

Three new *Aloe* species from Madagascar

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Abstract

Exploratory botanical expeditions to three remote and little-known regions of Madagascar have resulted in the discovery of three new species of *Aloe*, a diverse genus of leaf-succulent perennials with a rosulate habit, leaves typically armed with marginal teeth, and united (rarely completely free) perianth segments that are fleshy and brightly colored. The new species are: *Aloe analavelonensis* from humid forest on the Analavelona Massif northeast of Toliara; *Aloe beankaensis* from the Beanka Forest and Tsingy de Bemaraha, both dry forests on tsingy limestone in the west; and *Aloe ivakoanyensis* from humid forest on the Ivakoany Massif in the southeast. The sectional placement of *A. analavelonensis* is uncertain but the other two new species belong to section *Lomatophyllum*, an assemblage of some 19 species with fleshy semi-dehiscent fruits that is largely restricted to Madagascar and some Mascarene Islands. These new species are described, mapped, illustrated, and compared with presumed relatives. We also evaluate the conservation status of each species in the context of IUCN Red List guidelines and criteria.

Key words: *Aloe*, Analavelona, Beanka, Ivakoany, flora, *Lomatophyllum*, Madagascar

Résumé détaillé

Des expéditions botaniques dans trois régions éloignées et peu connues de Madagascar ont

abouti à la découverte de trois nouvelles espèces d'*Aloe*. C'est un genre diversifié à de feuilles succulentes vivaces habituellement en rosette, généralement armées de dents marginales et de périanthes unis (rarement libres) qui sont charnus et de couleur vive. Les nouvelles espèces sont les suivantes: *Aloe analavelonensis* de la forêt humide du Massif d'Analavelona, au Nord-est de Toliara ; *Aloe beankaensis* de la forêt de Beanka et du Tsingy de Bemaraha, deux forêts sèches sur calcaire de « tsingy » dans l'Ouest ; et *Aloe ivakoanyensis* de la forêt humide du Massif d'Ivakoany dans le Sud-est. La position de l'*A. analavelonensis* dans une section est encore incertaine, mais les deux autres nouvelles espèces appartiennent à la section des *Lomatophyllum*, un assemblage de 19 espèces environs avec des fruits charnus semi-déhiscent qui sont en grande partie limitées à Madagascar et aux îles Mascareignes. Ces nouvelles espèces sont décrites, cartographiées, illustrées et comparées avec des espèces apparentées. Nous avons également évalué le statut de conservation de chacune d'entre elles selon les directives et les critères de la Liste Rouge de l'IUCN des plantes menacées.

Mots clés : *Aloe*, Analavelona, Beanka, Ivakoany, flore, *Lomatophyllum*, Madagascar

Introduction

Aloe L., with some 624 taxa (Grace *et al.*, 2011), is a largely African genus with a major center of diversity in South Africa and Madagascar (Reynolds, 1966; Mabberley, 2008; Castillon & Castillon 2010; Grace *et al.*, 2011). For decades, its placement in the Liliaceae went unquestioned (Perrier de la Bâthie, 1938; Reynolds, 1966). Although its relationship to allied South African genera like *Astroloba* Uitew., *Chortolirion* A. Berger, *Haworthia* Duval, *Gasteria* Duval, and *Poellnitzia* Uitew is well established and without controversy (Smith & Steyn, 2004), the familial placement of *Aloe* and its allies has been a subject of unsettled opinions based on both morphological and molecular phylogenetic studies. *Aloe* has been recognized as a member of its own family, the Aloaceae (Newton, 2001, 2004; Smith & Steyn, 2004), but it has also been assigned to the Asphodelaceae (Smith & Van Wyk, 1998; Heywood

et al., 2007), the Xanthorrhoeaceae subfamily Asphodeloideae (Stevens, 2001 onwards; Angiosperm Phylogeny Group III, 2009) and the Asparagaceae (The Plant List, 2012). Despite these varied familial assignments, *Aloe* is readily distinguished by its perennial leaf-succulent habit, rosulate or distichous leaves that are commonly armed with sharp marginal teeth, racemose or paniculate inflorescences, non-articulated pedicels, united (rarely completely free) perianth segments that are fleshy and brightly colored, and prevailingly loculicidal capsular fruits with numerous seeds. Although the majority of described species have capsular fruits, some 19 species with fleshy semi-dehiscent baccate fruits that are largely restricted to Madagascar and some Mascarene Islands (with one species each on Pemba and Aldabra) have been recognized in the genus *Lomatophyllum* Willd. (Perrier de la Bâthie, 1926; Rauh, 1998; Smith & Van Wyk, 1998); this genus has recently been reduced to a section of *Aloe* (Rowley, 1996; Newton & Rowley, 1998; Newton, 2001).

