

Pinanga subterranea, a New Arecoid Palm from Borneo that Flowers Underground

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A new acaulescent species of *Pinanga* (Arecoideae: Areceae: Arecinae) is described and illustrated here. This remarkable new species is the first palm described as flowering and fruiting underground, highlighting Borneo as a hotspot for palm diversity.

The palm genus *Pinanga* Blume has radiated extensively in Borneo, where it is represented by 40 species (POWO 2023). However, several Bornean species are known only from their types, and little is known of their range of

variation (Dransfield 1980). *Pinanga* diversity in Borneo has not received much attention recently. So far only three species have been described during the 21st century, namely *P. jambusana* C.K.Lim (Lim 2005), *P. limbangensis* C.K.Lim (Lim 2005) and *P. schwanerensis* Randi, Hikmat & Heatubun (Randi et al. 2019), although several undescribed taxa are known.

In Borneo, *Pinanga* displays great variation in size, form and ecology (Dransfield 1991). Almost all Bornean species are small understorey palms with slender stems, but some are acaulescent. Here, we describe a new acaulescent *Pinanga* from Borneo in which the stem, crownshaft and inflorescence are buried below ground level. Following initial observations in Sarawak, where we had recorded the species under the preliminary name *P. aff. brevipes* (Petoe et al. 2020), we have made extensive direct observations in the wild in multiple localities across Borneo of its extraordinary habit of flowering and fruiting underground. The presentation of inflorescences and infructescences below the soil surface (a form of geocarpy) has not been reported previously in any other palm species (Kuhnhäuser et al. 2023). All characters and measurements presented below are based on

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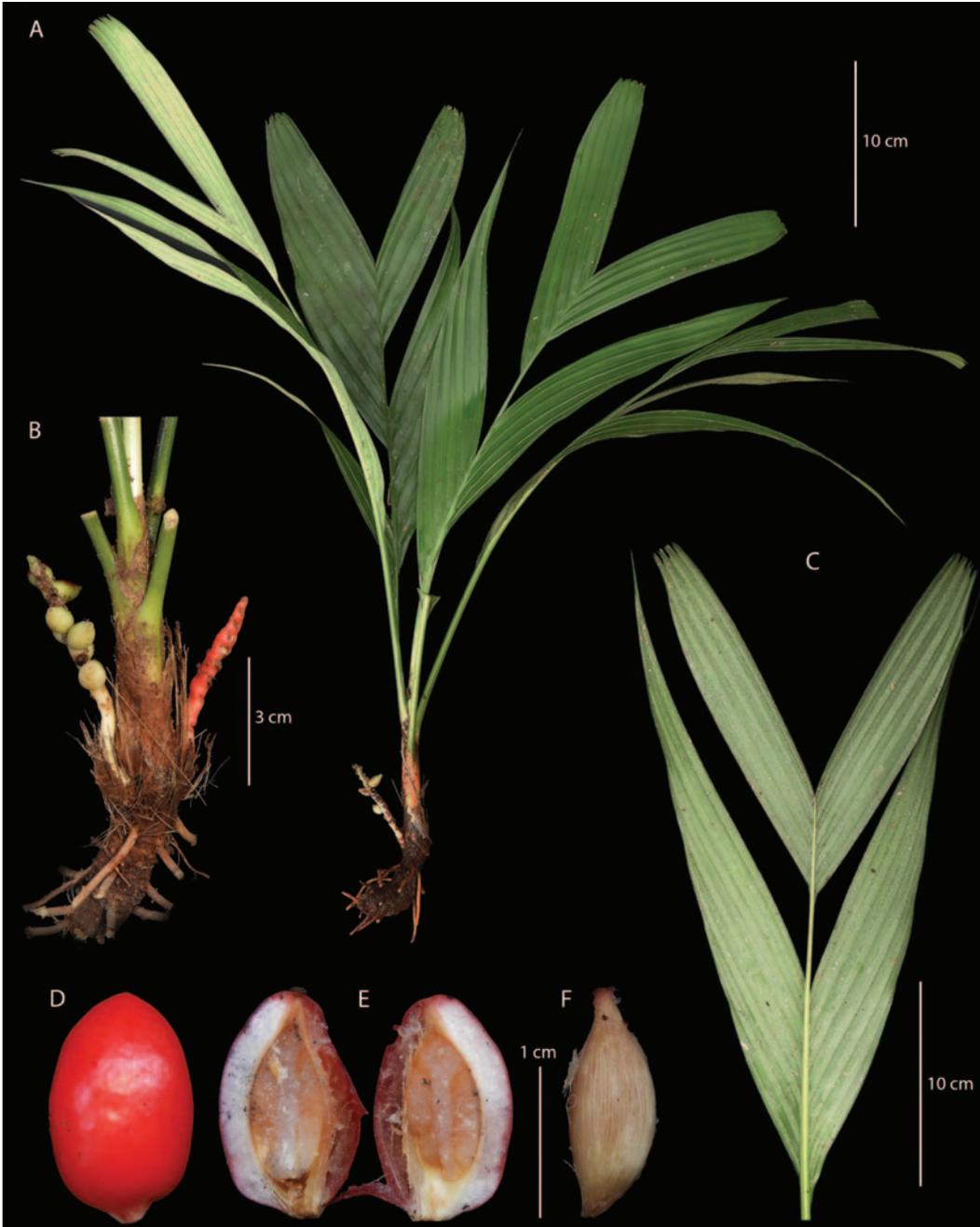
observations of both fresh and dried specimens, and terminology follows Beentje (2010).

