

## A new species, a new combination and a new subsection of *Cycas* from Odisha, northern Eastern Ghats of India

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(Accepted June 15, 2015)

### ABSTRACT

*Cycas circinalis* var. *orixensis* Haines (Cycadaceae) is raised to species rank and a new species, *Cycas nayagarhensis* is described and illustrated from the state of Odisha in the northern Eastern Ghats of India. Both of these Odisha *Cycas* species described here, have characteristic megasporophylls having spinescent lateral teeth and a spear-like long apical spine. Male cones are the most peculiar in having microsporophylls with upturned, one to variously forked apical spines. *Cycas nayagarhensis* is distinguished from *C. orixensis* by its massive arborescent stem, large male cones, with microsporophylls having entire or variously forked apical spine and radially compressed ovules. A comparative table of the northern Eastern Ghats *Cycas* and a key to all the Indian species are provided. The infrageneric classification of the genus *Cycas* is modified and a new Subsection Orixenses under Section *Cycas* is created here to accommodate these two morphologically distinct endemic taxa from Odisha.

**Key words:** *Cycas orixensis*, *Cycas nayagarhensis*, Eastern Ghats, Odisha, India

### INTRODUCTION

In 1924, Haines described *Cycas circinalis* var. *orixensis* from Orissa (now Odisha). He described the taxa on the basis of forked tips of the microsporophylls in male cones and comparatively longer spinescent apical spine and lateral spines in megasporophylls. Though he did not cite any type, he mentioned about its occurrence in wild in the hill forests of the Mals of Puri which extends northward up to Angul. In “Flora of Madras Presidency”, Gamble (1928) reported only two species of *Cycas* namely *C. circinalis* and *C. beddomei*. In cycad taxonomy, male cone characters are usually not used for differentiating taxa (Walters et al., 2004) and as a rule, the basic morphology of the mature microsporophyll is found to be fairly uniform in having a wedge shaped fertile part which expands distally from a narrow point of attachment and bears a large number of microsporangia on its abaxial surface followed by a sterile end part which usually tapers into a pointed or truncated, upcurved, unbranched apex (Whitelock, 2002; Jones, 2002). Forked apical spine of the microsporophyll in the generally known morphological nature of microsporophyll is considered to be as an “abnormality” (De Laubenfels, 1999; Jones, 2002; Whitelock, 2002). Characteristic forkings in the microsporophylls as mentioned by Haines could not be examined by later authors as all the herbarium collections housed at Kolkata, Dehradun and Kew have specimens of either leaves or sterile megasporophylls.

Hill and Lindstrom (2007) synonymised *C. circinalis* var. *orixensis* under *Cycas sphaerica* Roxb., from the plants under cultivation in the Royal Botanic Gardens, Sibpur, Howrah (now known as Acharya Jagdish Chandra Bose Indian Botanic Garden). The plants were said to have been introduced from the Moluccas in 1798-9. Roxburgh’s herbarium collection at CAL, Howrah have only the parts of megasporophyll and vegetative leaves (CAL: Roxburgh 448261-73), microsporophylls are not preserved as was the case with *Cycas circinalis* var. *orixensis*. Hill and Lindstrom believed *Cycas sphaerica* Roxb. originated from Odisha and according to them “this species is similar to *Cycas circinalis* in most respects, differing in the broader megasporophyll apex with longer teeth” and is distributed in Odisha, Tamil Nadu, Karnataka and Andhra Pradesh (Lindstrom & Hill 2007). During our field survey and taxonomic study of *Cycas* over several years in Odisha and adjoining areas, we have concluded that Odisha *Cycas* populations have distinctive male and female cone characters.

On the basis of variously forked apices in the microsporophylls and characteristic spinescent lateral teeth and a spear-like long apical spine of megasporophylls, *Cycas circinalis* var. *orixensis* is raised to the rank of species, *Cycas orixensis* (Haines) R. Singh and J.S. Khuraijam comb. et stat. nov. This species is distributed in six districts of Odisha state namely Angul, Boudh, Dengkanal, Ganjam, Kendujhar and Mayurbhanj. During field surveys in Central Odisha in the district of Nayagarh, few populations having more robust habit and different and distinct morphological features from *Cycas*

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*orixensis* were discovered. These populations are described and illustrated here as a new species, *Cycas nayagarhensis* R. Singh, P. Radha & J.S. Khuraijam sp. nov.

A new subsection is added in the infrageneric classification of the genus *Cycas* (sensu Hill, 1995) to accommodate these two distinct species, *C. orixensis* (Haines) R. Singh and J.S. Khuraijam comb. et stat. nov. and *C. nayagarhensis* R. Singh, P. Radha & J.S. Khuraijam sp. nov. which are endemic to the northern Eastern Ghats of India.

#### Section *Cycas*

##### A Subsection *Cycas*

##### **B Subsection *Orixenses*** R. Singh and J.S. Khuraijam, **subsect. nov.**

Masculum coni unus-multis-furcatis, spiniscent apicalibus spina de microsporophyll, feminam sporophyll longiori spiniscent lateralibus et dentes et diu prominent apicalibus spine.

TYPE: *Cycas orixensis* (Haines) R. Singh & J.S. Khuraijam comb. et. stat. nov.

This new subsection is characterised by the one- to many- forked, spiniscent apical spine of the microsporophyll, female sporophyll with longer spiniscent lateral teeth and a long prominent spear-like apical spine. The subsection contains *C. orixensis* (Haines) R. Singh & J.S. Khuraijam comb. et. stat. nov. and *C. nayagarhensis* R. Singh, P. Radha & J.S. Khuraijam sp. nov.