In this paper, we recognize three new species with restricted distributions from remote and little-studied sites in Madagascar. Baccate fruits are definitely known for only one of the new species (*Aloe ivakoanyensis*). Mature fruits for the other two are presently unknown, but based on presumed affinities discussed here, we strongly suspect that *A. beankaensis* will probably belong to section *Lomatophyllum* (Willd.) G. D. Rowley but the sectional placement of *A. analavelonensis* is presently uncertain. These new species are described, illustrated, mapped, and compared with presumed relatives. We also evaluate the conservation status of each in the context of IUCN Red List guidelines and criteria (IUCN Standards and Petitions Subcommittee, 2010). With the addition of these three new species, Madagascar now has over 118 species of *Aloe* (Castillon & Castillon, 2010, 2011) and still other new taxa remain to be formally described. Ultimately, Madagascar may exceed South Africa in the number of *Aloe* species. To be sure, among countries with a wealth of *Aloe* species, Madagascar is unique in that all of its species appear to be endemic to the island.

Descriptions

Aloe analavelonensis Letsara, Rakotoarisoa & Almeda, sp. nov.

Type – Madagascar. Ex-Province of Toliara: Region of Atsimo Andrefana, Sakaraha, Analavelona Forest, 22°40'S, 44°10'E, elevation 1,035 m, *Letsara*,

Andriamihajarivo & Rakotonasolo 938 (holotype: TAN; isotypes: CAS, K).

Perennial acaulescent **herb** with basal offshoots to form dense clustered mats. **Leaves** 9-12 per plant, rosulate, 12-15 cm long, 2.0-2.5 cm wide at the base, narrowly linear, spreading horizontally at first, becoming slightly recurved upwards, epidermis smooth, upper surface channelled, upper and lower surface green with 6-8 faint parallel veins; the margins armed with green or light brown, erect or antrorsely curved deltoid teeth, 1.6 mm long spaced 3-5 mm apart, the leaf apices free of teeth or variously shortly-bifid; exudate colorless. **Inflorescence** erect, unbranched 18 cm long; **peduncle** brownish, 5 mm in diameter with 3 sterile pale brown, scarious spreading bracts; **racemes** cylindrical, 8.5 cm long, 4-5 cm wide, lax, 6-10-flowered, buds erect, flowers pendant at anthesis; **floral bracts** subtending pedicels ± deltoid, scarious, pale brown, 2-3 mm wide at the base; **pedicels** reddish-orange, glabrous, 14 mm long. **Perianth** cylindrical, orange or reddish-orange at base but yellow-green distally and dark green where the nerves coalesce toward the apex, 26 mm long, 6 mm across the ovary, narrowed above the ovary and somewhat flaring towards the apex; outer tepals free, 3-5 nerved becoming intense green towards the apex, inner tepals free, 3-nerved, otherwise like the outer tepals. **Filaments** yellow, 20-25 mm long, with attached anthers exerted 2-5 mm beyond the perianth tube. **Style** and **stigma** yellow, 20 mm long, barely exerted. **Pollen** grain surface smooth, elliptical, monosulcate, heteropolar, the exine perforate, longest axis 18-36 µm. **Fruit** and **seeds** not seen (Figures 1 & 3a-e).

Distribution, habitat, and phenology (Figures 2 & 3j)

This species is known only from the Analavelona Massif northeast of Toliara, an island of unique humid forest in southwestern Madagascar at just over 1,000 m surrounded by anthropogenic savanna. It was collected in forest shade on rocky substrate near a waterfall along the Manasay River. Cultivated plants of this species in the garden of the CAS Biodiversity Center in Antananarivo flowered in May.

Aloe analavelonensis is distinguished by its acaulescent habit that offsets prolifically to form dense mats of dozens of individuals. Each plant has only 9-12 relatively short leaves (12-15 × 2.0-2.5 cm) that are green, unmarked throughout, and armed with erect deltoid teeth that are spaced about 3.5 mm apart. The inflorescence is a simple few-flowered (6-10) raceme and the tepals are orange or reddish-orange basally but yellow-green distally and dark green

