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## ***Dioscorea orangeana* (Dioscoreaceae), a new and threatened species of edible yam from northern Madagascar**

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**Summary.** A new species of yam (*Dioscorea orangeana* Wilkin) is described and illustrated. It differs from *D. comorensis* R.Knuth by having undulate leaf margins and a broader torus and tepals in both the male and female flowers. In female flowers of *D. orangeana* the floral stipe between the ovary and the torus is shorter than in *D. comorensis*. The tuber morphology of the species is atypical among Malagasy species in that there are several digitate lobes rather than a single tuber per growing season, although more research is needed on tuber morphology. *D. orangeana* is reported to be edible. It is endemic to the Forêt d'Orangea near Diego Suarez (Antsiranana) in Antsiranana Préfecture. Its conservation and sustainable use are thus matters of concern.

**Key Words.** *Dioscoreaceae*, *Dioscorea*, yams, Madagascar, new species, edible, conservation

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## Introduction

In 2003 the first author saw the specimen *Humbert & Cours* 32277 at the Muséum national d'Histoire naturelle (MNHN) in Paris (P, see below for source of herbarium abbreviations), which had been collected in 1960 at the Forêt d'Orangea near Diego Suarez (Antsiranana) in Antsiranana Préfecture. It was unique among specimens of *Dioscorea* from Madagascar in possessing leaves with undulate margins, which are broad in relation to length, giving them a reniform appearance. Unfortunately the male flowers of this specimen are immature. No other specimens appear to have been collected between 1960 and June 2001, when Annette and Marcel Hladik collected leafless, fruiting material at the same locality, as *Hladik* 6621 (K, P). Since 2001 further specimens have been obtained; Rogers found both male and female flowering plants in 2003 (*Rogers et al.* 161 and 160 respectively, both at MO, P and TAN). Male and female fruiting specimens were obtained in 2004 by Marcel and Annette Hladik (*Hladik* 6828, 6829, 6830, 6835 and 6836, held at P). Male plants have also been collected by two other Missouri Botanical Garden (MO) collecting trips in 2003 and 2005 (*Miller et al.* 10178 and *Randrianaivo et al.* 1148 respectively). A comparative study of these specimens and those of other Malagasy yams was therefore undertaken.

## Materials & Methods

The Yams of Madagascar Project comprises comparative morphological study and databasing of 1059 specimens from the following herbaria: B, BH, BM, BR, G, GH, GRA, K, MO, P, SNGF, TAN, TCD, TEF, WAG, UPS (abbreviations following Index Herbariorum, <http://sciweb.nybg.org/science2/IndexHerbariorum.asp>). The specimens used in the study of *D. orangeana* are cited below. Floral dissections were carried out where appropriate and measurements made using a Leica MZ95 or Carl Zeiss microscope with a measuring eyepiece. Vegetative and inflorescence characters were measured with a dial caliper. The distribution map and conservation status assessment were prepared using ArcView 3.3 as part of a larger study of the conservation status of *Dioscorea* in Madagascar (Wilkin *et al.*, unpublished data).

## Results

Comparative morphological study of the new material confirms that it is a species that was not included in the Flore de Madagascar treatment (Burkill & Perrier 1950). It is morphologically distinct from all other *Dioscorea* species in Madagascar in its underground, above-ground vegetative and reproductive organs. It most closely resembles *D. comorensis* R. Knuth, an endemic of the Comoro Archipelago (Wilkin *et al.* 2007), from which it differs by having undulate leaf margins and a broader torus and tepals in both the male and female flowers. In female flowers of *D. orangeana* the floral stipe between the ovary and the torus is

shorter than in *D. comorensis*. These differences are summarised in Table 1. This taxon is thus described below as a new species for Madagascar.