##### C Subsection *Endemicae*

##### D Subsection *Rumphiae*

***Cycas orixensis*** (Haines) R. Singh & J.S. Khuraijam **comb. et stat. nov.**

**Basionym:** *Cycas circinalis* var. *orixensis* Haines, Bot. Bihar Orissa 6: 1228 (1924).

**TYPE:** India, Odisha, Mals of Puri, Haines 5876, June 1917 (syn. K); Angul, Haines 5877, July 1917 (syn. K).

**EPITYPE:** India, Odisha: Angul District, Mar. 2010, R. Singh and J.S. Khuraijam, designated here – 67636 (♂) (currently housed at Herbarium, USEM, GGS Indraprastha University, New Delhi shall be deposited in CAL, Howrah). (Figs. 1-3)

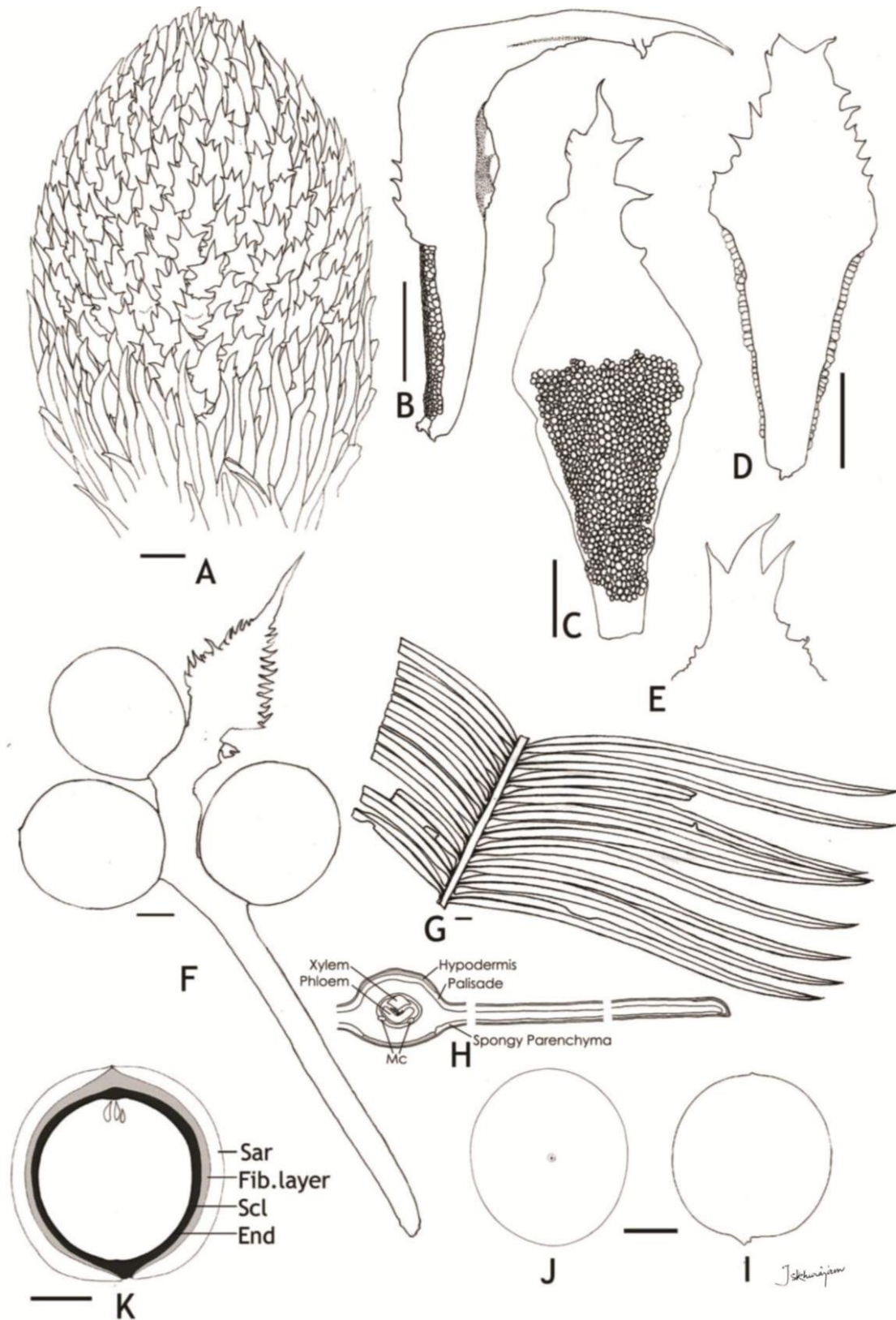
Planta arborescens; microsporophyllis obrullatis, perpendicularibus, spina apicali inflexa, integra vel 1-multi-furcata, furcis inaequalibus.

Trunk tall slender, upto 6 m in height, 12.5-32 cm in diam., generally unbranched older plants usually without persistent armour of leaf bases. Photosynthetic leaves pinnately compound with 40-96 pairs of pinnae, 70-190 cm long, dark green, discolorous, glabrous, petiole 20-30 cm long with 14-26 pairs of spines. Median pinnae 18-25 cm long, 7-15 mm wide, 7-10 mm apart, decurrently attached to the adaxial surface of the rachis at an angle of

40°-50°. In cross-section, pinnae show 2 to 3 mucilage canals towards the abaxial (phloem side) of the vascular bundle. Male cones ovoid, yellowish-orange turns orangish red during peak of the day at the time of anthesis or pollen dispersal, 11-21 cm long, 10-12 cm in diameter. Spirally arranged microsporophylls have obrulloid lamina, 40-45 mm long, 12-20 mm wide; fertile zone 23-29 mm long, sterile apex sharply upturned or inflexed (towards ventral side) into apical spine; apical spine 22-38 mm long; entire or forked, forking usually unequal, generally 1-3 however, a number of irregularly arranged protuberances and blunt spines were also observed below the apical spines along the margins of the apophysis. Female cones compact spirally arranged when young and laxes at maturity. Megasporephylls tomentose, amber coloured, 12-23 cm long, lamina dorsiventral, lanceolate, 45-75 mm long, 20-38 mm wide having 12-20 lateral spines on either side; lateral spines entire or occasionally forked, 6-17 mm long, 1-3 mm wide at the base, apical spine spear-like, 20-40 mm long, 4-8 mm wide. Ovuliferous region 5-9 cm long, ovules 2-6, glabrous, sessile, orthotropus, attached laterally, spheroidal to broadly ellipsoidal in shape, 30-34 mm long, 28-32 mm in diameter, sarcotesta after fertilisation turns yellow to mango-yellow at the time of shedding, 2-4 mm thick, fibrous layer present, sclerotesta stony, endotesta membranous, spongy tissue absent. Seeds platyspermic. Germination cryptocotylar.