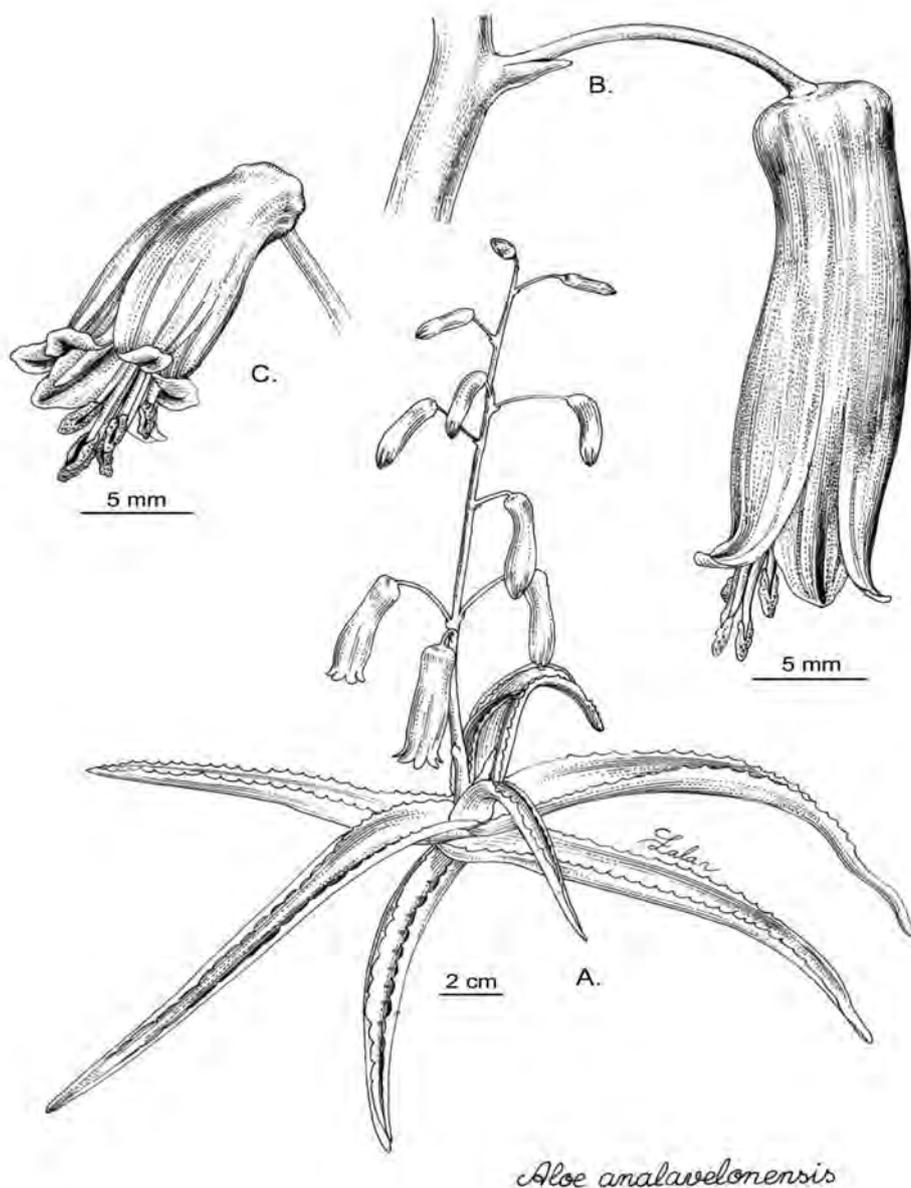


Figure 1. *Aloe analavelonensis* sp. nov. A) Habit with inflorescence. B) Profile of flower, showing pedicel, floral bract, and exserted stamens. C) Flower showing flaring tepals and stamens. (Drawing by Lala Roger Andriamiarisoa).

where the nerves coalesce toward the apex. Among described Malagasy species, *A. analavelonensis* may be confused only with *A. darainensis* J.-P. Castillon of section *Lomatophyllum* (Castillon & Castillon, 2010), which is known from the Sava region of the Ex-Province of Antsiranana in northern Madagascar where it occurs in dry woodland close to the town of Daraina (Castillon, 2009). The latter is so distinctly caulescent that plants often develop a creeping habit. The leaves are mostly flat adaxially and only 6-10 cm long. The marginal foliar teeth in *A. darainensis* are white (not green or brown) and more widely spaced (5-9 cm apart) and the inflorescence has more flowers (15) than *A. analavelonensis*. Flower color, size, and shape in *A. analavelonensis* are much like

A. rauhii Reynold, a species from the southwestern dry spiny forest-thicket, but the racemes of the latter are 12-18-flowered and the fruits are true capsules. The latter also differs markedly in having up to 20 leaves per plant that are lanceolate-deltoid, shorter (7-10 cm long), gray-green (sometimes with a reddish or brownish tinge), with numerous narrowly H-shaped white spots scattered irregularly over the entire adaxial surface. The sectional placement of *A. analavelonensis* is uncertain because the cultivated plants from which the only flowering material is known did not set fruit. Because it shares so many floral features with *A. rauhii*, we suspect that it may ultimately prove to be part of informal Group 1 that Reynolds (1966) designated for Malagasy aloes.

