The montane trees of the Cameroon Highlands, West-Central Africa, with *Deinbollia onanae* sp. nov. (Sapindaceae), a new primate-dispersed, Endangered species

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We test the hypothesis that the tree species previously known as *Deinbollia sp. 2*. is a new species for science. We formally characterise and name this species as *Deinbollia onanae* (Sapindaceae-Litchi clade) and we discuss it in the context of the assemblage of montane tree species in the Cameroon Highlands of West-Central Africa. The new species is a shade-bearing, non-pioneer understorey forest tree species reaching 15 m high and a trunk diameter that can attain over 40 cm at 1.3 m above the ground. Seed dispersal has been recorded by chimpanzees (*Pan troglodytes ellioti*) and by putty-nose monkeys (*Cercopithecus nictitans*) and the species is used by chimpanzees for nesting. Cameroon has the highest species-diversity and species endemism known in this African-Western Indian Ocean genus of 42, mainly lowland species. *Deinbollia onanae* is an infrequent tree species known from six locations in surviving islands of montane (sometimes also upper submontane) forest along the line of the Cameroon Highlands, including one at Ngel Nyaki in Mambilla, Nigeria. *Deinbollia onanae* is here assessed as Endangered according to the IUCN 2012 standard, threatened by severe fragmentation of its mountain forest habitat due to extensive and ongoing clearance for agriculture. The majority of the 28 tree species of montane forest (above 2000 m alt.) in the Cameroon Highlands are also widespread in East African mountains (i.e. are Afromontane wide). *Deinbollia onanae* is one of only seven species known to be endemic (globally restricted to) these highlands. It is postulated that this new species is morphologically closest to *Deinbollia oreophila,* a frequent species at a lower (submontane) altitudinal band of the same range. Detailed ecological data on *Deinbollia onanae* from the Nigerian location, Ngel Nyaki, where it has been known under the name *Deinbollia "pinnata",* is reviewed.

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ABSTRACT

We test the hypothesis that the tree species previously known as *Deinbollia sp. 2*. is a new species for science. We formally characterise and name this species as *Deinbollia onanae* (Sapindaceae-Litchi clade) and we discuss it in the context of the assemblage of montane tree species in the Cameroon Highlands of West-Central Africa. The new species is a shade-bearing, non-pioneer understorey forest tree species reaching 15 m high and a trunk diameter that can attain over 40 cm at 1.3 m above the ground. Seed dispersal has been recorded by chimpanzees (*Pan troglodytes ellioti*) and by putty-nose monkeys (*Cercopithecus nictitans*) and the species is used by chimpanzees for nesting. Cameroon has the highest species-diversity and species endemism known in this African-Western Indian Ocean genus of 42, mainly lowland species. *Deinbollia onanae* is an infrequent tree species known from six locations in surviving islands of montane (sometimes also upper submontane) forest along the line of the Cameroon Highlands, including one at Ngel Nyaki in Mambilla, Nigeria. *Deinbollia onanae* is here assessed as Endangered according to the IUCN 2012 standard, threatened by severe fragmentation of its mountain forest habitat due to extensive and ongoing clearance for agriculture. The majority of the 28 tree species of montane forest (above 2000 m alt.) in the Cameroon Highlands are also widespread in East African mountains (i.e. are Afromontane wide). *Deinbollia onanae* is one of only seven species known to be endemic (globally restricted to) these highlands. It is postulated that this new species is morphologically close to *Deinbollia oreophila,* a frequent species at a lower (submontane) altitudinal band of the same range. Detailed ecological data on *Deinbollia onanae* from the Nigerian location, Ngel Nyaki, where it has been known under the name *Deinbollia "pinnata",* is reviewed.

INTRODUCTION.

As part of the project to designate Important Plant Areas (IPAs) in Cameroon (also known as Tropical Important Plant Areas or TIPAs, https://www.kew.org/science/our-science/projects/tropical-important-plant-areas-cameroon), we are striving to name, assess the conservation status and include in IPAs (*Darbyshire et al., 2017*) rare and threatened plant species in the threatened natural habitat of the Cross-Sanaga interval (*Cheek et al., 2001*).