**Distinguishing characters.** — *Cycas orixensis* is distinguished from *C. circinalis* by its slender trunk (12.5-32 cm diam.); entire or differently forked nature of the apical spine of the microsporophylls; character of sterile apex of the megasporephylls; size, shape, color, and number of the ovules. It is also distinct from *C. sphaerica* Roxb. in having microsporophyll with one – to many-forked apical spines and the lanceolate lamina of megasporephylls with a long, prominent spiniscent apex. Although Lindstrom and Hill (2007) synonymised *Cycas circinalis* var. *orixensis* under *C. sphaerica*, our observation over a period of 2007-2012 shows forked character of microsporophylls of *C. orixensis* is entirely restricted to Odisha populations. However, female and male cones of *Cycas* populations in Srikakulam, Andhra Pradesh resemble morphologically to *Cycas sphaerica* (Lindstrom and Hill, 2007). None of the vouchers deposited at CAL have preserved microsporophylls. In that case, we assign *Cycas* populations of Srikakulam described by earlier authors to *C. sphaerica*.

**Distribution and Ecology.** — *Cycas orixensis* is distributed from Mayurbhanj, Kendujhar, Dengkanal, Angul in north and crossing Mahanadi River up to Boudh in Central Odisha. The distribution of the species further extends upto Ganjam district in southern Odisha (Fig. 7). They are generally understory constituents of the tropical moist deciduous forest having *Shorea robusta* Gaertner, *Dendrocalamus strictus* Nees and *Bambusa arundinacea* Willd. as dominant species. In Satkosia Tiger Reserve which embraces part of Boudh and Angul, the habitats are swampy and remain inundated during monsoon months of



**Figure 1.** *Cycas orixensis* (Haines) R. Singh and J.S. Khuraijam comb. et. stat. nov. **A.** Male cone with differently forked apical spines. **B-D.** Microsporophylls; lateral view showing inflexed apical spine, lower surface (dorsal) with microsporangia; upper surface (ventral). **E.** Magnified sterile tip of the microsporophyll. **F.** A megasporophyll. **G.** Median part of the leaf. **H.** Cross section of a pinna showing one side of the lamina. **I.** Longitudinal section of an ovule showing sarcotesta (sar), fibrous layer (Fib. layer), Sclerotesta (Scl), Endotesta (End). **J.** Ovule, top view. **K.** Mature seed with intact sarcotesta. Scale bar: 1 cm.



**Figure 2.** *Cycas orixensis* (Haines) R. Singh and J.S. Khuraijam comb. et. stat. nov. **A.** female plant bearing megasporophylls. **B.** A crown of loosely arranged megasporophylls with intact mature seeds. **C.** Male cone. **D.** Magnified male cone showing forked microsporophylls. **E.** A megasporophyll. **F.** Magnified view of the sterile lamina showing apical and lateral spines. **G.** Entire ovule. **H.** Magnified view of the sterile lamina showing forked lateral spines. **I.** Section of ovule. **J-L.** Microsporophylls with differently forked tips and dentate margin of the apophyses (J – Lower surface, K – Upper surface, L – Lateral surface). **M, N.** Forked sterile tip of the microsporophyll (Top view). Scale bar: 1 cm.



**Figure 3.** *Cycas orixensis* (Haines) R. Singh and J.S. Khuraijam comb. et. stat. nov. **A-F.** Male cones with varying colours, different shapes and various forking patterns of microsporophylls.

June to August, they are mostly associated with members of Zingiberaceae and Dipterocarps. The male plants of the southern populations of Ganjam start coning much ahead of the northern populations of Angul and Boudh. Northernmost distribution of *Cycas orixensis* occur in Mayurbanj district where it grows in Simlipal Tiger Reserve. The species also grow in Kendujhar district which lie on the south of Mayurbanj district.

*Phenology.* — Male plant start coning in mid or late March and female plant start producing megasporophylls in May-June.

*Vernacular names.* — *Cycas orixensis* is known by several names in Odisha: *Aruguna*, *Oruguna*, *Orguna*, *Oranga* and *Odissimari*. These names changes along with their ethnic uses.

*Conservation status.* — Cycad populations in the region are under anthropogenic threat primarily due to decimation, clearing and transformation of the uphill forests into cultivable land and secondly due to prevalent practice of harvesting leaves and shoot apex for religious and cultural activities and fertilized ovules or seeds prior to their shedding by the local people and tribals residing in the vicinity of the natural populations. Male cones are also harvested and used as pesticides. The species may be currently regarded as Endangered C2(ai) [IUCN Redlist Categories and Criteria (Ver. 9, 2011)].

#### Selected specimens examined.

**INDIA. Odisha:** Mals of Puri, *Haines* 5876, 5877 (♀), June 1917 (K – images K000077087, K000077088); Angul, *Haines* 18520 (♀), August 1917 (DD); Athamallik, Hathidhara Block, *H. F Mooney* 2867 (♀), May 1947 (DD).

#### Topotypes:

Angul, *R. Singh & J.S. Khuraijam* 67603 to 67630, Sep. 2007; *R. Singh & J.S. Khuraijam* 67631 to 67650 Mar. 2010; *R. Singh & J.S. Khuraijam* 67651 to 67665 Sept 2011; Boudh, *R. Singh & J.S. Khuraijam* 68401 to 68410 Sep. 2007; Dhenkanal, *R. Singh & J.S. Khuraijam* 67601-67602, Sep. 2007; Ganjam, *R. Singh, A.K. Singh & J.S. Khuraijam* 68467-475 Mar 2008; Mayurbanj, *J.S. Khuraijam* 67501-67506 July 2010. These vouchers are housed at Herbarium, USEM, GGS Indraprastha University, New Delhi.

