41 mm cells, similar to those of the exodermis but longitudinally elongated and sharply pointed. Inner cortex is 675-1050 mm wide and composed of three distinct zones. Outer zone is 3-5 layered and made up of small, compactly arranged cells with few intercellular spaces. Middle zone is 1-3 mm wide, cells large, intercellular spaces wider forming the aerenchyma. Air cavities vary in size, and arranged in 3-7 rings. Inner zone 3-5 layered (120-150 mm), made of dense tissue of smaller cells arranged in concentric circles with small intercellular spaces. Endodermis is the innermost layer of the inner zone, single layered composed of cells with unthickened outer walls, centripetally thickened radial walls and strongly thickened inner walls. Passage cells have not been

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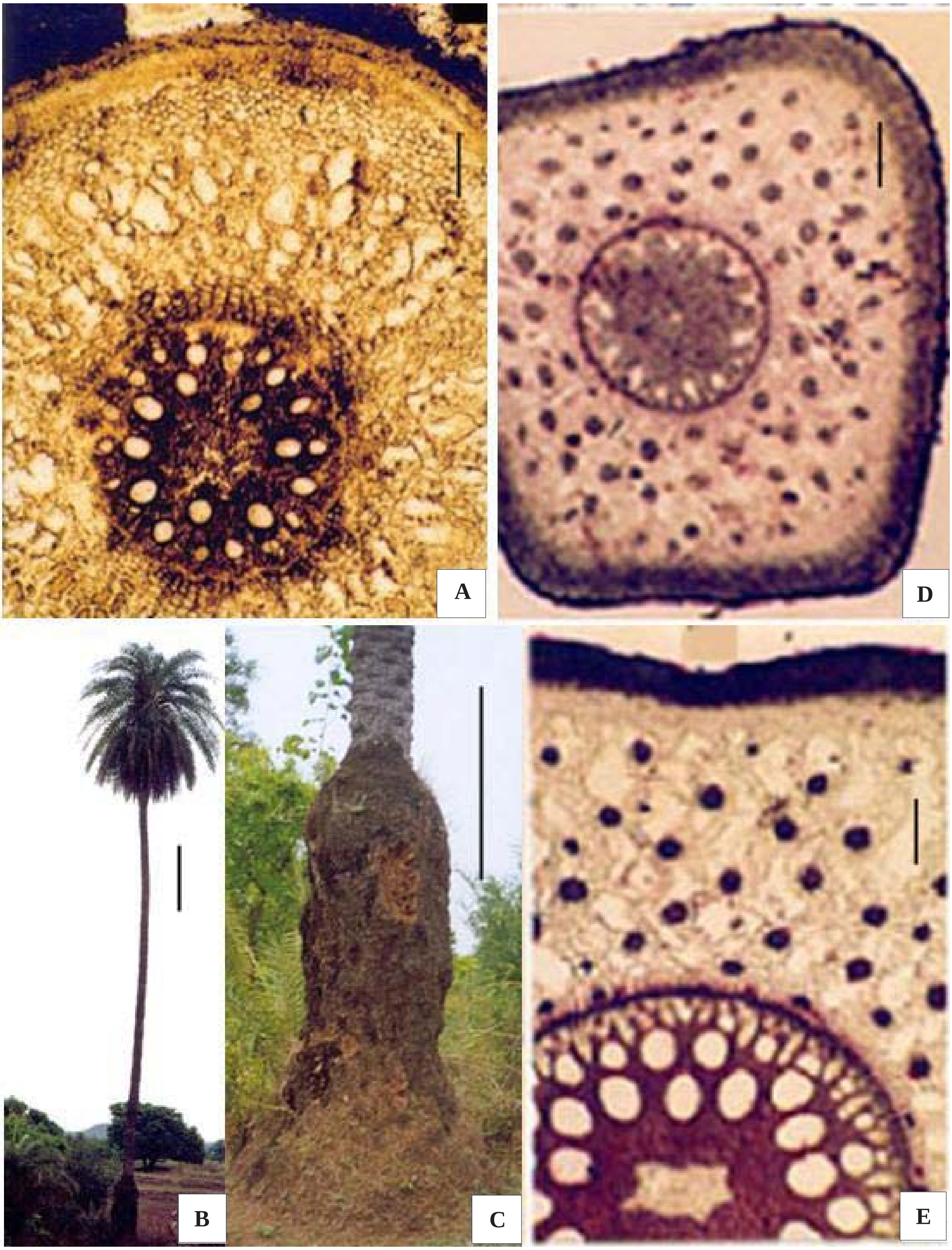
Fig. 2—*Rhizopalmoxylon singulare* sp. nov. **A.** Transverse section of medium sized root showing thick exodermis, round to elongated air canals in rings in the middle zone of inner cortex and central stele, Scale bar = 300 mm. **B.** The plant *Phoenix sylvestris* showing root mantle at the basal region of the stem. Scale bar = 2 m. **C.** Basal region of the stem enlarged showing root mantle. Scale bar = 1 m. **D.** Transverse section of small root from the root mantle of *Phoenix sylvestris* showing fibre bundles and round air canals in rings in the cortex. Scale bar = 150 mm. **E.** Transverse section of a root from root mantle of *Hyphaene dichotoma* showing fiber bundles and round air canals in rings in the cortex. Scale bar = 300 mm.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observed. Fibre cells are irregularly distributed in the outer and middle zones of inner cortex (Fig. 1B). Pericycle is the outermost layer of the vascular cylinder. It is 1-3 layered with thin walled cells. Inner side of the stele consists of 12-15 separate xylem and phloem bundles at different radii, alternate to one another in the thick walled sclerotic conjunctive tissue composed of elongated fibre-like cells. The xylem bundle consists of a radial series of tracheary elements, progressively wider in centripetal developmental order. The innermost metaxylem vessels are the widest, round to oval, 105 x 105 – 105 x 150 µm. Phloem bundles are circular, 150 x 180 µm. Pith is circular, 750–1050 µm in diameter, sclerenchymatous with 34 x 42 mm cells. Medullary bundles are 1-3, present in medium sized roots only. The medullary bundle consists a single large vessel surrounded by a fibrous sheath. Pith is circular, sclerenchymatous, sometimes becoming hollow due to disintegration of cells (Fig. 1C, A). The smaller roots of 0.5-1.0 mm size show very little differentiation in the inner cortical tissues, fewer number of xylem and phloem bundles and a solid parenchymatous pith (Fig. 1 D).