Several of these species were previously designated as new to science but not formally published in a series of checklists (see below) ranging over much of the Cross-Sanaga interval. The Cross-Sanaga has the highest vascular plant species diversity per degree square in tropical Africa (*Barthlott et al., 1996*) but natural habitat is being steadily cleared, predominantly for agriculture.

In this paper we test the hypothesis that the high-altitude tree species formerly designated as "*Deinbollia* sp. 2" (*Harvey et al., 2004, Cheek et al., 2004, Cheek et al., 2010*), "*Deinbollia* sp." (*Chapman & Chapman, 2001*) or "*Deinbollia pinnata"* (*Abiem et al., 2020*), is a new species to science, and we describe, characterise, and name it as *Deinbollia onanae Cheek.* The species is discussed in the context of the assemblage of the other montane forest tree species (occurring above 2000 m alt.) in the Cameroon Highlands (see Discussion below).

The genus *Deinbollia* Schum. & Thonn. is traditionally placed in the tribe Sapindeae DC. and is characterised by its 1-pinnate, imparipinnate leaves, flowers with petals well developed and about the same in number as the imbricate sepals, the petals with a well-developed ligule (or appendage) on the adaxial surface and with stamens 9–30 in number, the intrastaminal disc central, the edge with more than 5 shallow ridges. The fruits develop 1–3 indehiscent, apocarpous fleshy mericarps (*Fouilloy & Hallé, 1973*).

Molecular phylogenetic sampling of the Sapindaceae is incomplete with many African genera not represented, as can be seen in *Buerki et al.,* (*2009*). In that study *Deinbollia* is represented by six samples of four species, all from Madagascar (on which limited basis it appears monophyletic) and is resolved in the informally named 'Litchi Group' of genera, where it is in a

sister relationship to a subclade comprising the genera *Lepisanthes* Blume (Africa to Asia) *Atalaya* Blume (American) and *Pseudima* Radlk. (American) (*Buerki et al., 2009*). The delimitation of Sapindaceae in this paper follows the evidence of *Buerki et al.,* (*2010*), that is, excluding Aceraceae, Hippocastanaceae and Xanthoceraceae which have sometimes been included within it.

Deinbollia has 42 accepted species, one shared between Africa, Reunion and Madagascar, five endemic to Madagascar, and 35 species restricted to subsaharan continental Africa. The species predominantly occur in lowland evergreen forest and are absent from countries that lack this habitat such as Rwanda, Burundi, Swaziland and Lesotho (high altitude) and Namibia, Botswana, Eritrea, Mali and Burkina Faso (low rainfall and lacking significant evergreen forest). The highest species diversity is found in Cameroon, with 16 species (Plants of the World Online accessed May 2020). Cameroon has the highest levels of country-level endemism known in the genus. Ten of the Cameroon species are globally threatened with extinction (Cheek in *Onana & Cheek 2011: 314–316; Cheek, 2004a; Cheek, 2017a; Cheek, 2017b*). In contrast only 10 species are recorded for the whole of West Tropical Africa (*Keay, 1958*). Since the Flore Du Cameroun account was published (*Fouilloy & Hallé, 1973*), several further species apart from those listed below, were published for Cameroon by *Thomas* (*1986*). The genus was last revised by *Radlkofer* (*1932*).

In the 21st century only two new species to science have been published in the genus, *Deinbollia mezilii* D.W.Thomas & D.J.Harris (*Thomas & Harris, 2000*) and *D. oreophila* Cheek (*Cheek & Etuge 2009*), both from Cameroon. But specimens often remain unidentified in herbaria. For example, 16 specimens unidentified to species are listed in the Gabon Checklist (*Sosef et al.,2005*). The genus has no major uses, but the fruits of several species are reported as being edible by humans, and the seeds are probably primate-dispersed or dispersed by large frugivorous birds, and the flowers probably bee-pollinated (*Cheek & Etuge, 2009*). Several species are recorded to be useful locally in West Africa especially medicinally, e.g., the bark of *D. grandifolia* Hook.f. is used for treating jaundice and the wood for planks (*Burkill, 2000:*17–19).