### Taxonomic Description

***Dioscorea orangeana*** Wilkin, **sp. nov.**, *D. comorensis* R.Knuth affinis sed planta glabra, foliis ad marginem plerumque undulatis, *florum masculorum* toro 1.3 – 2.6 mm (nec 0.8 – 1.5 mm) lato tepalis exterioris 1.0 – 1.6 mm (nec 0.4 – 1.1) latis ovatis vel late ellipticis (nec lanceolatis neque ellipticis neque elliptico-oblongis neque anguste elliptico-oblongis), tepalis interioris 1.2 – 2.1 mm (nec 0.8 – 1.3 mm) latis latissime ovatis vel latissime ovato-orbiculatis vel latissime ovato-oblongis (nec elliptico-oblongis neque ovatis neque late ovatis), *florum femineorum* stipite florali 0.2 – 0.5 (nec 0.4 – 0.8 mm) longo, tepalis exterioris 1 – 1.2 mm (nec 0.5 – 0.8 mm) latis ovatis vel late ovatis (nec ellipticis neque elliptico-oblongis neque lanceolatis), tepalis interioris 1.2 – 1.8 mm (nec (0.6 –) 0.8 – 1.1 mm) latis latissime ovatis vel ovato-orbiculatis vel oblongo-orbiculatis (nec ellipticis neque elliptico-oblongis neque late elliptico-oblongis) differt. Typus: Madagascar. Orangea, about 1.5 km NE of Military Camp ‘Orangea’, on sandy road along trail to ocean, ♂ fl. 15 Feb. 2003, Rogers, Rakotonasolo & Vigneau 161 (holotypus P!; isotypi MO!, TAN). Figs 1, 2.

*A twining vine* to no more than 5 m, stems annual from a fleshy tuber. *Tuber* to c. 20 cm in diam., apically dome-shaped, with several digitate young growths below (Fig. 2H), epidermis pale to dark brown (latter in older parts), parenchyma creamy white. *Indumentum* wholly absent, even from axillary buds. *Stems* left-twining, to c. 5 mm in diameter, quite woody, nodes swollen towards base above and below ground, in soil descending vertically, with a white, roughened epidermis, producing thick roots at nodes, above ground bearing small brown prickles at extreme base, grey-brown, towards base with longitudinal ridges and channels between them when dry, distal shoots terete with weak longitudinal ridges, unarmed, pale green when fresh. *Leaves* (Fig. 1A) alternate, blade 17 – 68 × 12 – 65 mm, ovate to ovate-deltoid or ovate-sagittate, sometimes broadly ovate-orbicular, broadly ovate-reniform or orbicular-reniform, main stem leaves tending to be broader, chartaceous to thinly so, juvenile leaves often variegated by possessing an ovate to elliptic, cream to pale yellow or pale green splash with irregularly toothed margins extending from the point of petiole insertion, mid green above, paler and glossy below, drying dull olive-green, slightly paler below, sometimes with a few black glands (like those of e.g. *D. trichantha* Baker or *D. seriflora* Jum. & H.Perr.) scattered near the point of petiole insertion, glossy, circular to oval, with an annulus around the outside, less visible on upper surface where they lack an annulus and are less clearly defined; margins usually entire and undulate (e.g. apical leaf of Fig. 1A, more easily seen in living plants), sometimes also

weakly lobed towards stem base; basal sinus 0.5 – 19 mm deep, weakly and broadly cordate to narrowly so, subhippocrepiform or with inner margins of basal lobes overlapping and sinus very narrow; apex 1.4 – 15 mm long, acuminate to long-acuminate, with a c. 0.5 – 4.5 mm long, narrowly deltoid, dark brown forerunner tip, or in broadly ovate-reniform leaves with rounded or truncate apices the acumen consists only of the forerunner tip, veins 5, only 3 reaching apex in smaller leaves with a smaller, often bifid, vein to each basal lobe, primary venation prominent on lower leaf blade surfaces; petiole 11 – 72 mm long, ± terete with longitudinal ridges and channels like stem when dry, with a broader channel on upper surface, basal and apical pulvinus drying darker, but paler green in fresh material, petiole base expanded and deltoid where it is inserted on to node, especially on lower stems, appearing homologous with cataphylls at stem base; lateral nodal organs (“stipules” of Burkill (1960) present as a pair of fleshy, obtuse projections on either side of node; cataphylls present towards stem base, to c. 5 mm long, broadly to very broadly ovate, base clasping stem, apex acuminate, drying dark brown; bulbils (only produced in the axils of plants cultivated by Annette Hladik), pale brown, elongate-cylindrical but rather irregular, warty. *Male inflorescences* 1–2 per axil, pendent, racemose, simple or compound through suppression of leaves in axillary shoots, where compound sterile base of primary axis c. 10 mm long, fertile part shorter (Fig. 1C), both flattened and winged like partial inflorescence axis, colour as stem; partial inflorescence bracts c. 1.5 mm long, ovate to narrowly so, acuminate, membranous, with a thicker midrib; partial inflorescence peduncle 5 – 18 mm long, axis (6.5 – )33 – 155 × 0.5 – 1.2 mm, flattened and winged, wing widest at nodes; flowers in cymules of (1 – )2 – 4 (Fig. 1D), cymules 0.5 – 6( – 11) mm apart, regularly to irregularly spaced, sometimes very dense towards apex where axis elongation appears to have failed or subopposite elsewhere, cymule bracts 1 per node, 1.1 – 2.1 mm long, narrowly ovate to elliptic, acuminate to long-acuminate, membranous, with a thicker midrib, cymule primary branch 0.1 – 1 mm long. *Female inflorescences* to c. 18 cm long, simple, spicate, pendent, axis flattened and winged like male, colour as stem. *Male flowers* lime-green to yellow-green, scent not recorded, pedicellate, floral bract at pedicel base 0.8 – 1.7 × 0.2 – 0.8 mm, narrowly ovate to lanceolate, acuminate, membranous, with a thicker midrib; pedicels 1 – 2.1 × 0.2 – 0.6 mm, narrowly obdeltoid in outline; tepals differentiated into 2 whorls of 3, (inner broader, Fig. 1E), membranous with a thicker midrib, both whorls inserted on a shallow, open, saucer- to bowl-shaped torus 0.3 – 1.2 × 1.3 – 2.6 mm (Fig. 1G), membranous and semi-translucent like tepals, abruptly thickened towards centre where filaments are inserted (perhaps only thickened part is true torus and the rest fused tepals); tepals erect in bud, ± patent to torus margin (i.e. spreading) at anthesis, outer whorl 1.2 – 1.9 × 1 – 1.6 mm, ovate to broadly elliptic, apex acute to acuminate, inner whorl 1.2 – 2 × 1.2 – 2.1 mm, very broadly ovate to very broadly ovate-orbicular or very broadly ovate-oblong, apex obtuse to acute; stamens inserted in a ring on a thickened area in the