DISCUSSION

Morphological affinity—Adventitious root system is a character of all the monocotyledons. However, coralloid aerial roots forming a thick mantle has been noted only in palms (Mahabale & Udwadia, 1960; Mahabale, 1982; Tomlinson, 1990). Thick exodermis; wide cortex divisible in three distinct zones with air cavities in 3-7 rings; dispersed fibre cells and sclerenchymatous pith with 1-3 medullary bundles strongly suggest affinity of *R. singulare* with Arecaceae (Cormack, 1896; Drabble, 1904; Mahabale & Udwadia, 1960; Seubert, 1996a, b, 1997, 1998a, b).

Comparison with the fossil palms—Felix (1883) assigned permineralized roots of palms to *Rhizopalmoxylon*. However, he has neither provided any description nor diagnosis and as such it remains as a *nomen nudum* under ICBN (McNeill *et al.,* 2006). Gothan (1942) validly instituted the genus *Rhizopalmoxylon* with two species, *R. glaseli* and *R. bohlenianum* from the Tertiary of Bohlen, Germany. Gothan's work has also been referred in the Index of Generic Names of Fossil Plants, 1820-1965 (Andrews, 1970) and the Index Nominum Genericorum - Plantarum (Farr *et al.*, 1979). The later workers (Tidwell *et al.,* 1972; Mahabale & Rao, 1973; Cevallos-Ferriz & Ricalde-Moreno, 1995; Awasthi *et al.*, 1996) overlooked the work of Gothan (1942) and referred their species to *Rhizopalmoxylon* Felix (loc.cit.). However, Gothan has not indicated the type species. *Rhizopalmoxylon glaseli* Gothan has been cited here as a Lectotype as per the Article 10.1 & 10.2 of ICBN (McNeill *et al.*, 2006). Since Gothan (1942) has validly instituted the genus *Rhizopalmoxylon* for isolated permineralized roots of palms, *Palmoxylon angiorhizon* Stenzel (1904) and *Palmoxylon macrorhizon* Stenzel (1904) become *Rhizopalmoxylon angiorhizon* (=*Palmoxylon angiorhizon* Stenzel, 1904) comb. nov. and *Rhizopalmoxylon macrorhizon* (=*Palmoxylon macrorhizon* Stenzel, 1904) comb. nov.

Rhizopalmoxylon Gothan (1942) possesses 12 species, viz., *R. glaseli* Gothan (1942), *R. bohlenianum* Gothan (1942), *R. libycum* Koeniguer (1970), *R. behuninii* Tidwell *et al.* (1972), *R. blackii* Tidwell *et al.* (1972), *R. scottii* Tidwell *et al.* (1972), *R. sundaram* Mahabale and Rao (1973), *R. huepaciense* Cevallos-Ferriz and Ricalde-Moreno (1995), *R. teguachiense* Cevallos-Ferriz and Ricalde-Moreno (1995), *R. borassoides* Awasthi *et al.* (1996), *R. angiorhizon* (= *Palmoxylon angiorhizon* Stenzel, 1904) comb. nov. and *R. macrorhizon* (= *Palmoxylon macrorhizon* Stenzel, 1904) comb. nov.