***Pinanga subterranea* Randi & W.J.Baker, sp. nov.** (Figs. 1–4). Type: MALAYSIA. Sarawak: Sri Aman Division, Lanjak Entimau Wildlife Sanctuary, ridge path ca. 400 m SSW of Lanjak Field Station, 359 m elev., 1°24'41"N,

112°0'13"E, 2 Nov. 2018, Petoe et al. 32 (holotype K!; isotype SAR).

Diagnosis: This species is superficially similar to *P. tenacinervis* J.Dransf. (1980) but can be easily distinguished by its solitary habit (vs. clustering in *P. tenacinervis*), stem, crownshaft and inflorescence that are usually subterranean (vs. all above ground), and erect, usually

1. *Pinanga subterranea*. A. Entire plant; B. Stem, crownshaft and infructescences; C. Leaf blade abaxial surface; D. Ripe fruit (side view); E. Longitudinal section of ripe fruit showing inside of the seed; F. Fibrous endocarp that encloses the seed. All photos by A. Randi, from West Kalimantan.





2. *Pinanga subterranea*. A. Wild population; B. A mature individual; C. Buried infructescence excavated with unripe white fruits. All photos by W.J. Baker, from Lanjak Entimau Sarawak.

subterranean infructescence (vs. pendulous, aerial).

Solitary, understorey, geocarpic palm, with a very short stem, with 4–6 leaves in crown; stem buried underground, up to 6 cm long, 1.2–1.8 cm diameter; internodes very closely spaced, 2–4 mm apart, scars conspicuous and slightly thickened; crownshaft often completely subterranean, or only partially rising above ground level, 7–12 × 1.4–2.2 cm., tubular, swollen at base. Leaf sheath 6–10 cm long, 4.5–7 cm wide at the widest point, pale to deep yellow or green when not buried, covered with dense reddish-brown scales; ligule drying early, only visible on the very young leaf, ca. 1 cm long. Leaf 25–85 cm long including 9–25 cm long petiole; petiole plain green to yellowish at base, with sparse indumentum, flat to slightly channeled adaxially and rounded abaxially; rachis weakly impressed, with adaxial longitudinal ridge, rounded abaxially; blade 16–60 cm long, 14–30 cm wide at the widest point in the middle, pinnate or sometimes undivided, base attenuate into petiole, symmetrical or slightly asymmetric, adaxial surface light to dark green and shiny when fresh, with sparse and scat-

tered white scales, glaucescent abaxially, with dense scales; leaflets 2–4 on each side of the rachis, alternate or subopposite, connected or with short intervals between them (usually less than the width of one segment), somewhat sigmoid to linear lanceolate or linear oblong, 18–32 × 2.5–5.8 cm, with long tapering tip, surface flat to folded or slightly undulate, with 4–8 folds and prominent adaxial ribs; apical leaflet pair joined, each lobe 8–20 cm long on the longest side, 2–7 cm wide, tip dentate, with 5–10 folds. Inflorescence infrafoliar, usually presented underground, or partially exposed above surface of soil or leaf litter, erect, comprising two or rarely one rachilla, white to yellowish or green when young then turning red, swollen and fleshy when the fruit are ripe, glabrescent; peduncle 1.2–3.5 cm long; rachilla 4.2–9.2 cm long, slightly zig-zag when young and becoming straight with age, tapering at the end, each rachilla bearing up to 30 triads on each side, arranged distichously along its length. Pistillate flower: calyx with 3 incurved sepals, free at base, each sepal 2.1–3.2 × 2.5–4.5 mm, keeled and with sparse scales abaxially, base thickened, apex rounded or nearly flat, margins membranous; corolla with 3 petals, smaller than sepals, each petal 1.8–