torus centre, filaments 0.3 – 1.2 mm long, erect at base, free and reflexed in an arching manner towards apex so that anthers face basal half of filament (Fig. 1F) and are held roughly half way between torus centre and rim (Fig. 1G), anthers 0.15 – 0.45 × 0.15 – 0.35 mm, basifixed, yellow; pistillode if present concealed by anthers. *Female flowers* lime-green, (sub)sessile until capsule development begins, scent not recorded; floral bract 1.2 – 1.5 × 0.5 – 1 mm, elliptic to ovate or broadly so, acuminate to long-acuminate, membranous, with a thickened midrib, bracteole like bract but shorter, narrower and inserted at 90° to it (Fig. 2B); ovary c. 4.6 – 6.6 mm long, 3-angled, oblong to narrowly elliptic-oblong in outline, green, apex acute to obtuse; floral stipe (between ovary and torus, Fig. 2B) 0.2 – 0.5 mm long; tepals spreading at anthesis, differentiated into 2 whorls of 3, thickly membranous, with a thicker midrib, inserted on the rim of a 0.5 – 0.7 × 1.3 – 1.6 mm, open, saucer- to shallowly bowl-shaped torus, texture like tepals but thickening gradually towards style bases; outer tepals 1.4 – 1.6 × 1 – 1.2 mm, ovate to broadly so, apex acute to acuminate; inner tepals 1.2 – 1.8 × 1.2 – 1.8 mm, very broadly ovate to ovate-orbicular or oblong-orbicular, apex obtuse to rounded; staminodia 6, 0.3 – 0.6 mm long, inserted around the style base near the most sharply curved part of torus (Fig. 2C, D), erect, filiform with a capitate, erect to recurved apex in which the upper antheriform part consists of more translucent tissue; styles 0.9 – 1.2 mm long, fused to form an erect column for c. 0.7 mm, apices free, recurved, bifid, bearing 2 deltoid, horn-like stigmas c. 0.5 mm long, spreading and borne patent to the style branch (Fig. 2D). *Capsule* ascending at c. 45 – 5° to axis at dehiscence (Fig. 2E) on a clavate, angled capsular stipe to 2.5 mm long, 19 – 29 × 10 – 12 mm, oblong to narrowly so, base shallowly retuse to rounded, apex shallowly retuse to acute, margin separating as an opercular strip (Fig. 2F), tepal bases or floral stipe usually persistent as an apiculus on each lobe of capsule, opening to more than half length to release seeds, pale brown with chestnut-brown flecking. *Seeds* winged at base only (Fig. 2G), 4.8 – 6.5 × 3.8 – 4.2 mm excluding wing, ovoid-lenticular to flattened ovoid-reniform, matt dark brown, wing 8.4 – 10.5 × 4.3 – 6.2 mm, narrowly to broadly oblong, apex obtuse to rounded, membranous, golden-brown with slightly darker flecking.