METHODS & MATERIALS

The electronic version of this article in Portable Document Format (PDF) will represent a published work according to the International Code of Nomenclature for algae, fungi, and plants (ICN), and hence the new names contained in the electronic version are effectively published under that Code from the electronic edition alone. In addition, new names contained in this work which have been issued with identifiers by IPNI will eventually be made available to the Global Names Index. The IPNI LSIDs can be resolved and the associated information viewed through any standard web browser by appending the LSID contained in this publication to the prefix "http://ipni.org/". The online version of this work is archived and available from the following digital repositories: PeerJ, PubMed Central, and CLOCKSS.

Fieldwork in Cameroon resulting in the specimens cited in this paper was conducted under the terms of the series of Memoranda of Collaboration between IRAD (Institute for Agronomic Research and Development)-National Herbarium of Cameroon and Royal Botanic Gardens, Kew beginning in 1992, the most recent of which is valid until 5th Sept. 2021. The most recent research permit issued for fieldwork under these agreements was 000146/MINRESI/B00/C00/C10/C12 (issued 28 Nov 2019), and the export permit number was 098/IRAD/DG/CRRA-NK/SSRB/12/2019 (issued 19 Dec 2019). At the Royal Botanic Gardens, Kew, fieldwork was approved by the Institutional Review Board of Kew entitled the Overseas Fieldwork Committee (OFC) for which the most recent registration number was OFC 807-3 (2019). The most complete set of duplicates for all specimens made was deposited at YA, the remainder exported to K for identification and distribution following standard practice. Field work methodology followed was *Cheek & Cable* (*1997*).

Herbarium citations follow Index Herbariorum (*Thiers et al., 2020*). Specimens indicated "!" were seen by one or both authors, and were studied at K, P, WAG, and YA. The National Herbarium of Cameroon, YA, was also searched for additional material of the new taxon as was Tropicos (http://legacy.tropicos.org/SpecimenSearch.aspx). During the time that this paper was researched in 2019–2020, it was not possible to obtain physical access to material at WAG (due to the transfer of WAG to Naturalis, Leiden, subsequent construction work, and covid-19 travel and access restrictions). However images for WAG specimens were studied at https://bioportal.naturalis.nl/?language=en and those from P at https://science.mnhn.fr/institution/mnhn/collection/p/item/search/form?lang=en_US. Specimens of *Deinbollia* at FHO could not be accessed due to covid-19 and are not available digitally. Specimens at FHI are also not available digitally. We also searched *JStor Global Plants* (*2020*) for additional type material of the genus not already represented at K.

Binomial authorities follow the International Plant Names Index (*IPNI, 2020*). The conservation assessment was made using the categories and criteria of *IUCN* (*2012*). GeoCAT was used to calculate red list metrics (*Bachman et al., 2011*). Herbarium material was examined with a Leica Wild M8 dissecting binocular microscope fitted with an eyepiece graticule measuring in units of 0.025 mm at maximum magnification. The drawing was made with the same equipment using Leica 308700 camera lucida attachment. Flowers from herbarium specimens of the new species described below were soaked in warm water to rehydrate the flowers, allowing dissection, characterisation, and measurement. The terms and format of the description follow the conventions of *Cheek & Etuge* (*2009*). Georeferences for specimens lacking latitude and longitude were obtained using Google Earth (https://www.google.com/intl/en_uk/earth/versions/). The map was made using SimpleMappr (https://www.simplemappr.net).

RESULTS

TAXONOMIC TREATMENT

Deinbollia sp. 2 (Fig. 1), because it has leaves of flowering branches less than 1 m long, only sparsely hairy on the lower surface, leaflets more than 15 cm long and sepals adaxially glabrous, flower buds very sparsely hairy and less than 5 mm diam., borne on a branched inflorescence 10–30 cm long, keys out in the Flore Du Cameroun treatment of *Deinbollia* (*Fouilloy & Hallé,*

