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Rhizopalmoxylon gothanii sp.nov- a new record of permineralized adventitious roots from the Deccan Intertrappean beds of Umaria and Its Environmental Significance

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Abstract
A new species of Permineralized adventitious palm roots having root-matrix, have been reported under the organ genus *Rhizopalmoxylon* (*Rhizopalmoxylon gothanii* sp.nov.) from Deccan Intertrappean beds exposed at Umaria, Madhya Pradesh, India. The present specimen shows the closest resemblance with the artificial genus *Rhizopalmyxylon* Gothan of the family Arecaeae.. Morpho-anatomical characters of the root indicate that the present fossil root differs from the known species of *Rhizopalmoxylon* Gothan. However, it does not show resemblance in toto with any of them and hence a new species *Rhizopalmoxylon gothanii* sp.nov. is created. The abundance of costal and mangrove fossil plants and marine algae from the Deccan Intertrappean beds of this area indicates, in past, this region was much more humid and receives more rainfall and point out marine influence and existence of tropical rainforest ecosystem in the vicinity of this fossil locality in contrast to the deciduous forests occurring there at present.

Key words— *Rhizopalmoxylon*, Permineralization, Deccan traps, Anatomy, Adventitious roots.

Introduction

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. Isolated adventitious monocotyledonous roots indicating affinities with family Aracaceae are described under the organ genus *Rhizopalmoxylon* Gothan. The name *Rhizopalmoxylon* was first used by Felix (1883) for permineralised roots of palms. However, he did not provide the description or diagnosis and hence it became invalid (*Nomen nudum*). Lateron, Gothan (1942) validly published the name *Rhizopalmoxylon* providing the diagnosis and description. *Rhizopalmoxylon* Gothan possesses 13 species, viz., *R. glaseli* Gothan (1942), *R. bohlenianum* Gothan (1942), *R. libycum* Koeniguer (1970), *R. behuninii* Tidwell, Medlyn & Thayn (1972), *R. blackii* Tidwell *et al.* (1972), *R. scottii* Tidwell *et al.* (1972), *R. sundaram* Mahabale & Rao (1973), *R. huepaciense* Cevallos-Ferriz & Ricalde-Moreno (1995), *R. teguachiense* Cevallos-Ferriz & Ricalde-Moreno (1995), *R. borassoides* Awasthi *et al*. (1996), *R. angiorhizon* (= *Palmoxylon angiorhizon* Stenzel, 1904) Bonde *et al*. (2008), *R. macrorhizon* (= *Palmoxylon macrorhizon* Stenzel, 1904) Bonde *et al*. (2008) and *R. singulare* Bonde *et al*. (2008). In addition, Verma (1974) reported a root comparable to *Nypa* and Ambwani (1981) a borassoid root from Mohgaonkalan and Nawargaon Intertrappeans respectively.

Fossil roots reported so far have not been described with uniform terminologies which lack precision and delimitations of the tissues. Considering a need to have uniform terminologies in the description of permineralized roots, a system based upon Seubert's work has been proposed by (Bonde, 2009) to describe the monocotyledonous roots.

Materials and Methods

The present work is based on a permineralized chert piece collected from Deccan Intertrappean beds exposed at Umaria (23º38' to 24º20' N, 80º28' to 82º12'E), Madhya Pradesh, India, from where quite many angiosperms remains, especially the fossil record of Arecaceae are rich and widespread. Specimen No. specimen numbered U 11/98 is 14 cm long and 14x15 cm -12x22 cm. wide show large sized monocotyledonous roots embedded in the chert matrix. The root wood exhibits adventitious roots of medium size measuring 5-9 mm in diameter. 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 Power shot S45 Digital Camera. Looking at the arbitrary use of anatomical terminologies by

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Volume: I

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 ontogenetically 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.

Systematic Description

Family : Arecaceae (Palmae).

Genus : *Rhizopalmoxylon* Gothan (1942).