**DISTRIBUTION.** Found only in the Forêt d'Orangea near Antsiranana in Northern Madagascar.

**MADAGASCAR.** Antsiranana, Forêt d'Orangea, ♂ fl. buds 22 Jan. 1960 *Humbert & Cours* 32277 (P); Forêt d'Orangea, Camp Militaire, ♂ fl. 1 Feb. 2004 *Hladik* 6830 (P); Forêt d'Orangea, Camp Militaire, ♂ fl. 1 Feb. 2004, *Hladik* 6836 (P); Forêt d'Orangea, Camp Militaire, ♂ fl. 1 Feb. 2004, *Hladik* 6835 (P); Forêt d'Orangea, Camp Militaire, sterile 1 Feb. 2004, *Hladik* 6828 (P); Forêt d'Orangea, Camp Militaire, sterile 1 Feb. 2004 *Hladik* 6829 (P); Forêt d'Orangea, Camp Militaire, ♀ fr. 14 June 2001, *Hladik* 6621 (K, P) and specimen grown from its seed, sterile with bulbils, *Hladik* 6621A (P); Orangea, about 1.5 km NE of

Military Camp 'Orangea', on sandy road along trail to ocean, 12° 14' 18" S 49° 21' 49" E ♀ fl. & immature fr. 15 Feb. 2003, Rogers, Rakotonasolo & Vigneau 160 (MO, P, TAN); Forêt d'Orangea, along the dirt track near the remains of the French fort on the hill above Ramena, 12°15'01"S 49°21'39"E, ♂ fl. and fl. buds 20 Jan. 2003, Miller, Applequist, Rabenantoandro & Ranaivojaona 10718 (MO); Diego II, Ramena, Forêt d'Orangea, à 2 km à l'Est du village de Ramena 12°15'05"S 49°22'01"E, ♂ fl. 12 Jan. 2005, Randrianaivo, Rakotonandrasana, Rakotondrajaona, Guittou & Benjara 1148 (MO)

**VERNACULAR NAME.** *Angona* (Antakarana, Sakalava, Forêt d'Orangea). However, more than one wild yam species appears to be known as *Angona* in the Antsiranana region.

**ECOLOGY.** Found in deciduous forest on sand at altitudes not exceeding 100 m.

**PHENOLOGY.** Flowering in January and February, fruit developing thereafter, dehiscing in June.

**CONSERVATION STATUS.** Figs 3 and 4 show the distribution of this species in Northern Madagascar through georeferencing the specimens cited above. The extent of occupancy (EOO) of *D. orangeana* is 3.6 km<sup>2</sup>, and its area of occurrence is 1.7 km<sup>2</sup> using a cell size of 0.58 km<sup>2</sup>; it occupies five cells. Both of these measures suggest that the appropriate IUCN red list assessment is CR. In December 2002 CMH found a tuber on a sterile plant in a transect at 12°16'45.0"S 49°23'41.3" E, near Andovokonko, c. 10 km South-east of Ramena, which matched the form found in *Hladik* 6828. Should this locality prove to hold *D. orangeana*, it would extend the range of the species outside the Forêt d'Orangea and increase the EOO and AOO. There is also a significant area of dry forest north of Antsiranana, in the northernmost part of Madagascar. This region is botanically poorly known, but may provide suitable habitat for *D. orangeana*. However, in the absence of further specimens clearly belonging to *D. orangeana* we suggest a provisional IUCN red list assessment of CR B1ab(iii); B2ab(iii).

*D. orangeana* is reported to be abundant in the Forêt d'Orangea, but the tubers are thought to be extracted in large quantities: AH and CMH saw a large number of "yam holes" in the Forêt d'Orangea. It appears that all of the yams known as *Angona* in the Antsiranana region are favoured edible species and thus heavily exploited. As Fig. 4 shows, the Forêt d'Orangea is not protected, and the nearest such area is at least 20 km away.

**USES.** Tuber edible.

**ETYMOLOGY.** The vernacular name *Angona* is also applied to *D. sambiranensis* R.Knuth (Burkill & Perrier 1950) amongst other species. Thus the epithet *orangeana* was chosen to reflect the endemic distribution of the species in the Forêt d'Orangea.

**NOTES.** *D. orangeana* differs from all other species of *Dioscorea* in Madagascar by usually

possessing leaves with undulate margins. The variegated juvenile leaves may also be a useful spot character. Of the other differences between *D. orangeana* and *D. comorensis* (Table 1) most are discrete. In some, such as tepal width, there is a small range overlap between the two species. They are clearly different in shape, however, with *D. orangeana* having broader tepals in both whorls. In both species, the inner whorl of tepals is broader than the outer. It also appears that the seeds and capsules of *D. orangeana* are narrower than those of *D. comorensis*, but for both species the measurements are based on just one known fruiting specimen.