1973) to a couplet leading to *D. grandifolia* Hook.f. and *D. maxima* Gilg. However, it differs from these two species in having (2–)8–11-jugate leaves (not 4–7-jugate), and in other characters shown in Table 1. In its Nigerian location our species has been referred to as *D. pinnata* (*Abiem et al., 2020*). *Deinbollia pinnata* Schum. & Thonn. is a common lowland West African species that occurs from Guinea to Nigeria, it differs in being densely hairy, so that the lower surface of the leaflets are softly hairy to the touch due to dense, patent, translucent hairs, and it is usually a small shrub of disturbed habitats, with an unbranched, raceme-like inflorescence that is pendulous in fruit, with hairy fruits 12-13 mm wide (see https://commons.wikimedia.org/wiki/File:Deinbollia_pinnata_MS6765.jpg; Keay 1958: 714–715). In contrast, *Deinbollia sp. 2* has only a very few, sparse, red, subappressed hairs along the midrib and secondary nerves, is a tree of intact high elevation forest, the inflorescence is erect, with numerous long branches bearing glabrous fruits 20 mm or more wide (see description below). Additional characters separating *Deinbollia sp. 2* from *Deinbollia pinnata* are included in Table 1.

The affinities of *Deinbollia* sp. 2 may be with the recently described *D. oreophila* since this species also occurs at altitude in the Cameroon Highlands and both species share numerous raised lenticels and also leaflets with high length: breadth ratios and with high numbers of secondary nerves. Both species share an unusual structure which is also seen in *Deinbollia pinnata:* the adaxial surface of the leaf rhachis is not rounded as in the other West African species, but flattened, the margins slightly raised forming acute angles with the sides, with a distinct, raised midline (*Cheek & Onana, 2009*: Fig. 1C). In fact, at two locations, Mt Kupe and Bali Ngemba, the two species *D. oreophila* and *Deinbollia* sp. 2 are sympatric and their altitudinal ranges can overlap (*Cheek et al., 2004; Harvey et al., 2004*). However, without DNA studies, convergent evolution cannot be ruled out. As the only two species of the genus to grow at altitude in the Cameroon Highlands, there is a possibility that they might be confused with each other. The two species can be separated using the morphological characters presented in Table 2.

Deinbollia onanae *Cheek sp. nov.* – Fig. 1–4

Similar to but differing from *Deinbollia oreophila* Cheek in the length of leaves of flowering stems (14–)60–70 cm (versus 25–63 cm), number of leaflets per leaf (4–)16–23 (versus (4–)6–8(–10)), width of leaflets (2.1–)2.5–4 cm (versus (3–)5.5–9(–10.2) cm, number of secondary nerves on each side of midrib (15–)17–18, (versus (7–)9–14(–17); stems with lenticels brown, concolorous and inconspicuous, (versus discolorous, bright white and conspicuous), ovary bilocular (versus trilocular).Typus: Cameroon, *Mt Oku and the Ijim Ridge*, Aboh to Tum, 2400 m alt., fl. 22 Nov. 1996, *Etuge* 3600 (holotype K000337729! Fig. 2, isotypes MO!, WAG0336084!, WAG0336083!, YA0057050!);

Deinbollia cf. pinnata Schum. & Thonn., sensu Cheek, in *Cheek et al.,* (*2000*:162).

Deinbollia sp. 2 sensu Cheek in *Harvey et al.,* (*2004:* 125); Cheek & Etuge in *Cheek et al.,* (*2004*: 399); Cheek in *Cheek et al.,* (*2010*: 143, fig 23).

Deinbollia sp. Chapman & Chapman (*Chapman & Chapman, 2001*: c41)

Monoecious tree or treelet (4–)5–15 m tall, trunk 14.5–40 cm diameter at 1.3 m from the ground, lacking exudate or scent when wounded, sparingly branched, nearly glabrous, apart from the inflorescence. Stems of flowering branches terete 1–1.5 cm diameter, solid (not hollow), second internode below apical inflorescence 2–2.5 cm long, outer epidermis pale grey-brown, contrasting with the darker brown bases of the adjoining petiolar pulvini, lenticels dense, raised, elliptic, 0.6–1.1 mm long, concolorous, inconspicuous, glabrescent, hairs sparse to dense, dark brown, cylindric 0.1–0.5 mm long.