3. *Pinanga subterranea*. Stem, crownshaft, and infructescences are buried in the ground. Inset showing fruits. Photos by A. Randi from West Kalimantan.

2.5 × 2.0–3.1 mm, base thickened, apex obtuse to nearly flat, glabrous on both sides, margins membranous. Fruits ovoid when ripe, 1.5–1.9 × 1.3–1.5 cm, white to green then purplish brown to bright red when ripe; base usually pale white, apex with dark brown persistent stigmatic remains; epicarp glabrous, thin and shiny; mesocarp ca. 2 mm thick, white, fleshy and juicy; endocarp fibrous, extending from base to apex. Seeds narrowly ovoid, 8–13 × 4–6 mm; endosperm ruminant, with irregular orange intrusions; embryo basal.

Distribution: Endemic to Borneo. This species occurs at the type locality in Sarawak, Malaysia, and in West and Central Kalimantan, Indonesia (Fig. 5).

Habitat: Mainly recorded from lowland mixed dipterocarp forest valleys and on slopes near streams. On clay soils on chalk, red clay soils, or sandy clay soils, up to 650 m elevation.

Vernacular name: *Pinang Tanah* (Malay, West Kalimantan). *Pinang Pipit*, *Muring Pelandok* (Kendur language, Central Kalimantan). *Tudong Pelandok* (Iban language, Sarawak).

Uses: In Central Kalimantan, the ripe fruit flesh is often eaten raw; it has a soft and juicy texture and a predominantly sweet taste.

Etymology: The specific epithet “subterranea” is derived from the Latin word *subterraneus*, meaning “underground.” This reflects the position of the stem, inflorescences and crownshaft below ground level.

Preliminary conservation status assessment: Least Concern (IUCN 2022). *Pinanga subterranea* is widespread throughout primary forests in Borneo and populations often have numerous individuals. Based on the Extent of Occurrence (EOO) this species also qualifies for the category Least Concern (EOO = 63,979.667 km²). We used the EOO because the Area of Occupancy (AOO) is thought often to be a gross underestimate due to low collecting effort (AOO = 24 km²) (Bachman et al. 2011). *Pinanga subterranea* is known at present in at least four protected areas in Borneo, which are Lanjak Entimau Wildlife Sanctuary and Batang Ai National Park in Sarawak, and then in Gunung Niut Natural Reserve and Bukit Baka Bukit Raya National Park in Kalimantan. An ex-situ conservation initiative has been undertaken since 2017 being cultivated at the Arboretum Sylva UNTAN Pontianak.