Both the male and female flowers of *D. orangeana* have saucer- to bowl-shaped, relatively open tori like *D. sterilis* Weber & Wilkin and *D. decaryana* H.Perr., but the torus is semi-translucent and tepal-like in texture, not thicker and opaque as in those species. The torus of *D. orangeana* is less deep and more open than those species with campanulate tori (Wilkin *et al.*, in press). In the remaining species in Madagascar and the Comoro Archipelago, the tori are differently shaped, but they are all thicker than the tepals and opaque in dried and fresh specimens.

### **Tuber morphology**

The unusual tuber of this species (Fig. 2H) was observed by AH in both plants in the field and in young plants grown from seed taken from *Hladik* 6621. However, VJ found only yams with one vertically oriented tuber per growing season in sterile plants of unknown species during field study around Antsiranana in August 2006. It remains possible that this organ is polymorphic in *D. orangeana*; more research is needed. One vertically oriented (at least at its point of attachment to the crown) tuber per growing season is the most common condition in Madagascar and the Comoros. More rarely, some species possess several narrow, cylindrical, laterally spreading tubers with thickened apices (e.g. *D. bemarivensis* Jum. & H.Perr., *D. proteiformis* H.Perr.). The tuber of *D. comorensis* falls into the former category, based on a photograph of the tuber of a plant from near Itsamia Ngouni on Mwali (Daan Ouni Msoili, pers. comm).

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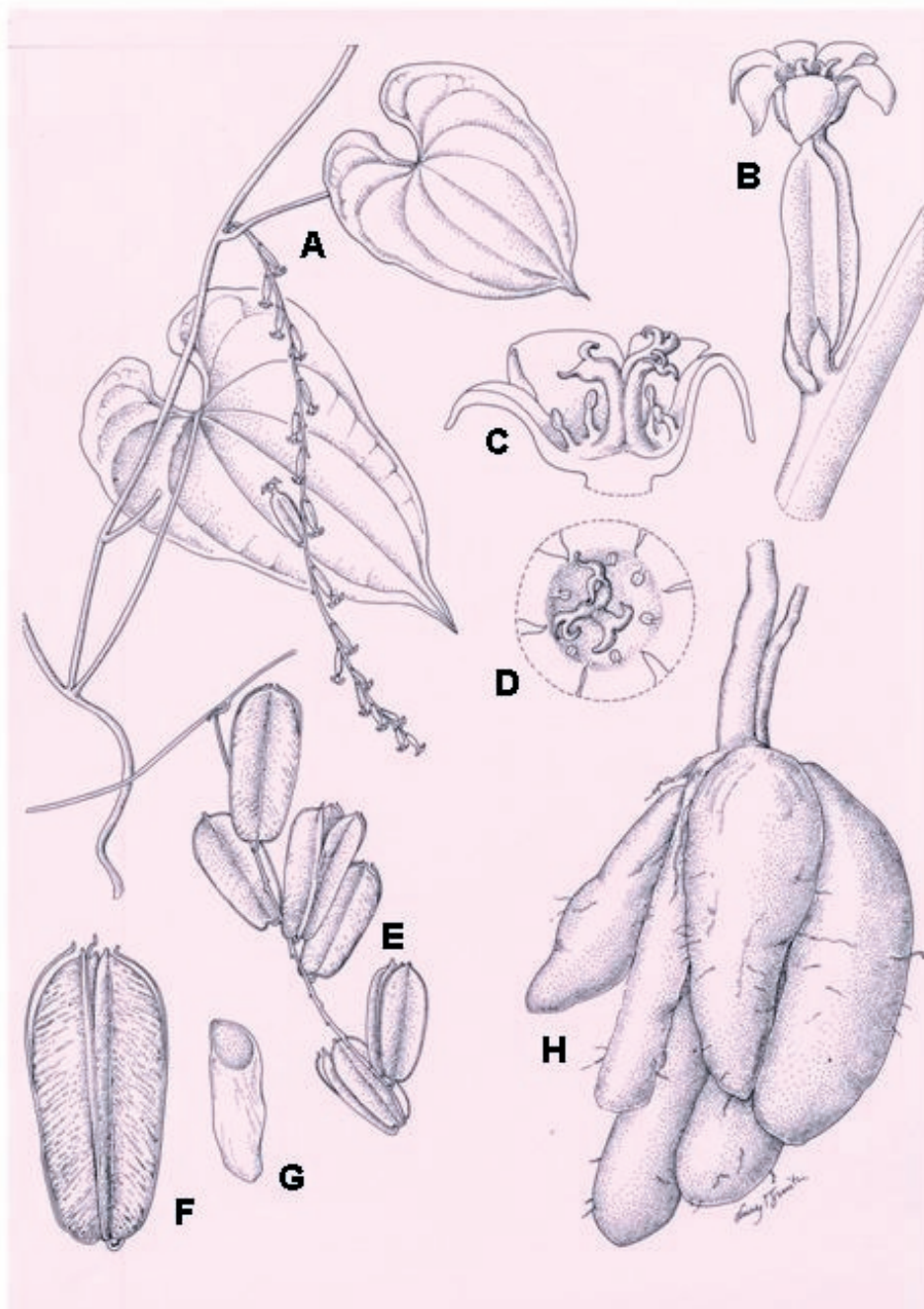
Table 1. A summary of the main character state differences between *D. comorensis* and *D. orangeana*