Leaves alternate, pinnately compound, (14–)60–70 cm long; leaflets (4–)16–23 per leaf on flowering stems, leaflets 10–14 per leaf on leaves of juvenile trees. Petiole (4–)9.5–20.8 cm long, terete, c. 4 mm diameter at midpoint, drying pale yellow; basal pulvini dark brown; rhachis (4.5–)32–44 cm long, (2–)8–11-jugate on flowering stems, 5–7-jugate on non-flowering stems of juvenile trees, the upper surface of the distal half flattened with two thin lateral wings and with a central dark hairy rounded central ridge, the rest of the rhachis glabrescent with sparse inconspicuous hairs (*de Wilde* 4555), or with sparse dark brown appressed hairs (*Cable* 3386). Leaflets mostly oblong (6.6–)14–19.5 x (2.1–)2.5–4 cm, (but leaflets of sterile branches to 6.5 cm wide), acumen c. 1 cm long, base broadly acute, slightly asymmetric, (basalmost leaflets lanceolate and about half the length of the other leaflets) lateral nerves and midrib yellow, raised above and below, convex, (15–)17–18 on each side of the midrib, nearly brochidodromous, the lateral nerve apices forming a weak irregular submarginal nerve, stronger branches uniting with the secondary nerve above, intersecondary nerves strong, parallel to the secondaries, tertiary and quaternary nerves reticulate raised yellow and conspicuous, on both surfaces, contrasting with the pale grey-green areolae (except in *Cable* 3386(K) where they are concolorous and so inconspicuous above, possibly an artefact of poor drying); upper surface glabrous, lower surface with inconspicuous, minute, cylindrical, subappressed glossy dark-brown hairs c. 0.25 mm long, distributed very sparsely along the midrib and secondary nerves, absent from mature leaves of non-flowering specimens (e.g. *Cheek* 8709) but then the same hair type present on axillary buds and young leaves; petiolules yellow, 2–5 mm long, glabrous.

Inflorescence a 80–120-flowered, loose, terminal panicle 25 x 10 cm; auxiliary inflorescences sometimes present in the axils of the distal 1–4 leaves (*Cheek* 13625); peduncle of terminal inflorescences 0–2 cm long; rhachis internodes (1–)2–3 cm long, shortest in the distal portion; first order bracts caducous; indumentum brown hairy; primary branches 10–20 per inflorescence, 2–8 cm long, each bearing (1–)2–5 partial-inflorescences; partial-peduncles 0–5 mm long, apex with a cluster of 3–5 bracteoles; bracteoles subulate to narrowly lanceolate, 2–3 mm long, apex narrowly acute, partial-inflorescences (1–)3-flowered in glomerules, pedicels erect, terete, 3–4 x 1.5 mm (female), 4–5 x 1mm (male), sparsely puberulent, hairs 0.1–0.5 mm long.

Flowers white, scent not recorded, flower buds c. 4 mm diam., open flowers c. 6 x 7 mm. Calyx with sepals 5(–6), orbicular to broadly ovate, concave, green colour, 4–5 x 3.5–4.5 mm apex obtuse. Corolla apex slightly exserted from calyx, petals rhombic or spatulate. Male flowers (Fig. 1C). Petals 5(–6), white, rhombic c. 5 x 3 mm, apex obtuse-acute, base cuneate, margins densely ciliate, hairs 0.3 mm long, outer surface glabrous, inner surface glabrous in distal half, proximal half compressed funneliform with ventral appendage adnate at margins, retuse (notched) for 0.5 mm at midline, adaxial surface moderately densely hairy, hairs c. 0.3 mm long. Extra-staminal disc torus-like, glabrous, irregular, outer wall convex, lacking constrictions or teeth with c. 15 poorly defined lobes, 2.5–3 mm wide, c. 0.8 mm high. Stamens c. 15, erect, slightly exserted by 1–2 mm at anthesis, c. 5–6.5 mm long; filament 4–5 mm long, straight, densely puberulent the entire length (Fig. 1D); anthers yellow, ovate-ellipsoid, 1–1.3 mm long. Ovary (vestigial, Fig. 1E) bilobed, c. 1 x 1.5 mm densely appressed hairy, hairs c. 0.5 mm; style 0.7 mm long, glabrous.