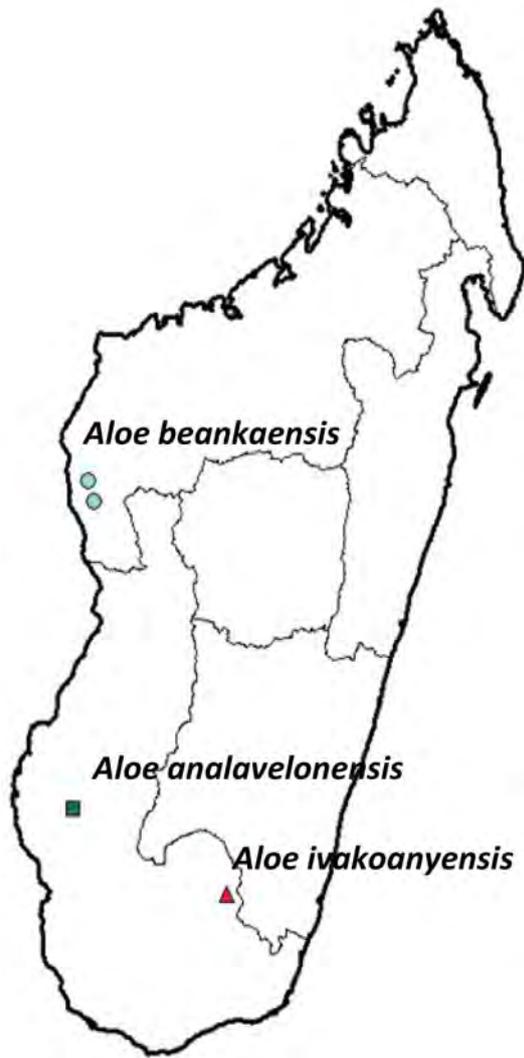


Figure 2. Distributions of *Aloe analavelonensis*, *A. beankaensis*, and *A. ivakoanyensis*.

Conservation status – *Aloe analavelonensis* is known to us from a single population of fewer than 250 mature individuals that formed a dense mat about 2 x 1 m in extent. During the four days that our expedition team spent on the Analavelona Massif, no other populations were encountered. Based on IUCN criteria (IUCN Standards and Petitions Subcommittee, 2010), we recommend a conservation classification of Vulnerable (VU). The relict forest on this massif has no official governmental protection, but it is currently receiving community-based management with assistance from the Missouri Botanical Garden. The continued survival of this forest may be secure because it is considered sacred by people living in surrounding villages (Moat & Smith, 2007). Although there is no cutting of trees, the Analavelona Forest is used to hide cattle from rustlers. The immediate threats appear to be burning of forest edges for cattle grazing.

Etymology – The species epithet, *analavelonensis*, refers to the name of the forest where this species is evidently endemic. It is derived from “*ala*”, forest and “*velona*”, living or alive: the place of a living forest. It is called “*ala faly*” and considered sacred by the local Bara people.

***Aloe beankaensis* Letsara, Rakotoarisoa & Almeda, sp. nov.**

Type – Madagascar. Ex-Province of Mahajanga: Region of Melaky, Maintirano, Beanka Forest, 18°01’S, 44°30’E, elevation 225 m, *Letsara, Andriamihajarivo & Rakotonasolo* 937 (holotype: TAN; isotypes: CAS, K).

Perennial short-caulescent **herb** with basal offshoots to form small groups of 2-5 rosettes; **stem** slender, decumbent or ascending, 6 x 0.3-0.4 cm. **Leaves** 6-10 per plant, 8.5 cm long, 0.8 cm wide at base, narrowly linear, cauline-dispersed but becoming crowded at the stem tips with age, spreading horizontally then becoming recurved towards the apex, upper surface slightly channeled, lower surface rounded, both surfaces with scattered elliptical white spots and darker green longitudinal veins; margin armed with white, spreading, deltoid teeth, 1 mm long, spaced 3-4 mm apart, leaf apices usually entire or with 1 or 2 small teeth; exudate colorless. **Inflorescence** erect, unbranched 19.70 cm long; **peduncle** brownish, 4 mm in diameter, **sterile bracts** on the peduncle and at the inflorescence apex at first pale tan with a darker green central nerve, becoming scarious with a dark brown central nerve at maturity; **raceme** capitate, 5-8 cm long, rather lax, 8-9 flowered, buds spreading horizontally becoming somewhat pendant at anthesis; fertile **floral bracts** narrowly lanceolate, scarious, pale tan, 8-10 mm long, 1-nerved; **pedicels** reddish, glabrous, 3-4 mm long. **Perianth** cylindrical to somewhat bowed, reddish-orange, the distal lobes yellow, ± 21 mm long, 7 mm across the ovary, somewhat narrowed above the ovary and slightly flaring distally, horizontally spreading to pendent; outer and inner tepals free, yellow with a dark green longitudinal band. **Filaments** yellow, 12 mm long, with attached anthers not exerted beyond the perianth tube. **Style** yellow, 12 mm long, not exerted. **Pollen, fruit, and seeds** not seen (Figures 3f & 4).