Character	<i>D. comorensis</i>	<i>D. orangeana</i>
Tuber(s) Indumentum	One vertically oriented, unbranched tuber per growing season Colourless, caducous hairs to 0.7 mm long present on buds and shoots, sparsely persistent around the axil and on the leaf blade lower surface	Apically dome-shaped, with several digitate young growths below Glabrous
Leaf blade dimensions and shape	(2.7 – )46 – 81 x (20 – )35 – 68 mm, ovate to narrowly so or deltoïd-ovate.	17 – 68 x 12 – 65 mm, ovate to ovate-deltoïd or ovate-sagittate, sometimes broadly ovate-orbicular, broadly ovate-reniform or orbicular-reniform
Leaf margins	Entire, not undulate	Usually entire and undulate, sometimes also weakly lobed towards stem base
Male flower torus dimensions	0.2 – 0.5 x 0.8 – 1.5 mm	0.3 – 1.2 x 1.3 – 2.6
Male flower outer tepal dimensions and shape	0.9 – 1.5 x 0.4 – 1.1 mm, lanceolate to elliptic, elliptic-oblong or narrowly so	1.2 – 1.9 x 1 – 1.6 mm, ovate to broadly elliptic
Male flower inner tepal dimensions and shape	0.7 – 1.6 x 0.8 – 1.3 mm, elliptic-oblong to ovate or broadly so	1.2 – 2 x 1.2 – 2.1 mm, very broadly ovate to very broadly ovate-orbicular or very broadly ovate-oblong
Female flower ovary length	2.6 – 3.8 mm	6.4 – 6.6 mm
Female flower floral stipe length (between ovary and torus)	0.4 – 0.8 mm	0.2 – 0.5 mm
Female flower torus dimensions	0.3 – 0.7 x 1 – 1.6 mm	0.5 – 0.7 x 1.3 – 1.6 mm
Female flower outer tepal dimensions and shape	1.1 – 1.7 x 0.5 – 0.8 mm, elliptic to elliptic-oblong or lanceolate	1.4 – 1.6 x 1 – 1.2 mm, ovate to broadly so
Female flower inner tepal dimensions and shape	1.2 – 1.8 x (0.6 – )0.8 – 1.1 mm, broadly elliptic to elliptic-oblong or broadly so	1.2 – 1.8 x 1.2 – 1.8 mm, very broadly ovate to ovate-orbicular or oblong-orbicular
Capsule dimensions	1.8 – 2.3 x 1.1 – 1.4 mm	1.9 – 2.9 x 1.0 – 1.2
Seed dimensions	5.4 – 6.2 x 4.2 – 4.7 mm	4.8 – 6.5 x 3.8 – 4.2

## Captions

Fig. 1. *Dioscorea orangeana* habit, male inflorescences and flowers

- A. Habit, stem and simple axillary inflorescences with flowers at the bud stage. The apical leaf shows its undulate margin most clearly. Scale bar = 2 cm.
- B. A node with a simple axillary inflorescence bearing flowers at anthesis. Scale bar = 2 cm.
- C. A node with a leaf and a basally branching compound inflorescence bearing flowers at anthesis. Scale bar = 2 cm.
- D. A cymule showing an open flower at anthesis and two buds. Scale bar = 2.5 mm.
- E. A flower (top view) showing the tepals (inner whorl broader), torus and position of the stamens. Scale bar = 2.5 mm.



F. The stamens with the torus and tepals cut away, showing their habit due to the recurvature of the filaments. Scale bar = 1.2 mm.