#### Additional specimens examined:

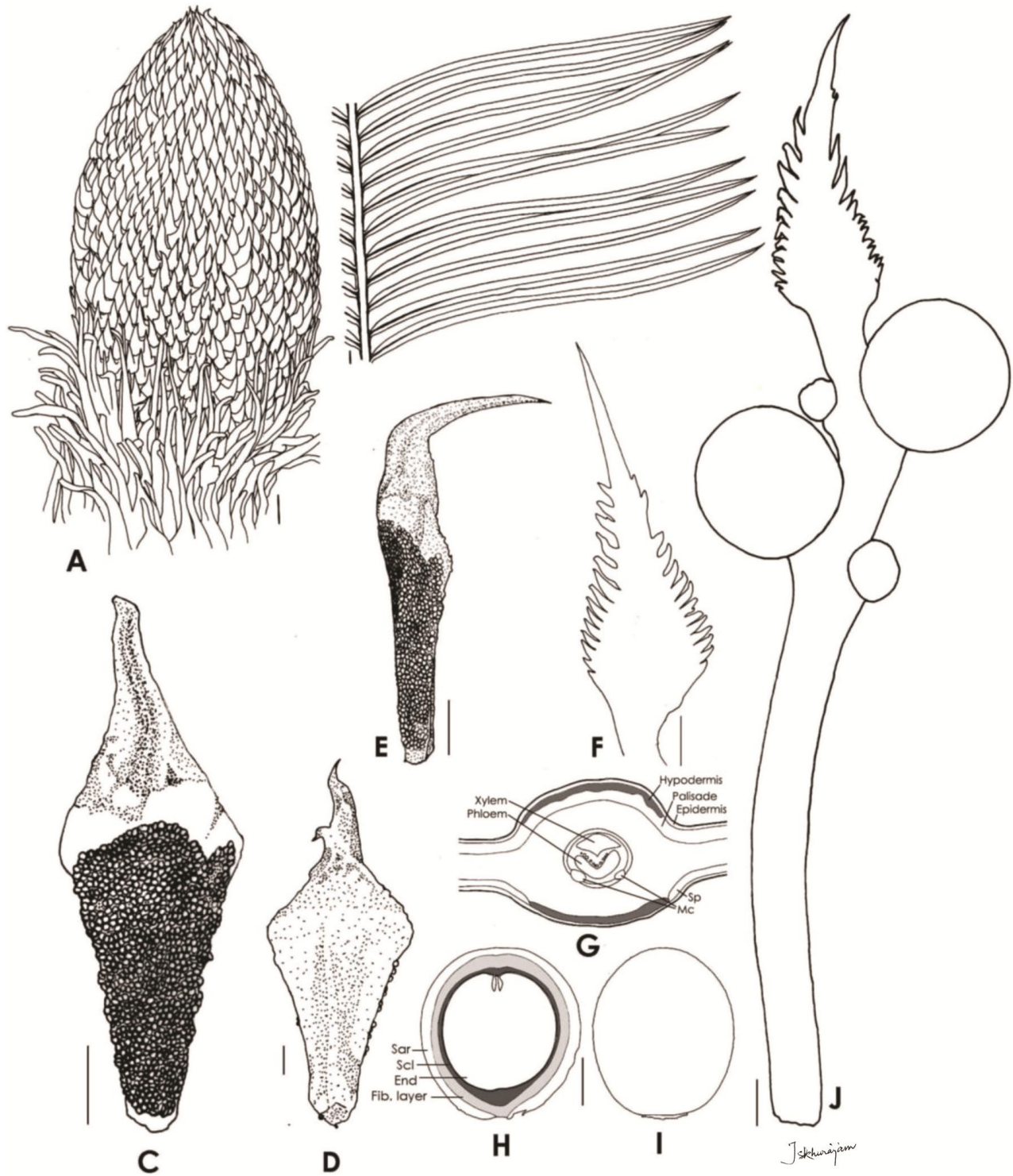
**West Bengal:** CAL (currently known as Central National Herbarium), Howrah, *Roxburgh* 448261, 448262, 448263, 448264, 448265, 448266, 448267, 448268, 448269, 448270 (♀), Jan. 1883; 448271, 448272, 448273 (♀), Aug. 1882.

*Cycas nayagarhensis* R. Singh, P. Radha & J.S. Khuraijam **sp. nov.**

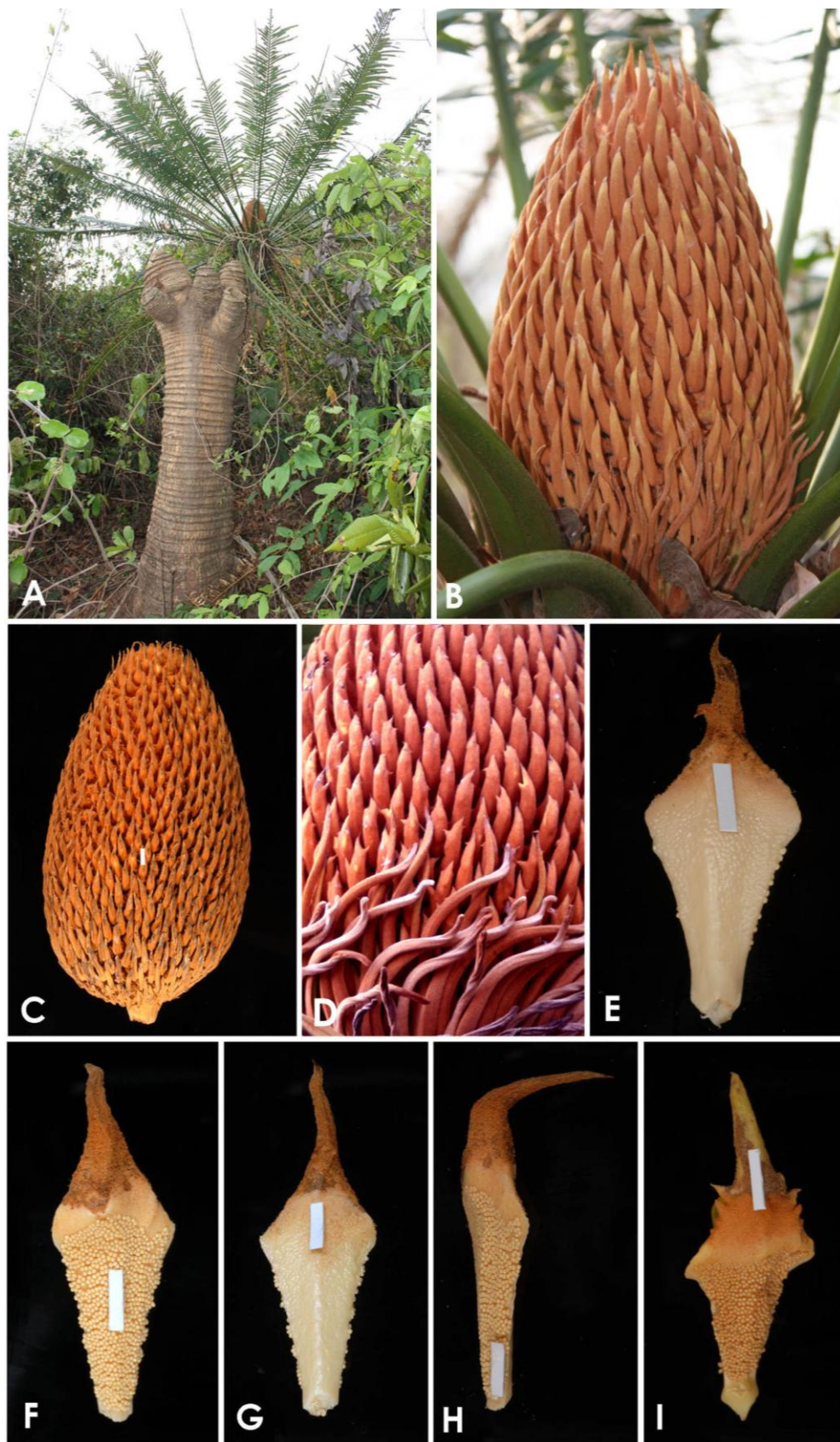
**TYPE:** INDIA. Odisha: Nayagarh, May 2009, *R. Singh & J.S. Khuraijam* (Holotype: 67409, currently housed at Herbarium, USEM, GGS Indraprastha University, New Delhi shall be deposited at CAL, Howrah). (Figs.4-6)