Distribution, habitat, and phenology (Figures 2 & 3k) – Known from the Beanka Forest in western Madagascar, a little-known forest on razor-sharp *tsingy* limestone, 75 km east of Maintirano on the

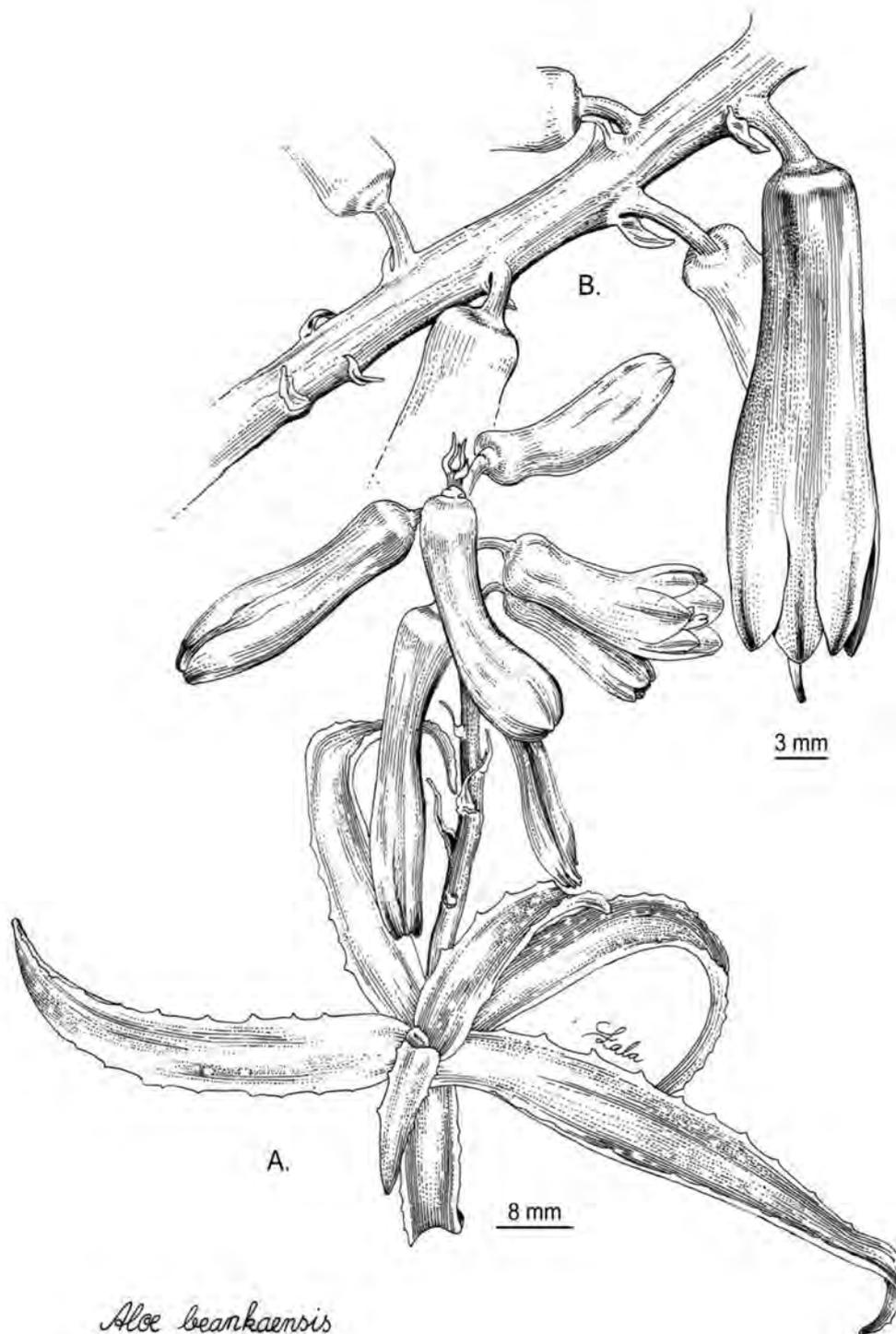


Figure 3. Images of *Aloe* and habitats. a-e) *A. analavelonensis*. F) *A. beankaensis*. g-i) *A. ivakoanyensis*. j) Analavelona Massif showing savanna in foreground and forest in background. k) Beanka Forest with disturbed savanna in foreground and deciduous forest in background. l) Humid forest on the Ivakoany Massif.

road towards Morafenobe between the villages of Ambinda and Ambohimiary. The plant was discovered along a path parallel to the Kinahengo River at 225 m. The Beanka Forest is a dense deciduous forest with *Dalbergia* L. f., *Commiphora* Jacq., and *Hildegardia* Schott & Endl. (Humbert & Cours Darne, 1965) or what has more recently been described as western dry forest (Moat & Smith, 2007). *Aloe beankaensis* has also recently been discovered in the Tsingy de Bemaraha National Park (Bemaraha NP) which is just south of the Beanka Forest (Castillon & Castillon,

2011). Cultivated plants of this species at the CAS Biodiversity Center in Antananarivo flowered in early November.