Female flowers (Fig. 1G), with sepals and petals as the male flowers, but petals c. 6 x 2.6–2.9 mm, usually detaching with a stamen attached, probably due to interlocking hairs (see Fig. 1 J), proximal two-thirds claw-like, c. 0.7 mm wide, margin sparsely and irregularly ciliate; ventral appendage with apex deeply bilobed, lobes c. 1 mm x 1 mm; disc as in male flower. Stamens c. 10 (see Fig. 1I), included at anthesis, filament c. 2.5 mm long, proximal half to quarter glabrous, distal part densely hairy; anther as male flowers but indehiscent; ovary bilobed (see Fig. 1 H), 3.2 x 5 mm, indumentum as male flower, style c. 5 mm long, apical 1 mm, curved, surface papillate-minutely puberulent, apex subcapitate. Infructescence, of same dimensions as inflorescence, erect. Fruit colour recorded as nearly black when ripe, tasting sweet-sour (Elisha Barde, see uses below), and notcoloured yellow when ripe (as in other species of the genus), mericarps 1 or 2, transversely ellipsoid, c.1.8 x 2.1 x 1.2 cm (hydrated), the surface leathery, shallowly and finely muricated, glabrous, mesocarp spongy and juicy, 1-seeded. Seed ellipsoid, c. 1.8 x 1.1 x 0.8 cm, testa thin, parchment like, endosperm absent, cotyledons fleshy.

Phenology: flowering in November-December; fruiting in February and April, immature fruit recorded in December and June.

Local name and uses: none are reported in Cameroon but in Ngel Nyaki, Nigeria, Elisha Emmanuel Barde of the Nigeria Montane Forest Project (pers. comm. to M. Cheek Dec. 2020), Nyeberehi (Fulfude) is the general name for all *Deinbollia* species while Jellahi (Fulfude) is a specific name for *Deinbollia onanae* in Ngel-Nyaki where Fulfude speakers (Fulanis) use the bark of this species as medicine for themselves to treat stomach aches as well as an anti-helminthic. It is not used for treating cattle. The fruits are reported to taste sour-sweet by Mr Barde. The species is also known as Pabba (Ndolla language).

Etymology: The specific epithet of *Deinbollia onanae* means ‘of Onana’ commemorating Dr Jean-Michel Onana, currently Senior Lecturer in Botany at the University of Yaoundé I, Cameroon, champion of plant conservation in Cameroon, specialist in Sapindales (Burseraceae, author of Flore Du Cameroun Burseraceae (*Onana, 2017*), co-chair of the IUCN Central African Red List Authority for Plants, former Head of the National Herbarium of Cameroon (2005–

2016), co-author of the Red Data Book of the Plants of Cameroon (*Onana & Cheek, 2011*) and the Taxonomic Checklist of the Vascular Plants of Cameroon (*Onana, 2011*). He led field teams of YA staff working with those of K that resulted in the collection of several of the specimens of this species and personally collected this species in the field (*Onana* 1600, K, YA).

Distribution & ecology: known only from the Cameroon Highlands of Cameroon (one location in the adjoining Mambilla Plateau, Nigeria) Fig. 3. Upper submontane & montane evergreen forest, sometimes in gallery forest; (1200–)2050–2200 m alt.