Species: ***Rhizopalmoxylon gothanii* sp.nov.**

(Plate I Figs. a- h).

Specific Diagnosis

Roots adventitious, size large. Rhizodermis, without appendages. Exodermis thin. Outer cortex single zoned composed of small thick walled cells. Inner cortex three zoned, middle zone aerenchymatous; air cavities small, radially elongated in 9-11 rings. Vascular region wide. Xylem / phloem bundles, 17-25 in a ring. Medullary bundles large, 5-11. Pith large, 1.6-2.2 mm in size. Fibre bundles, fibre cells present.

Holotype : U 11/98 (Slide Nos. 1-13). Department of Palaeobiology, Agharkar Research Institute, Pune.

Horizon : Deccan Intertrappean Beds of India.

Locality: Umaria, District Mandla, Madhya Pradesh, India.

Age : Upper Cretaceous (Maastrichtian).

Etmology : The specific epithet "*gothanii*" is after a well known Palaeobotanist, Professor W. Gothan of Berlin, Germany.

Plate I

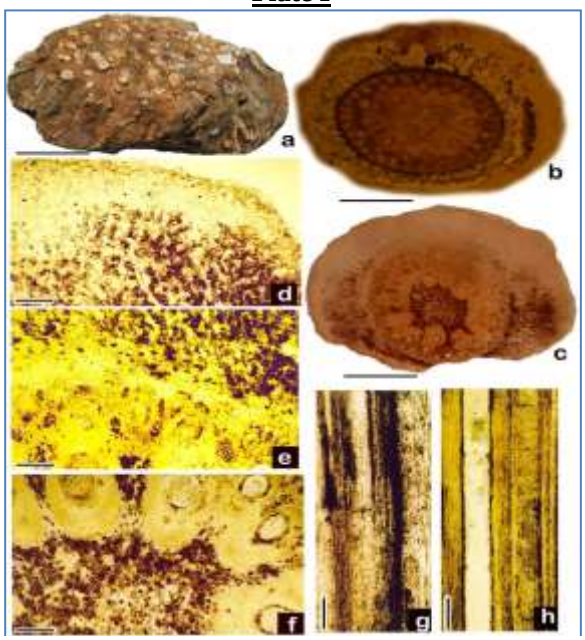

Fig.a -Entire specimen of a chert showing embeded roots, Scale bar = 0.6 cm. **Fig.b& c** - T.S. of root showing cortex and vascular regions, Scale bar = 0.26 mm. **Figs d, e & f** – T.S of root showing cortical and vascular regions : d- outer cortical region; e- inner cortical and vascular regions; f- medullary bundles in pith. Scale bar = 45 µm. **Fig.g** - L.S. showing the horizontal end plate and cortex. Scale bar = 45 µm. **Fig.h** - L.S. showing vessel length. Scale bar = 45 µm.

Description

A fossil specimen numbered U 11/98 is 14 cm long and 14x15 cm -12x22 cm. wide show large sized monocotyledonus roots embedded in the chert matrix. The root wood exhibit adventitious roots of medium size measuring 5-9 mm in diameter (Fig. a) .It has a single layered rhizodermis composed of thin walled tangentially elongated cells and there are no appendages. Inside is 4-5 layered exodermis 65-90 µm wide. It is composed of compactly arranged thick walled small cells. *Outer cortex* is single zoned, 60-90 µm wide and made up of compactly arranged polygonal thick walled cells with very small intercellular spaces. *Inner cortex* is very wide occupying almost two third width of the cortex. It is divisible into three zones. Outer zone is 105-120 µm wide, composed of small thin walled cells having small intercellular spaces. The cells are 15x 22 µm in size. Middle zone is 1500-1700 µm wide. The cells are radially elongated and form large intercellular spaces. Air cavities are radially elongated, arranged in 9-11 radial rows. These air