Sterile plants of this species were collected on 26 October 2009 during a joint expedition of the California Academy of Sciences, Parc Botanique et Zoologique de Tsimbazaza, Missouri Botanical Garden, and Association Vahatra, to the Beanka Forest. Our description of this species is based on garden grown material, since no fertile material was encountered in the wild.



Aloe beankaensis

Figure 4. *Aloe beankaensis* sp. nov. A) Habit with inflorescence. B) Portion of inflorescence showing lateral view of flower, pedicels, and floral bracts. (Drawing by Lala Roger Andriamiarisoa).

Aloe beankaensis is characterized by its short-caulescent habit with basal offshoots to form small groups of 2-5 rosettes, relatively small, narrowly linear leaves with scattered elliptical white spots on both surfaces, white deltoid marginal teeth that are spaced 3-4 mm apart, and short, 8-9 flowered racemes.

One member of our team initially thought that this species might be *A. progagulifera* (Rauh & Razaf.) L.

E. Newton & G. D. Rowley, a species that is very close to and arguably distinct from *A. prostrata* (H. Perrier) L. E. Newton & G. D. Rowley and *A. ankaranensis* Rauh & Mangelsdorff (Castillon & Castillon, 2010). When the planted Beanka material came into flower, careful analysis of the plants revealed that this taxon is distinct and not attributable to any described species. *Aloe progagulifera* differs in being

acaulescent, its gray-green leaves are larger with a wider base (20 × 1.5-2.0 cm) and the adaxial surface is covered with an irregular mixture of white spots, blotches, and broad lines or bands. Its inflorescence also differs in being a capituliform raceme and usually produces bulbils. *Aloe beankaensis* is superficially reminiscent of two other species of limestone habitats in northern Madagascar, *A. antsingyensis* (Leandri) L. E. Newton & G. D. Rowley and *A. darainensis*. The former differs in having thin stems to 1 m tall, narrow unmarked linear leaves that are 20-40 cm long, and inflorescences that are conspicuously shorter than the leaves. The latter is also distinctly caulescent (up to 15 cm tall) with leaves that are uniformly green on both surfaces and marginal foliar teeth spaced 5-8 mm apart. *Aloe darainensis* also differs from *A. beankaensis* in having more leaves per plant (15) and a longer perianth (26 mm).

Conservation status – The Beanka Forest population of *Aloe beankaensis* consists of about 15 mature individuals spread over an area of 10 × 2 m. During a week of fieldwork in the area, our expedition team found no other individuals or populations of this species. We have no information on the size of the Bemaraha NP population since no details were provided when it was recently reported from that area (Castillon & Castillon, 2011). Based on IUCN criteria (IUCN Standards and Petitions Subcommittee, 2010), we recommend a conservation classification of Least Concern (LC). Despite the small size of known populations and fragmented distribution, both the Beanka Forest and Tsingy de Bemaraha NP (a World Heritage Site) are remote protected areas with limited visitation. The 14,000 ha Beanka Forest is essentially a northern extension of Tsingy de Bemaraha NP that has been managed since late 2007 by Biodiversity Conservation Madagascar (BCM) and funded by Bioculture (Mauritius) Ltd. BCM is a Malagasy Association that focuses on forest conservation and restoration and the initiation of programs for socio-economic development of surrounding communities.

Etymology – The species epithet *beankaensis* refers to the name of the forest (Beanka) where this species was first discovered. Its place name is derived from the words “*be*”, many, and “*hanka*”, the Madagascar Long-eared Owl, *Asio madagascariensis* (Strigidae).

***Aloe ivakoanyensis* Letsara, Rakotoarisoa & Almeda, sp. nov.**

Type – Madagascar. Ex-Province of Toliara: Region of Anosy, Amboasary Sud, Ivakoany Forest, 23°52'S, 46°27'E, elevation 950 m, *Letsara & Andriamihajirivo 624* (holotype: TAN).