Detailed information on the ecology of *Deinbollia onanae* (under the name *D. pinnata*) is available from several studies led by Hazel Chapman at Ngel Nyaki, the largest or one of the largest, surviving forests in the Mambilla Plateau, a branch of the Cameroon Highlands that extends into Nigeria (see map, Fig. 3). At this submontane forest patch, area c.5.7 km^2, 1588–1690 m altitude, *Deinbollia* (Fig. 4) is recorded as one of the 20 most abundant woody plant species, with 158.68 stems above 1 cm diam. per ha (*Abiem et al., 2020*). In contrast, the 1970s 1 ha enumeration plot at Ngel Nyaki (*Chapman & Chapman, 2001*: 25–26) yielded five stems of "*Deinbollia* sp." in the C strata (understorey trees 7–13 m high) with diameter at 1.3 m above the ground exceeding 14.5 cm, of which two exceeded 28 cm and one 40 cm. This is more consistent with frequencies observed in Cameroon for *Deinbollia onanae*. The explanation between the disparity in stem numbers per ha between these two studies is probably that there is high mortality of juveniles of *Deinbollia onanae* at Ngel Nyaki, few surviving to make 14.5 cm diameter or more trees recorded in the second study. We speculate that an alternative explanation may be that the numerous small diameter individuals recorded by *Abiem et al.* (*2020*) may not be the usually infrequent *D. onanae,* but the similar but much smaller (0.8–3(–5) m tall) *D. oreophila* which at this altitude, over the border in Cameroon, is vastly more frequent in submontane forest (*Cheek & Etuge, 2009*). Many of the observations of animals e.g. putty-nosed monkeys (*Cercopithecus nictitans*) feeding on *Deinbollia* at Ngel Nyaki (*Gawaisa*, *2010*) were of primates in the crowns of trees so more likely to be of the larger, less frequent *D. onanae* which is evidenced at this location by two herbarium specimens (see "additional specimens" below) while *D. oreophila* has not yet been so recorded (and so may not in fact be present). Studies on the dietary preferences of the rare Nigerian-Cameroon chimpanzee (*Pan troglodytes ellioti*) by *Dutton & Chapman* (*2014*) at Ngel Nyaki found that among the 52 plant species consumed mainly as fruit, *Deinbollia* was the 4th (wet season) or 5th (dry season) species preferred of the 17 tree species over 10 cm diameter at breast height that were identified as seeds from 495 fecal samples. This record is certainly *D. onanae* since *D. oreophila* does not form trunks of such large diameters (*Cheek & Etuge, 2009*). However, *Deinbollia* was found in only one of these fecal samples, in which 47 of its seeds were recorded, collected in February 2011 (*Dutton & Chapman, 2014*). Only 16 weaned individuals of chimpanzee are known at Ngel Nyaki. More numerous and so probably more effective at seed dispersal are putty-nosed monkeys (*Cercopithecus nictitans*). *Gawaisa* (*2010*) reported that at Ngel Nyaki *Deinbollia* fruit ranked third in preferred species of fruits of *C. nictitans* during February and March, and fifth in January. *Hutchinson* (*2015*) has shown that males in particular show a preference for *Deinbollia* seeds in the rainy season (*Hutchinson 2014*). Seeds are both swallowed, passing through the gut (average 2 per faecal sample) and sucked and spat by the putty-nosed monkeys (averaging 5 seeds per spitting event) (*Chapman et al., 2010*). An experiment comparing germination time and success among *Deinbollia* seeds which had been defecated, spat and hand-cleaned found that

gut passage had a significant beneficial effect on germination rates. A higher proportion of defecated seeds (60–70%) germinated than spat (c. 40%) or hand-cleaned (c.35 %) seeds, and the defecated seeds germinated on average a few days earlier than non-defecated seeds (*Chapman et al., 2010*). In addition, leaves but not fruit of *Deinbollia* have been recorded as being consumed by tantalus monkeys (*Chlorocebus tantalus tantalus*), but only in very low quantities (*Agmen et al., 2010*). Putty nose monkeys also eat the leaves and flowers of *Deinbollia* (*Gawaisa, 2010; Hutchinson, 2015*). Studies of dispersal of seeds of about 40 Ngel Nyaki forest species up to 30 m into grassland from the forest edge using seed traps showed that *Deinbollia* was one of the small number of forest species that do not disperse seeds out of the forest, but that within forest, natural regeneration from seed does occur. The species has been classified as a shade-bearer and is not a pioneer (*Barnes & Chapman, 2014*). *Deinbollia "pinnata"* was one of three species of tree used to test the Janzen-Connell hypothesis at this site. Five hundred and seventy seedlings were raised and planted at distances of up to 25 m from 19 mature conspecific "mother" trees and monitored over the three months of the study. Predation was significantly higher closer to the mother trees than distant from them (c. 30% vs. 20%), but there was no support for Janzen-Connell effects in seedling height growth. About 80% of the seedlings survived, and they grew 4.5–5.5 cm over the 3 months (*Matthesius et al., 2011*). *Deinbollia "pinnata"* is one of 28 identified tree species used by chimpanzees as nesting trees at Ngel Nyaki, but is not among the preferred top five (*Dutton et al., 2016*).