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Volume: I

cavities are bounded by one to two layered parenchymatous diaphragms. The inner zone is 3-5 celled (60-90 µm) wide. The cells are smaller in size, measuring 15 x 30 µm and are arranged in 3-5 concentric rings with small intercellular spaces. *Endodermis* is single layered without any passage cells (Figs. b, d, e). The radial and inner walls of the cells are thickened whereas the outer walls are thin and they show Russow's thickenings. *Pericycle* is single layered and made up of tangentially elongated thin walled, 15 x 30 µm cells. Inside the pericycle is a sclerotic zone enclosing 18- 24 separate xylem (165 x 180-195 x 240 µm) and phloem (90 x105-105 x 105 µm) bundles in a ring alternate to each other embedded in sclerotic ring. Inside the sclerotic zone lies the pith. The pith is heterocellular with small intercellular spaces. It is 1.6-2.2 mm in diameter. Medullary bundles are 1-3, measuring 180 x 180-180 x 195 µm (Figs. c,f). The metaxylem vessels of the xylem bundles and medullary bundles are embedded in the parenchymatous tissue. Sclerotic cells and small fibre bundles are abundant in the entire cortex and pith regions. The vessels are long. The endplate possesses simple perforation or sometimes having 1-2 bars in the endplate.

Comparison and Discussion

Normal absorbing adventitious small to large sized roots; wide cortex, inner cortex with elongated air spaces in 9-11 concentric rings; 17-25 xylem bundles alternating with phloem bundles in a ring; abundance of sclerotic cells and fibre bundles and large number of medullary bundles are the characteristic features of the present fossil roots suggesting its affinity with palms, Family Aracaceae / Palmae (Seubert 1996 a, b, 1997, 1998a, b).

Comparison with fossil palms

The present fossil root resembles *R. huepaciense*, *R. teguachiense*, *R. borassoides*, *R. sundaram*, *R. singulare* and *R. macrorhizon* in some characters. *R. huepaciense* differs in having 3-10 rings of air cavities in the middle zone of inner cortex, 3-45 xylem bundles and few diminutive bundles. *R. teguachiense* differs in having thick walled pericycle, vascular bundles surrounded by thin walled elongated cells, homocellular parenchymatous pith and few medullary bundles. *R. borassoides* differs in having thick exodermis, large air cavities in the inner cortex, endodermis with barrel shaped cell, few medullary bundles and homocellular pith. *R. sundaram* differs in having thick roots, thick exodermis, wide outer cortex, large number of xylem bundles and sclerenchymatous pith. *R. singulare* differs as these are the coralloid roots forming a thick mantle, have air cavities in 3-7 circles, 1-3 layered pericycle, few medullary bundles and sclerenchymatous pith. *R. macrorhizon* differs in having tanniniferous cells in the exodermis, fibre bundles in the cortex, Russow's thickening in endodermis and few medullary bundles. The present root show some resemblance with the roots of *Palmoxylon phytelephantoides* sp. nov.(Chate, 2010) in having thick exodermis, single zoned outer cortex, wide inner cortex and heterocellular pith. However, it differs due to air cavities in 4-5 radial rings, endodermis with Russow's thickening and large number of medullary bundles. *Rhizopalmoxylon mahabalei* sp. nov. in the present thesis also differs in having narrow middle zone of inner cortex, air cavities in 3-4 rings, unthickened endodermis and few (1-3) medullary bundles. The above discussion indicates that the present fossil root differs from the known species of *Rhizopalmoxylon* Gothan. Hence a new species is created.