R. glaseli and *R. bohlenianum* resemble *R. singulare* in having medullary bundles but differs in having thick exodermis, distribution of air cavities in the cortex and large number of xylem and phloem bundles. *R. behuninii, R. blackii* and *R. scottii* lack the rhizodermis, exodermis and medullary bundles. Air cavities in these roots are very long and radially elongated in 1-2 rings. *R. scottii* possesses very few air cavities. *R. sundaram* Mahabale and Rao differs from the newly described species in having mucilaginous or tanniniferous cells in the exodermis, indistinct endodermis, 2-5 layered pericycle and 31-45 xylem bundles. *R. singulare* resembles *R. huepaciense* and *R. teguachiense* due to air cavities in rings and fibres in the cortex but differs due to absence of medullary bundles in them. *R. borassoides* differs in having air cavities in 1-3 rings and 22-26 xylem strands. The new species resembles *R. angiorhizon* in having small to medium sized roots and medullary bundles but differs in the cortical tissues. Although *R. macrorhizon* and *R. singulare* have medullary bundles, the roots of *R. macrorhizon* are thick and possesses large number of xylem bundles in the stele.

R. singulare differs from the roots described in conjunction with *Palmoxylon* species (Stenzel, 1904; Stockmans & Williere, 1943; Shukla, 1946; Ogura, 1962; Lakhanpal, 1955; Rao & Menon, 1965; Menon, 1968; Tidwell *et al.*, 1971; Bonde *et al.*, 2004); root comparable to *Nypa* (Verma, 1974) and borassoid palm roots (Ambwani, 1981). All these roots appear to belong to the 'Normal absorbing roots' (Mahabale & Udwadia, 1960; Mahabale, 1982). The new species differs from the above roots as it forms a thick mantle of small to medium sized coralloid aerial roots, thick exodermis, round to elongated air chambers in 3-7 rings, presence of fibre cells, fewer (12-15) number of xylem and phloem bundles and sclerenchymatous pith with 0-3 medullary bundles.

Comparison with extant palms—Blatter (1926), McCurrach (1960), Corner (1966), Langlois (1976), Mahabale (1982), Tomlinson (1990) and Uhl and Dransfield (1987) have studied the morphology of roots in palms. Four types of roots have been noted in palms (Mahabale & Udwadia, 1960; Mahabale, 1982). They are : Type-I. Normal absorbing roots - small and large sized secondary or tertiary roots forming a cluster at the basal region of the stem near the soil functioning as absorbing roots, e.g. *Areca, Borassus, Caryota, Cocos, Corypha,* etc. Type-II. Stilt roots - very thick and large sized aerial plagiotropic roots that produces secondary and tertiary roots after reaching the soil, e.g. *Campecarpus, Catoblastus, Iriartea, Iriartella, Pinanga, Socretea,* etc. Type-III. Aerial roots forming a mantle around the stem – endogeneously originated roots at the basal and epibasal region of the stem forming a thick jacket and growing downward in various angles but not reaching the soil, e.g. *Areca catechu, Caryota urens, Cocos nucifera, Hyphaene dichotoma, Phoenix sylvestris,* etc. and Type-IV. Pneumatophores - secondarily produced roots growing vertically upward in swampy habitats, e.g. *Mauritia, Metroxylon, Phoenix, Raphia,* etc. The roots of new species indicate their similarity with Type-III, where the aerial roots form a thick mantle around the stem.

The morpho-anatomical characters of the fossil roots have been compared with those of the root mantle in *Areca catechu* L., *Caryota urens* L., *Cocos nucifera* L., *Hyphaene dichotoma* (White) Furtado and *Phoenix sylvestris* (L.) Roxb. Of these, *Areca catechu, Caryota urens* and *Cocos nucifera* have thick roots similar to the normal absorbing roots present at the base of the stem running straight way down and possess 35-80 xylem bundles. Moreover, *Caryota urens* possesses fibre bundles while *Areca catechu* has both fibre and medullary bundles. The roots of new species show their resemblance with *Hyphaene dichotoma* (White) Furtado and *Phoenix sylvestris* (L.) Roxb. in having coralloid aerial roots forming a thick mantle, air cavities in rings, 1-3 medullary bundles but differs from them due to the lack of fibre bundles (Fig. 2B-E). Accordingly, these roots are described as *Rhizopalmoxylon singulare* sp. nov. from the Late Cretaceous Deccan Intertrappean beds of India.

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