G. A half-flower (longitudinal section) showing the shape of the torus, the insertion of the tepals onto it, and the insertion of the stamens. Scale bar = 1.2 mm. Drawn from *Humbert & Cours 33227 (A)* and *Rogers et al. 161 (B – G)*. DRAWN BY LUCY SMITH.

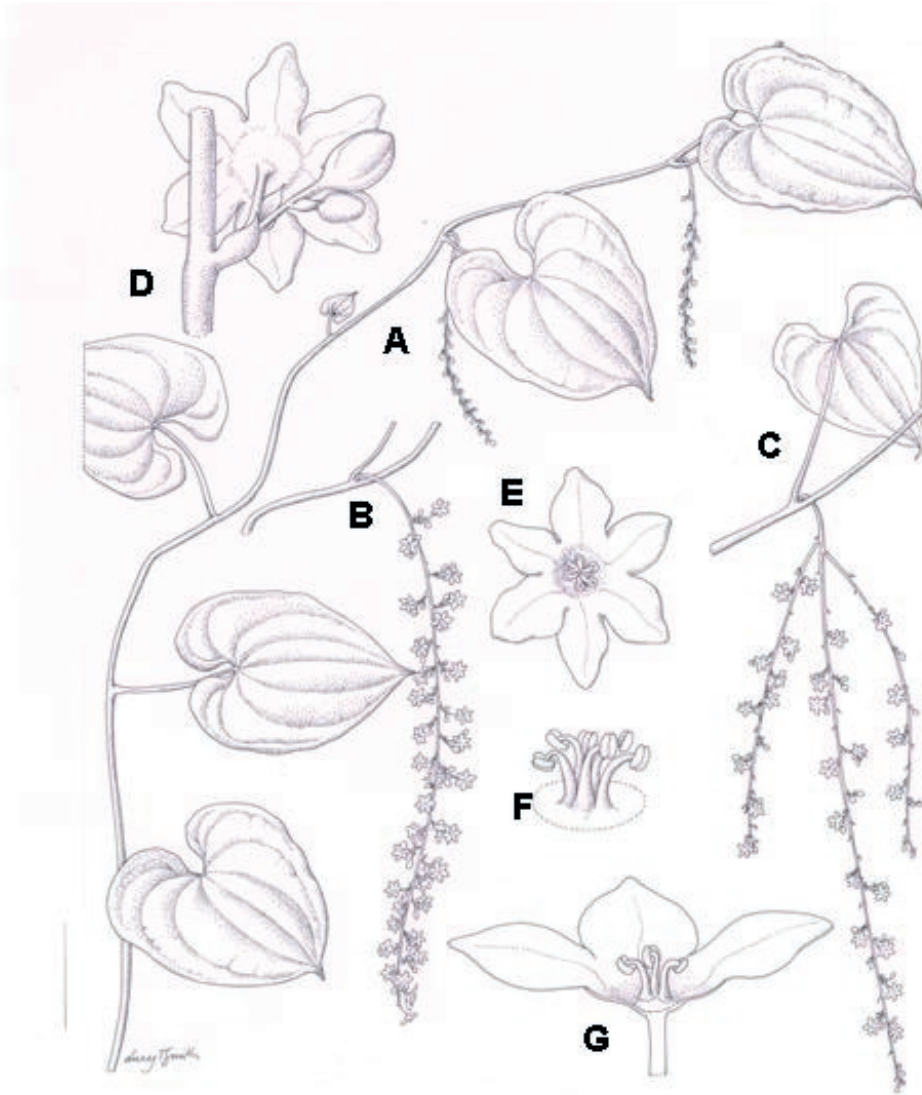


Fig. 2. *Dioscorea orangeana* female inflorescences, flowers and fruit.

A. Habit, stem and inflorescence with flowers at anthesis and in the early stages of capsule development (reflexed). Scale bar = 2 cm.

B. Flower, showing floral bract and bracteole, developing ovary and stipe between ovary apex and torus. Scale bar = 2.5 mm.

C. Half-flower (longitudinal section), showing torus shape, staminodia, styles and stigmas. Scale bar = 1.4 mm.

D. Top view of the torus showing the insertion of the staminodia and position of the stigmas. Scale bar = 1.7 mm.

E. Infructescence at dehiscence. Scale bar = 1.5 cm.

F. Capsule at dehiscence. Scale bar = 1 cm.

G. Basally winged seed. Scale bar = 1 cm.

H. Tuber, crown and stem base. Scale bar = 5 cm.

Drawn from *Rogers et al.* 160 (A – D), *Hladik* 6621 (E – G) and a photograph of the tuber of *Hladik* 6828.