Planta arborescens; robustum trunco latior basi fastigatis apice, amplius ovoideae masculum conos, interdum furcatae, sterile apicem microsporophylls.

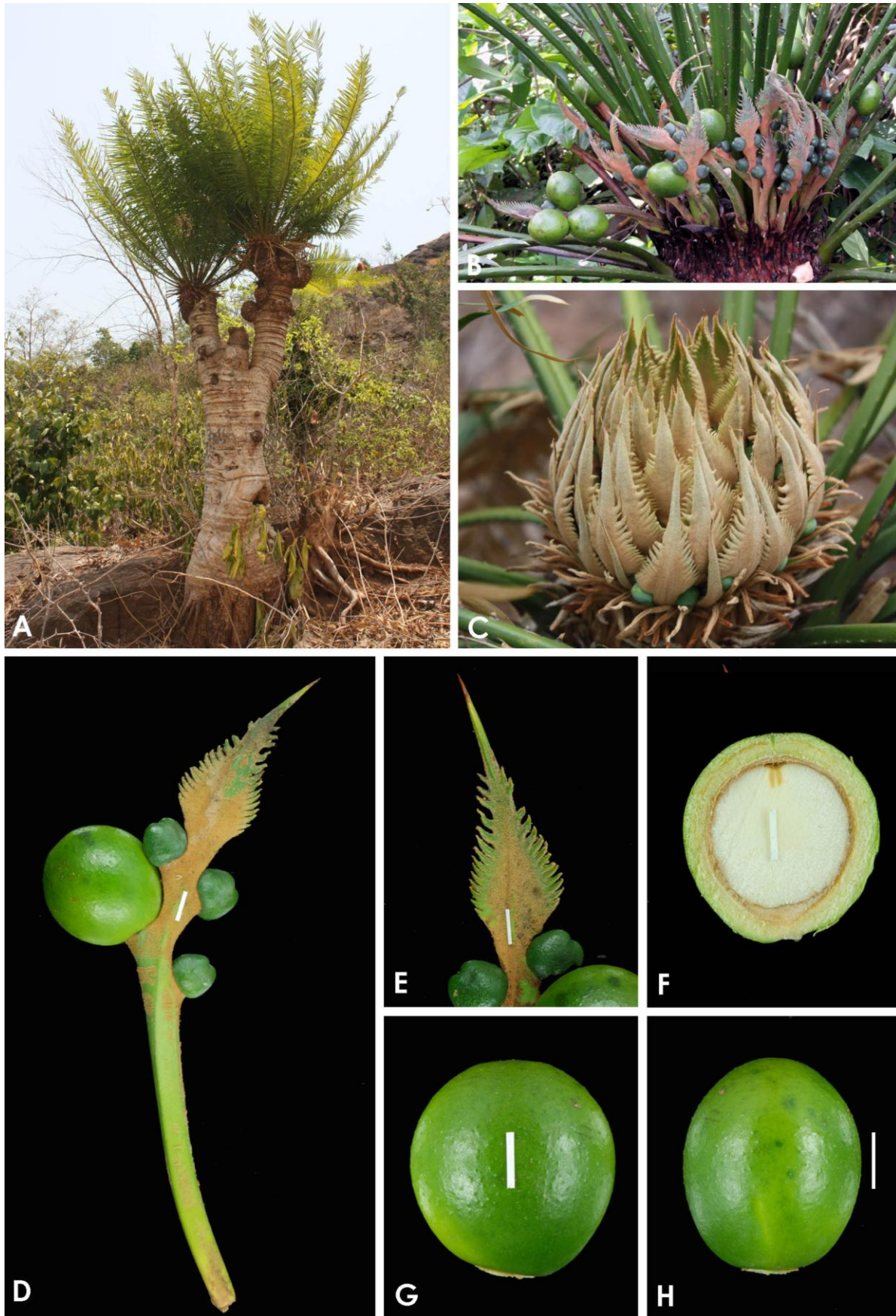
Stem arborescent, branched or unbranched, up to 5 m tall, 50-92 cm diameter. Bark thick with alternate bands of persistent leaf bases and cataphylls in young plants and smooth in mature trees. Photosynthetic leaves pinnately compound with 80-176 pairs of pinnae, 104-210 cm long,