Comparison with extant palms

Adventitious root system occurs in all the monocotyledons including palms. There are four types of roots in palms: I. Normal absorbing roots, II. Stilt roots, III. Aerial roots forming a mantle around the stem and IV. Pneumatophores (Mahabale & Udwadia, 1960; Mahabale, 1982). Mohl (1845, 1849) was the pioneer to describe the characteristic arrangement of the vascular tissues in roots and their connections with the stem vascular bundles in the root-stem transition zone. He has also noted the occurrence of medullary bundles that are characteristic to the palms. Karsten (1847) observed a single undifferentiated apical meristem. Naegeli (1858), Russow (1875), Falkenberg (1876), De Bary (1877), Van Tieghem (1870), Olivier (1880) and Mangin (1882) enriched our knowledge of the structure of roots in the palms. Cormack (1896) noted polystelic condition in *Areca***,** *Caryota, Corypha, Dypsis, Euterpe, Geonoma, Hyophorbe, Iriartea, Kentia, Livistona, Phoenix, Ptychosperma* and *Verschaffeltia*. Gillain (1900) observed three meristematic layers in the root apex of *Hydriastele* (*Kentia*) and also described the root structure in number of palms. Drabble (1904) investigated 67 species. Mahabale & Udwadia (1960) analyzed the structure of adult roots of 37 palms and initiated the work on the resolution of the genus *Rhizopalmoxylon* to the natural taxa. Seubert (1996a, b, 1997, 1998a, b) analyzed the structure of roots of 159 genera. Bonde (2009) has suggested a system for the resolution of fossil monocotyledons to the natural taxa including the palms. It is based upon Seubert's system (Seubert, 1997) of analysis of extant roots in Aracaceae. As per this system, the palm root exhibits the following tissues from periphery to the centre with little modifications.

1. **Extrastelar region** - 1. Rhizodermis, 2.

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Volume: I

Exodermis, 3. Outer cortex - generally homogeneous, more or less sclerenchymatic which is many a times divisible into three zones; outer and inner zones moderately sclerenchymatic, the middle zone composed of thin walled cells and 4. Inner cortex composed of three zones: outer zone made up of small cells with few small intercellular spaces; middle zone aerenchymatous with larger and wider intercellular spaces formed by disintegration of some of the cells; the inner zone composed of compact tissue of small cells oriented in concentric rows with minute intercellular spaces. Endodermis being the innermost layer of this zone.

2. **Stelar region (Vascular cylinder)** - Different types of steles ranging from eustele to polystele. 1. Pericycle – one to several (mostly 1-3) layered. 2. Sclerotic zone embedding separate xylem and phloem bundles alternate to one another. 3. Pith – sclerenchymatous and / or parenchymatous – homo or heterocellular and 4. Medullary bundles 5-11, composed of 1-2 vessels and / or phloem along with conjunctive parenchyma enclosed in sclerenchymatic tissue. Single layered tangentially elongated rhizodermis, many layered exodermis, single zoned outer cortex, three zoned inner cortex with well developed aerenchyma, sclerenchyma cells in the cortex and endodermis with Russow's thickening indicate its resemblance with palms such as *Chamaerops, Coccothrinax, Chelyocarpus, Pritchardia, Rhapis, Thrinax, Trachycarpus, Trithrinax, Colpothrinax, Bismarckia, Borassus, Borassodendron, Corypha, Hyphaene, Latania, Livistona, Guihaia, Phoenix*, etc. However, it does not show resemblance in toto with any of them. Accordingly, these roots are described as *Rhizopalmoxylon gothanii* sp. nov. from the Late Cretaceous Deccan Intertrappean beds of India.

Conclusion and Significance

The specimen was collected from the late Cretaceous sediments of Deccan Intertrappean beds, Umaria, Mandla district, Madhya Pradesh, India. The fossil record of Deccan Intertrappean Beds exposed at Umaria and nearby fossil localities such as Mandla, Ghugua and Dindori, etc. consists of mainly plants belonging to the topmost Cretaceous to early Tertiary periods of geological past.

The abundance of costal and mangrove fossil plants such as *Acrostichum* (Mangrove fern), *Nypa* (Mangrove Palm), *Cocos*, *Sonneratia*, *Phoenix* (Costal Palms) and marine algae from the Deccan Intertrappean beds of this area indicates, in past, this region was much more humid and receives more rainfall and point out marine influence and existence of tropical rainforest ecosystem in the vicinity of this fossil locality in contrast to the deciduous forests occurring there at present.

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Volume: I

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