DRAWN BY LUCY SMITH.

Fig. 3. A map of Madagascar showing the location of the Forêt d'Orangea east of Antsiranana where all existing collections of *D. orangeana* have been made.

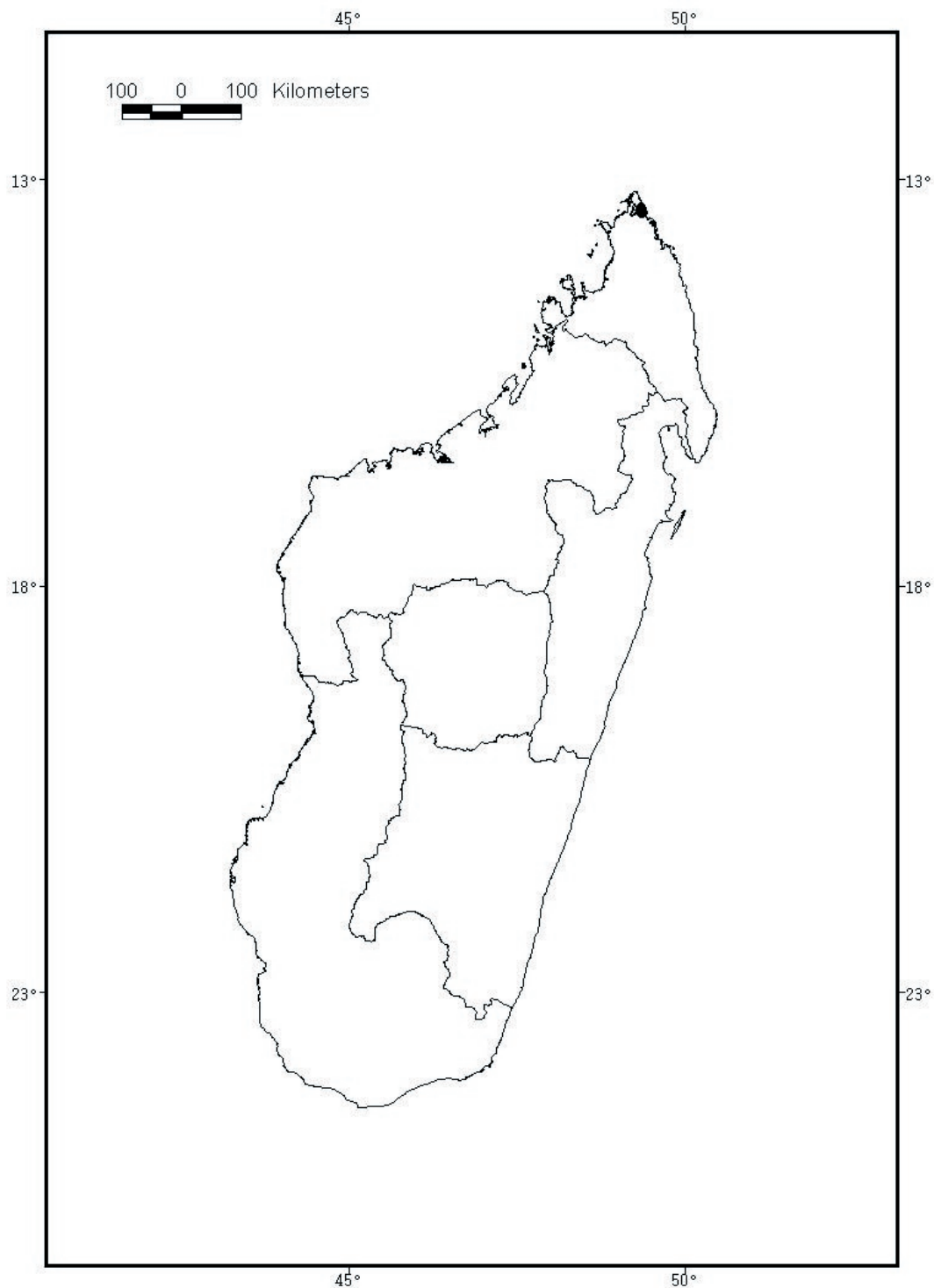


Fig. 4. A larger scale map of the northern tip of Madagascar showing the locations of the existing collections of *D. orangeana* near Ramena. The city of Antsiranana and the highest point of the Montagne des Français are indicated, and the nearest protected areas are shaded. Fig. 1.