**Figure 4.** *Cycas nayagarhensis* R. Singh, P. Radha and J.S. Khurajam sp.nov. **A.** A male cone, **B.** Median part of the leaf. **C-E.** Microsporophylls; lower surface (dorsal) with microsporangia; upper surface with forked sterile apex and lateral view. **F.** Magnified sterile tip of the microsporophyll. **G.** Cross section of a pinna showing one side of the lamina. **H.** Longitudinal section of an ovule showing sarcotesta (sar), fibrous layer (Fib. layer), Sclerotesta (Scl), Endotesta (End). **I.** Mature seed with intact sarcotesta. **J.** A megasporephyll. Scale bar: 1 cm



**Figure 5.** *Cycas nayagarhensis* R. Singh, P. Radha and J.S. Khuraijam sp.nov. **A.** Robust habit, **B-C.** Male cone. **D.** Magnified portion of male showing sterile apex. **E.** Microsporophyll with forked sterile apex. **F-I.** Microsporophylls (**F.** upper surface, **G.** lower surface, **H.** lateral view, and **I.** lower view showing lateral spines). Scale bar: 1 cm



**Figure 6.** *Cycas nayagarhensis* R. Singh, P. Singh and J.S. Khuraijam sp.nov. **A.** Habit. **B.** A female plant with megasporophylls. **C.** Young emerging megasporophylls. **D.** Megasporophyll with intact ovules. **E.** Magnified view of the sterile lamina showing apical and lateral spines. **F.** Section of ovule. **G.** Entire ovule. **H.** Lateral view of ovule. Scale bar: 1 cm



glossy (glaucous), bluish green in colour. Petiole 28-47 cm long, spinescent, spines 18-29 pairs. Pinnae lanceolate, glabrous, discolourous, margin entire beak shaped in cross section with ventrally prominent midrib. Median pinnae 19-28 cm long, 6-10 mm wide and attached to the rachis at 50-55°. Male cone ovoid, subconical, 18-43 cm long, 10-20 cm in diameter, yellow orange in colour. Microsporophylls 40-50 mm long, 20-25 mm wide, fertile zone 30-34 mm long, apical spine stout, upturned, 22-30 mm long, entire, occasionally forked. Female cones compact when young and megasporophylls loosely arranged on maturity. Megasporophylls tomentose, 12-19 cm long, lamina dorsiventral, lanceolate, 70-85 mm long, 28-37 mm wide, 13-25 lateral spines on either side, lateral spines entire, 4-9 mm long, 1-4 mm wide at the base, apical spine 30-46 mm long. Ovuliferous region 6-12 cm long, ovules 1-6, glabrous, sessile, laterally compressed, spheroidal to broadly ellipsoidal, 33-38 mm long, 35-39 mm in diameter, green when young turn mango yellow at maturity, sarcotesta 40-50 mm thick, fibrous layer present, sclerotesta stony. Seeds platyspermic. Germination cryptocotylor.

#### Selected specimens examined.

**INDIA. Odisha.** Nayagarh, *J.S. Khuraijam* (♂) May 2009, 67404-67434; *J.S. Khuraijam* (♂) July 2010, 67435-67444; *R. Singh & J.S. Khuraijam* (♀) Sep, 2011, 67445-67456.

*Distinguishing characters.* — Large trunk (50-92 cm in diam.), wider at base tapering apically, large ovoid male cones, occasionally forked sterile apex of the microsporophylls.

*Etymology.* — The specific epithet is named after the district Nayagarh in Odisha where this species is naturally found in three populations.

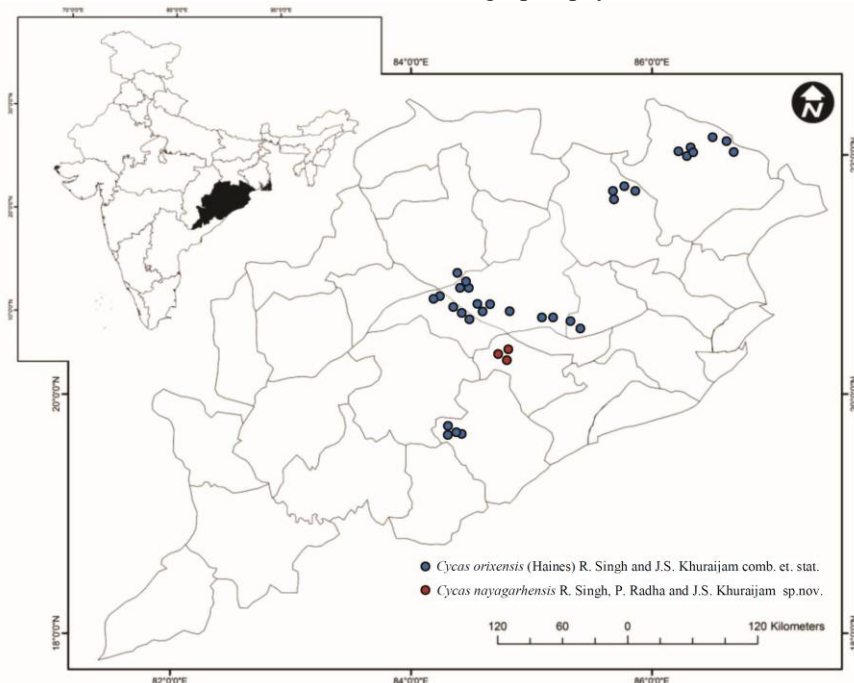
*Distribution and Ecology.* — *Cycas nayagarhensis* is reported from three populations in Nayagarh district of Odisha: Gamein Hills, Rukhi Hills and Balram Hills. This species grow on the open sandstone rocky hills at an elevation of 135-180 m.

*Phenology.* — Female cones start emerging in June-July and male cones in March-May.

*Vernacular names.* — *Aruguna, Oruguna, Orguna, Oranga* and *Odissimari*.

*Conservation status.* — Populations of *Cycas nayagarhensis* are severely affected by hacking of stems for religious and cultural rituals. Land transformation due to expansion of Nayagarh city has resulted in steep decline in the cycad population. The species grow only in three elevated localities Rukhi, Balram and Gamein with only few plants. Considering its small population size with very few mature trees, the species can be enlisted as Critically Endangered, B2ab(iii,v) [IUCN Redlist Categories and Criteria (Ver. 9, 2011)].