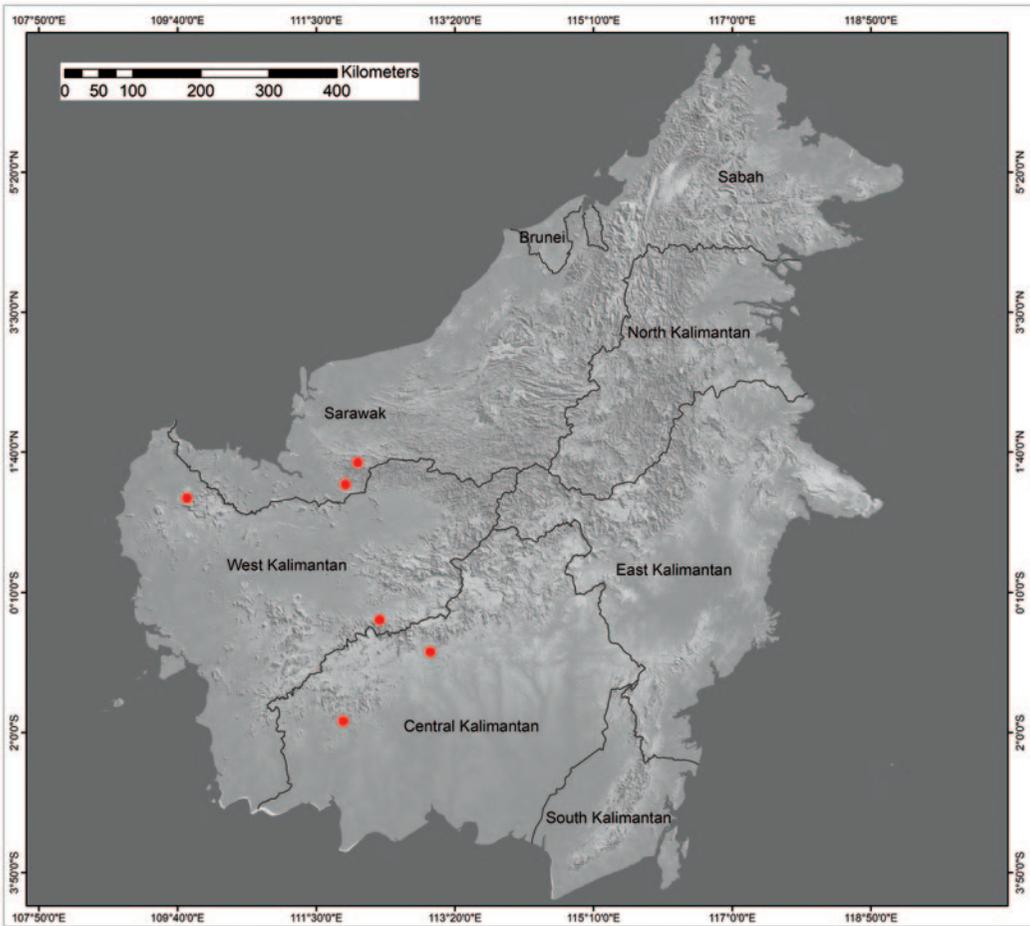
Additional examined specimens: MALAYSIA. Sarawak: Sri Aman Division, outside the



4. *Pinanga subterranea*. Stem excavated by erosion. Note 'saxophone growth' of the stem. Photos by A. Randi from West Kalimantan.

boundary of Lanjak Entimau Wildlife Sanctuary, Lanjak Field Station, on other side of bridge, 278 m elev., 1°24'50"N, 112°0'18"E, 3 Nov. 2018, Petoe et al. 34 (K!, SAR); Sarawak: Mamau, Ulu Sg. Engkari, Batang Ai, Lubok

Antu, 500 m elev., 14 Dec. 1994, Lai Shak Teck et al., S.68192 (K!, SAR). INDONESIA. West Kalimantan: Sintang Regency, HPH Km 70, NE of camp along main logging road and environs, 100 m elev., 0°51'53.6"S,



5. Distribution map of *Pinanga subterranea* (red dots indicate known occurrences).

112°13'29.9"E, 7 Apr. 1994, Church et al. 716 (BO, K!); West Kalimantan: Bengkayang Regency, Umbo Village in Gunung Niut Natural Reserve, 650 m elev., 1°3'12.55"N, 109°53'31.97"E, 6 Jun. 2017, Randi TCF 49 (WAN!, BO!); Central Kalimantan: Katingan Regency, Tumbang Habangoi Village, 340 m elev., 0°45'46.46"S, 112°58'34.16"E, 26 Nov. 2022, Randi 1093 (WAN!, BO!).

Discussion: Other than differences with *P. tenacinervis* as the most similar species mentioned in the diagnosis above, this species also differs from other acaulescent *Pinanga* species from Borneo, namely *Pinanga brevipes* Becc. (1886) in the unique combination of characters. *Pinanga subterranea* has a shorter petiole than the rachis, its stem, crownshaft and inflorescences are often completely subterranean, its leaflets are connected or separated by very short intervals, and its fruit are bright red when ripe, whereas *P. brevipes* has a petiole that is much longer than the

rachis, its stem, crownshaft and inflorescences are aerial, the leaflets are distantly separated, and the fruits are black when ripe.