Perennial acaulescent or short-caulescent **herb**, solitary or offsetting to produce 2-5 rosettes. **Leaves** 14-23 per plant, rosulate, 39-45 cm long, 3-4 cm wide at the base, ascendant but lax and more or less nodding, pendulous or curved backward distally (rarely straight but then not erect), triangular acuminate, narrowly lanceolate-triangular, upper surface deeply channelled, lower surface rounded, smooth, margins similar in colour to that of the leaf surface, with firm, pale marginal teeth, 3.5 mm long, 8-20 mm apart at mid-leaf; exudate green-yellowish. **Inflorescences** 1-5 produced simultaneously, 30 cm long, erect or ascending, usually unbranched, occasionally with one short lateral branch; **peduncle** green at its base but orange toward the apex, 9 mm wide at the base, with six **sterile bracts**, 10 mm long 5 mm wide, deltoid, reddish at the base otherwise tan and scarious, with 3 conspicuous brown-black nerves that fuse distally; **racemes** cylindrical to laxly conical, 10 cm long, 7 cm wide, buds erect to spreading and covered by floral bracts, flowers pendent at anthesis; fertile **floral bracts** narrowly lanceolate, scarious, pale tan, ± 4.0-4.5 mm long, with one prominent nerve extending the length of the bract; **pedicels** orange-red, 9 mm long. **Perianth** cylindrical, orange-red, paler towards distal end, green-tipped in bud, 28 mm long, 7 mm across the ovary, narrowed above the ovary. **Filaments** yellow-orange, 23.5-26.0 mm long, with attached anthers exerted 5 mm (including attached anthers) beyond the perianth tube. **Style** and **stigma** yellow, 26 mm long, exerted 3 mm. **Pollen** grain surface smooth, elliptical, monosulcate, heteropolar, exine reticulate, the longest axis 20-48 µm. **Fruit** a globose berry 18-19 mm long. **Seeds** dark brown, pyramidal and unwinged, 5 × 3 mm (Figures 3g-l & 5).

Distribution, habitat, and phenology (Figures 2; 3l) – Known only from rocky slopes in humid forest on the Ivakoany Massif in southeastern Madagascar at 925 m. In the wild, limited flowering was noted in November. In cultivation, this species flowered from August to November with fruits developing from September to March.

The forests of the Ivakoany Massif are rarely visited because of difficult accessibility. An expedition to the region was undertaken by a team from the