*Notes:* The stem of *Cycas nayagarhensis* resemble *C. swamyi* (Singh & Radha, 2008) in having columnar stem of equal diameter except for the broader base. The megasporophylls of *C. nayagarhensis* are covered with yellow-orangish hair and have pointed spear-like long apical spine *ca* 30-40 mm. *Cycas nayagarhensis* differ from *C. circinalis* in having forked tip of microsporophyll, and occasionally forked lateral spines and prominent spear-like apical spines of megasporophylls.



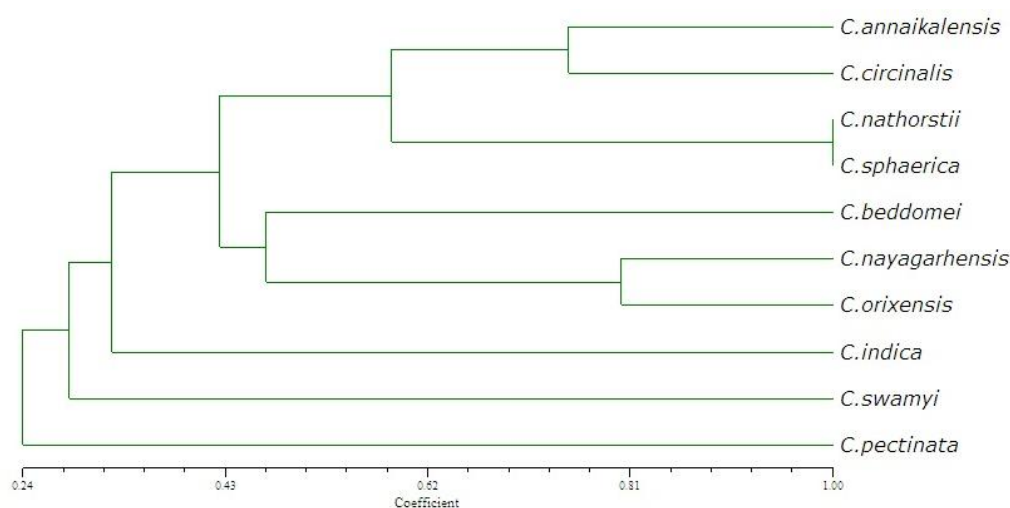
**Figure 7.** Map of Odisha showing distribution of *Cycas orixensis* (Haines) R. Singh and J.S. Khuraijam comb. et. stat. nov. and *Cycas nayagarhensis* R. Singh, P. Radha and J.S. Khuraijam sp. nov.

**Table 1.** Comparative morphological characters of northern Eastern Ghats *Cycas* and *Cycas circinalis* L.

Characters	<i>Cycas circinalis</i> L.	<i>Cycas sphaerica</i> Roxb. (Lindstorm & Hill, 2007)	<i>Cycas orixensis</i> (Haines) R. Singh & J.S. Khuraijam comb. et. stat. nov	<i>Cycas nayagarhensis</i> R. Singh, P. Radha & J.S. Khuraijam sp. nov.
<b>Habit and Stem</b>	Stem arborescent, 5 m tall, columnar, sometime branched, 18-83 cm in diam.	Stem arborescent, 5m tall, 9-27cm diameter, base not strongly swollen, bark thick with persistent leaf bases and cataphylls.	Trunk slender, upto 6 m tall, 12.5-32 cm in diam., generally unbranched without persistent armour of leaf bases.	Stem arborescent, branched or unbranched, up to 5 m tall, 50-92 cm diameter. Bark thick with alternate bands of persistent leaf bases and cataphylls when young and smooth in mature plants.
<b>Leaves</b>	Leaves 1-2.5 m long with 100-120 pairs of pinnae. Petiole 50-70 cm long, spinescent, spines ca 2.5 mm long. Median pinnae 30-35 x 0.9-1.4 cm.	Dark green, semiglossy, 95-185 cm long, flat (not keeled) in section, (opposing leaflets inserted at 180° on rachis), with 55-130 leaflets, with newly emerging leaves light green and lacking tomentum because tomentum sheds very early as leaf expands. Petiole 27-50 cm long, glabrous, spinescent for 20-100% of length. Leaflet 18-27 cm long, 0.7-1.2 cm wide	Photosynthetic leaves pinnately compound with 40-96 pairs of pinnae, 70-190 cm long, dark green, discolorous, glabrous, petiole 20-30 cm long with 14-26 pairs of spines. Median pinnae 18-25 cm long, 7-15 mm wide, 7-10 mm apart, decurrently attached to the adaxial surface of the rachis at an angle of 40°-50°. In cross-section, pinnae show 2 to 3 mucilage canals towards the abaxial (phloem side) of the vascular bundle.	Leaves 1.04-2.10 m long with 80-176 pairs. Petiole spinescent, 28-47 cm long, spines 18-29 pairs. Pinnae lanceolate, margin entire and glabrous with prominent midrib. Median pinnae 19-28 cm long × 0.6-1 cm wide and attached to the rachis at 50-55°.
<b>Male cone</b>	Male cone oblong to oval, deep yellow to orange in colour, 30-50 cm long. Microsporophylls 3.1-8.1x1.4-2.5 cm. Fertile zone 1.9-4.0 cm long, sterile zone length 1.5-4.2 cm.	Narrowly ovoid, orange, c.45 cm long, c. 10 cm diameter, microsporophyll lamina firm, not dorsiventrally thickened, 32-38 mm long, fertile zone 28-34 mm long, sterile apex c. 4 mm long, merging with apical spine; apical spine prominent, gradually raised, c. 17 mm long.	Male cones ovoid, yellowish-orange turns orangish red during peak of the day at the time of anthesis or pollen dispersal, 11-21 cm long, 10-12 cm in diameter. Spirally arranged microsporophylls have obtrulloid lamina, 40-45 mm long, 12-20 mm wide; fertile zone 23-29 mm long, sterile apex sharply upturned or inflexed into apical spine; apical spine 22-30 mm long; entire or forked, forking usually unequal, generally 1-3 however, a number of irregularly arranged protuberances and blunt spines were also observed below the apical spines along the margins of the sterile tip.	Male cone large, ovoid, sub conical, 18-43 cm long, 10-20 cm in diameter, orange in colour. Microsporophylls 40-50 mm long, 20-25 mm wide, fertile zone 30-34 mm long, apical spine stout, upturned, 22-30 mm long, entire, rarely forked.
<b>Female cone</b>	Megasporophylls 15.3-33 cm long. Megasporophylls lamina 5-9x2-4 cm regularly dentate on either side of the apical snout. Apical snout 1-4 cm long. Ovules 6-12, elliptic (3:2), 2.5-5.2x2-4.5 cm, green when young and orange to brown at maturity. Sarcotesta fleshy ca 3 mm thick, fibrous layer absent, sclerotesta stony, inner layer membranous. Spongy layer absent. Seeds platyspermic, germination cryptocotylor.	Megasporophylls 20-25 cm long, persistently orange-tomentose ; ovules 3-8, glabrous; lamina lanceolate, 28-43 mm long, 18-20 mm wide, shallowly pectinate or regularly dentate, with 21-25 pungent lateral spines 5-10 mm long; apical spine distinct from lateral spines, 17-29 mm long, 4-5 mm wide at base. Seeds sub-globose, 25 mm long, c.25 mm wide; sarcotesta yellow, fibrous layer absent; sclerotesta smooth; spongy endotesta absent.	Megasporophylls tomentose, amber coloured, 12-23 cm long, lamina lanceolate, dorsiventral, 45-75 mm long, 20-38 mm wide having 12-20 lateral spines on either side; lateral spines entire or sometimes forked, 6-17 mm long, 1-3 mm wide at the base, apical spine distinct, 2-0-40 mm long, 4-8 mm wide. Ovuliferous region 5-9 cm long, Ovules 2-6, glabrous, sessile, orthotropus, attached laterally, spheroidal to broadly ellipsoidal, 30-34 mm long, 28-32 mm in diameter, sarcotesta green when young turn yellow to mango-yellow at maturity, 2-4 mm thick, fibrous layer present, sclerotesta stony, endotesta membranous, spongy tissue absent. Seeds platyspermic and germination cryptocotylor.	Megasporophylls tomentose, 12-19 cm long, lamina 70-85 mm long, 28-37 mm wide, lanceolate, dorsiventral; 13-25 lateral spines on either side, lateral spine entire, 4-9 mm long, apical spine 3-4.6 cm long. Ovuliferous region 6-12 cm long Ovules 1-6, glabrous, laterally compressed, spheroidal to broadly ellipsoidal, 33-38 mm long, 35-39 mm in diameter, green when young, yellow at maturity, sarcotesta 4-5 cm thick, fibrous layer present, sclerotesta stony. Seeds platyspermic and germination cryptocotylor.