Pinanga subterranea also resembles *Pinanga acaulis* Ridl. (1905), an endemic of the Malay Peninsula. Both species are small, solitary, acaulescent, and have leaves that are entire or pinnate with few leaflets. However, *P. acaulis* has an unbranched inflorescence that is suberect to horizontal, whereas the inflorescence of *P. subterranea* is very rarely unbranched and entirely erect. Furthermore, *P. acaulis* has a short stem covered by old leaf sheaths that only appears to be buried; it is in fact aerial, with the whole of the inflorescence being clearly visible above ground.

Having observed populations of *P. subterranea* in the wild, we now understand why the stem, crownshaft and inflorescence are underground. Excavated plants show "saxophone growth" (Tomlinson 1990), with the stem growing initially downwards to a depth of 20–

30 cm and then upwards (Fig. 4). Internodes are highly condensed, so the stem remains buried entirely below the ground even in mature plants. Inflorescences are short and infrafoliar, and thus usually do not emerge above ground. In addition, organic litter accumulates around the stem by the widely spreading petioles and leaves. The litter then rots and is invaded by roots (which grow upwards into it), building up around the stem and crownshaft. Rain, which splashes sand and soil around, also plays a role. Together, these factors create the impression of the plant burying itself underground (Figs. 2 & 3). The inflorescence emerges within the soil and humus layer trapped around the stem and crownshaft, as if hiding the flowers and fruits that might reach the surface. We estimate the rate of accumulation of organic litter around plants is much faster than the growth of the plant itself. This mechanism may protect the inflorescence from predators. The pollination mechanism is still not known with certainty and requires further study. Besides that, a field observation from West Kalimantan found that wild bearded pigs dig up and eat the underground fruits. We have been able to grow *P. subterranea* from seeds retrieved from their faeces, demonstrating that they are effective seed dispersers (A. Randi, pers. obs. in 2017).

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LITERATURE CITED

- BACHMAN, S., J. MOAT, A.W. HILL, J. DE LA TORRE AND B. SCOTT. 2011. Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool. *ZooKeys* 150: 117–126.
- BECCARI, O. 1886. Nouvi studi sulle palme asiatiche. *Malesia* 3: 58–149.
- BEENTJE, H.J. 2010. The Kew plant glossary: an illustrated dictionary of plant terms. Royal Botanic Gardens, Kew, Richmond, x + 160 pp.
- BLUME, C.L. 1838. Reveue des Palmiers de l'Archipel des Indes Orientales. *Bulletin des Sciences Physiques et Naturelles en Néerlande* 1: 61–67.
- DRANSFIELD, J. 1980. Systematic notes on *Pinanga* (Palmae) in Borneo. *Kew Bulletin* 34(4): 769–788.
- DRANSFIELD, J. 1991. Notes on *Pinanga* (Palmae) in Sarawak. *Kew Bulletin* 46: 691–698.
- IUCN STANDARDS AND PETITIONS COMMITTEE. 2022. Guidelines for Using the IUCN Red List Categories and Criteria. Version 15. Prepared by the Standards and Petitions Committee.
- KUHNHÄUSER, B.G., A. RANDI, P. PETOE, P.K. CHAI, S. BELLOT, W.J. BAKER. 2023. Hiding in plain sight: the underground palm *Pinanga subterranea*. *Plants, People, Planet*. in press. <https://doi.org/10.1002/ppp3.10393>
- LIM, C.K. 2005. Two new species of *Pinanga* Blume (Arecaceae) from Sarawak, Malaysia. *Folia Malaysiana* 6(3&4): 73–82.
- PETOE, P., B.G. KUHNHÄUSER, C. GERI AND W.J. BAKER. 2020. Lanjak Entimau Wildlife Sanctuary – a palm hotspot in the heart of Borneo. *PALMS* 64: 57–84.
- POWO. 2023. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Available from: <http://www.plantsoftheworldonline.org/> (accessed 25 January 2023).
- RANDI, A., A. HIKMAT AND C.D. HEATUBUN. 2019. *Pinanga schwanerensis*, a new species of *Pinanga* (Arecaceae) from Kalimantan, Indonesia. *Phytotaxa* 402(2): 121–125.
- RIDLEY, H.N. 1905. New and little known Malayan plants. Series II. *J. Straits Branch Roy. Asiat. Soc.* 44: 189–211.
- TOMLINSON, P.B. 1990. *The Structural Biology of Palms*. Clarendon Press, Oxford, xii + 477 pp.