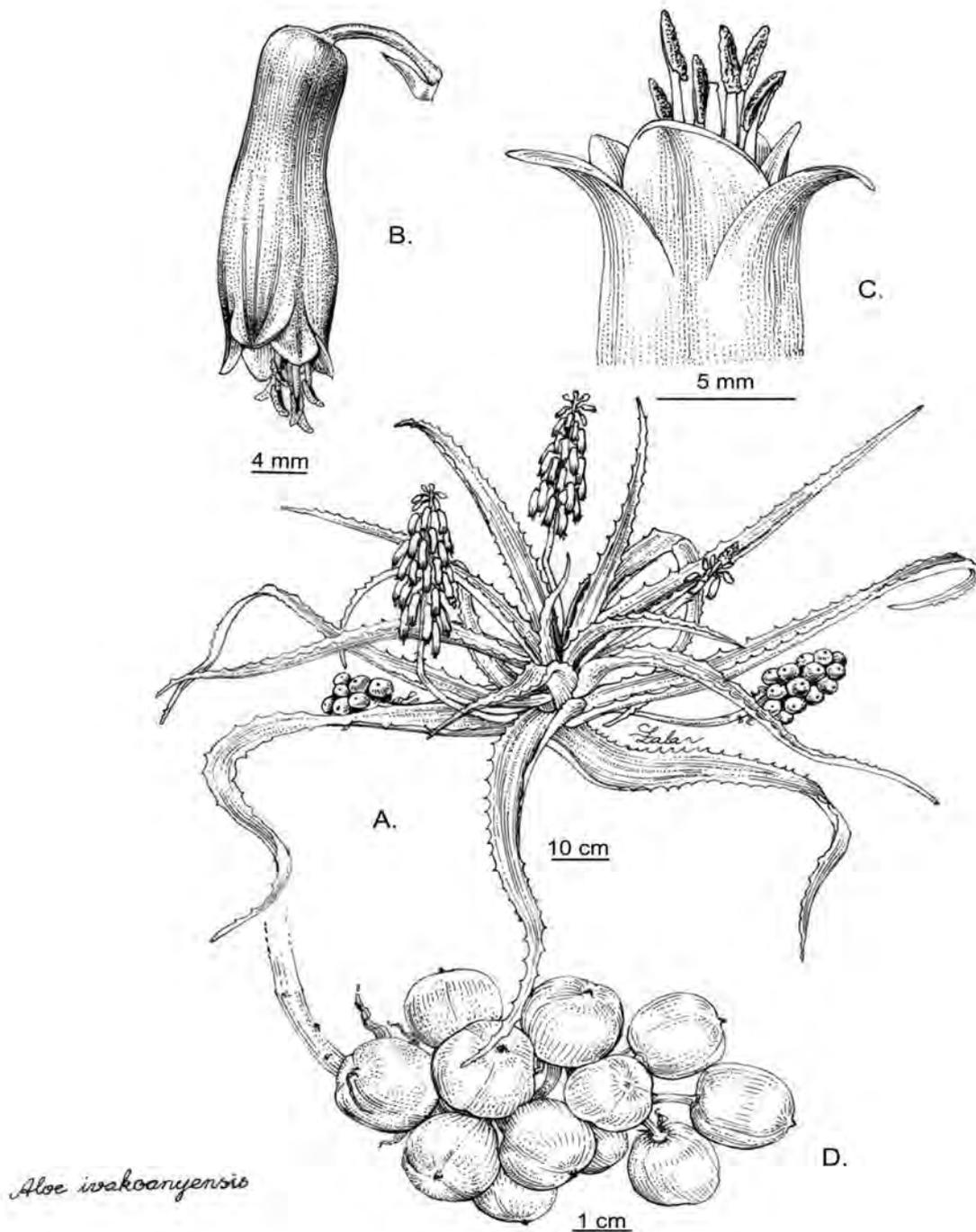


Figure 5. *Aloe ivakoanyensis* sp. nov. A) Habit with inflorescences. B) Profile view of flower showing pedicel, floral bract, and exserted stamens. C) Flaring tepal lobes and exserted stamens and style. D) Mature fruit. (Drawing by Lala Roger Andriamiarisoa).

California Academy of Sciences and the Missouri Botanical Garden in November of 2008 in search of *Rousseauxia humbertii* (H. Perrier) Jacq.-Fél. (Melastomataceae) known only from the type specimen. Although we did not find the latter, our field team collected live material of an unusual *Aloe* that was subsequently planted in the garden of the CAS Biodiversity Center in Antananarivo. Our analysis and description of this new species is largely based on material that was brought to flower in cultivation.

Aloe ivakoanyensis is distinguished by its acaulescent or short-caulescent habit, leaves that are elongate, uniformly green, lax and curving backward distally, pale greenish foliar teeth 3.5-5.0 mm long that are spaced 8-20 mm apart at mid-leaf, and cylindric simple raceme (occasionally with one short lateral branch). It superficially resembles other members of section *Lomatophyllum*, namely *A. aurelienii* J.-B. Castillon, *A. citrea* (Guillaumin) L. E. Newton & G. D. Rowley, *A. orientalis* (H. Perrier) L. E.

Newton & G. D. Rowley, and *A. rosea* (H. Perrier) L. E. Newton & G. D. Rowley. Among these congeners, only *A. rosea* appears to be particularly close to *A. ivakoanyensis*. Both are forest species that share a similar rosulate offsetting habit, leaves that are alike in size and shape, and the inflorescences of both are prevaillingly simple racemes of similar size. *A. rosea* has fewer leaves per rosette (12-15), shorter pedicels (5-6 mm), and shorter perianth parts (22-25 mm). Its foliar teeth are longer (5-8 mm) and its perianth is pink basally, but white flushed with green distally. Another characteristic feature of *A. rosea* is the very thin, scarious or translucent aging perianth parts. The geographic distributions of *A. ivakoanyensis* and *A. rosea* appear to be allopatric, but the distributional extent of *A. rosea* is not yet certain. In the protologue and subsequently, Perrier de la Bâthie (1926, 1938) reported it from the Eastern Domain and from the Central Highlands. Castillon & Castillon (2010) note that it is probably a species of the Central Highland forests north and east of Antananarivo.

The only other species with which *A. ivakoanyensis* might be confused is *A. megalocarpa* Lavranos, another member of section *Lomatophyllum*, which is known only from the hills around the Manambato River between Ambilobe and Iharana in northwestern Madagascar (Castillon & Castillon, 2010). The latter, which has fruits that are 20 mm or more in diameter, is readily separated from *A. ivakoanyensis* by its short creeping stems, longer leaves (50-80 cm), and consistently branched inflorescence.

Conservation status – Our field team spent two days on the Ivakoany Massif during which time they encountered only about 10 mature individuals of *A. ivakoanyensis* growing on rocky outcrops in humid forest over an area of some 10 m². Based on IUCN criteria (IUCN Standards and Petitions Subcommittee, 2010), we recommend a conservation classification of Critically Endangered (CR) for this species because of the very small population size, limited geographic range, and threat to the forest environments in southeastern Madagascar. The humid forest, which once covered extensive areas of southeastern Madagascar, is now reduced to fragmented remnants that are commonly surrounded by anthropogenic savanna. The forests of the Ivakoany Massif are rarely visited because of challenging terrain. Despite its isolation, it is not immune to forest destruction and periodic fires, which remain a conservation concern in rural Madagascar. To date, no area of the massif has been accorded official protected status.

Etymology – The species epithet, *ivakoanyensis*, refers to the name of the Ivakoany Massif where this species is evidently endemic. The origin of Ivakoany is uncertain, but it is probably from the words “i” a place of, and “vakoany” *Pandanus*.

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