## Key to the species of *Cycas* in India

1. Microsporophylls apex spinescent with one- to many-forking.
  2. Megasporophylls with long and broad apical spines (20-50×5-10 mm), tall and robust habit (50-92 cm in diam.), male cones large 18-43 cm long, microsporophylls apex with low degree of forking .....*C. nayagarhensis*
  2. Megasporophylls with slender apical spine, tall and slender habit (12.5-32 cm in diam.), male cones small 11-21 cm long, microsporophylls apex with high degree of forking .....*C. orixensis*
1. Microsporophylls apex entire without forking.
  3. Sarcotesta with a fibrous layer.
    4. Pinnae narrow (10-18 × 0.1-0.4 cm) with revolute margins, microsporangiate cones woody, persistent.....*C. beddomei*
    4. Pinnae broad (20-31.5 × 0.7-1.2 cm) with beak shaped or flat margin, deeply pectinate, microsporangiate cones massive 80 × 20 cm, microsporophyll with upturned spine, spines usually green and entire.....*C. pectinata*
  3. Sarcotesta without a fibrous layer.
    5. Pinnae midrib with a groove on the adaxial side, spongy layer present in seeds...*C. zeylanica*
    5. Pinnae midrib without a groove on the adaxial side, margins beak shaped, spongy layer absent in seeds.
      6. Megasporophyll lamina triangular, apiculate. Pinnae with or without mucilage canals.
        7. Margins of the lamina dentate with tough apical spine, apical spine, 0.3-2.5 cm long, ovules, 2-10, globose, 3.8-4.9 × 3.5-4.3 cm, pinnae with mucilage canals on the phloem side of the vascular bundles.....*C. annaikalensis*
        7. Megasporophylls lamina triangular, lateral spines soft, ovules, 4-10, globose, 2.5-4 × 2.3-4 cm, mucilage canals absent in the pinnae.....*C. swamyi*
      6. Megasporophylls lamina lanceolate, margin dentate, with or without distinct apical spine
        8. Megasporophyll without distinct apical spine.....*C. indica*
        8. Megasporophyll with distinct apical spine
          9. Megasporophyll lamina shortly dentate, apical spine distinct, ovules 6-10, flattened ovoid.....*C. nathorstii*
          9. Megasporophyll lamina dentate, apical spine distinct, mucilage canal present in pinnae
            10. Megasporophylls lamina dentate, apical spine distinct, ovules 3-8, spherical.....*C. sphaerica*
            10. Megasporophylls lamina dentate, with apical snout 1-4 cm long, without a distinct apical spine, ovules 6-12, seed elliptic (3:2), 2.5-5.2 × 2-4.5 cm.....*C. circinalis*



**Figure 8.** UPGMA dendrogram obtained through collective morpho-anatomical data, depicting the inter-specific relationship among the Indian *Cycas*. The branch lengths are based on the distance value computed using Jaccard's coefficient of NTYSYS pc 2.02K software.

## ACKNOWLEDGEMENTS

The authors are grateful to Ministry of Environment and Forests, Government of India for the financial support [AICOPTAX, No.J-22018/54/2000/CSC (BC)]. Mr. R. N. Reddy, IFS, Conservator of Forest, Odisha; Dr. Rekha Pai, IFS; Mr. Ashok Pai, IFS and Prof. S.P Adhikari are acknowledged for their kind support during field surveys.

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