Additional specimens: CAMEROON. South West Region, *Mt Kupe*, near main summit, immature fr., 26 June 1996, *Cable* 3386 (K000197863!, YA!); **North West Region.** *Bali Ngemba Forest Reserve*, fr. April 2002, *Onana* 1600 (YA!); *Mt Oku and the Ijim Ridge*: above Laikom, st. 21 Nov..1996, *Cheek* 8709 (K000337728! YA!); *Dom*, Kinjinjang Rock, st. 25 Sept. 2006, *Cheek* 13436 (K000580433!; YA!); ibid. Forest Patch 1, fl. buds, 27 Sept. 2006, *Cheek* 13625 (K000580434!, MO!,US!, YA!); ibid., Javelong Forest, st. 29 April 2005, *Pollard* 1400 (K000580432!; YA!); **Adamaoua Region**, c. 120 km E of Ngaoundéré, 15 km NE of Belel, falls in Koudini River, alt. ± 1200 m, fl. 4 Dec. 1964, *W.J.J.O. & J.J.F.E. de Wilde, B.E.E. de Wilde-Duyfjes* 4555 (K000593309!; K000593310!, WAG1269760! , YA). **NIGERIA. Taraba State, Mambilla Plateau,** Ngel Nyaki Forest Reserve, near camp, fr. 2 Dec. 2003, *H.M. Chapman* 481 (FHI, K!); ibid. female fl. 4 Dec. 2002, *H.M. Chapman* 484 (FHI, K!).

Notes: *Deinbollia onanae* first came to our attention in 2000 when completing the "Plants of Kilum-Ijim" (*Cheek et al., 2000*). Two specimens of *Deinbollia* matched no other and were named *Deinbollia cf. pinnata* (*Cheek et al., 2000*). In subsequent surveys this taxon was more explicitly referred to as a new species: *Deinbollia* sp. 2 (*Harvey et al., 2004, Cheek et al., 2004, Cheek et al., 2009*). However, the earliest known collection was made in 1964 (*W.J.J.O. & J.J.F.E. de Wilde, de Wilde-Duyfjes* 4555(K)).
This species is remarkable for the very large number of pairs of unusually long and slender leaflets (Fig. 4), and for the comparatively large size of the individuals which often attain 10-15 m in height (Fig. 4), among the largest trees known in the genus. However, at Ngel Nyaki trees can begin flowering at only 2.5 m in height (E. Barde pers. comm. to Cheek Jan. 2020)

Conservation: *Deinbollia onanae* is rare at each of its six known locations so far as is known, although at Ngel Nyaki this is difficult to establish due to potential confusion with *Deinbollia*

oreophila. Despite many thousands of herbarium specimens being collected at Kilum-Ijim, at Mt Kupe and the Bakossi Mts, at Ngel Nyaki and at Bali Ngemba (*Cheek et al., 2000; Cheek et al., 2004; Harvey et al., 2006*) only two specimens of this species at two sites, were made at each of the first three locations and only one at the third location. Surveys at other sites with suitable habitat in the Cameroon Highlands and elsewhere, e.g at Mt Cameroon and at the Lebialem Highlands, failed to find this species (*Cheek et al., 1996; Cable & Cheek 1998; Harvey et al., 2010; Cheek et al., 2011*). However, at Dom, where a targetted search for this species was made by the first author, three specimens were made, each representing single, isolated trees (*Cheek et al., 2010*). No more individuals than these were found. At Adamaoua Region, Cameroon it has only been collected once, and only a single tree was then noted (*W.J.J.O. & J.J.F.E. de Wilde, B.E.E. de Wilde-Duyfjes* 4555(K)). None of these locations is formally protected for nature conservation. Tree cutting for timber and habitat clearance for agriculture has long been known to be a threat at all but the last of these locations (references cited above). The range of the species is large: extent of occurrence was calculated as 50,525 km^2 using Geocat. However, severe habitat fragmentation has resulted over many hundreds of years, forest patches being now distant from each other by tens of kilometres, isolated in oceans of cultivation and secondary fire-maintained grassland making the possibility of primate-mediated dispersal from one forest area to another now extremely unlikely. Ecological evidence from Ngel Nyaki is that while *Deinbollia* regenerates in that forest patch, its primate dispersers do not, or seldom cross to other forest patches (Dutton & Chapman, 2014, see ecology notes above). We assess the area of occupancy of *Deinbollia onanae* as 34 km² using the IUCN preferred 4 km² cell size. Therefore, we assess this species as Endangered, EN B2ab(iii) using the *IUCN* (*2012*) standard. We suggest that this species be included in forest restoration plantings within its natural range to partly reverse its move to extinction. However, the large (c. 1 cm diam.), thin-walled seeds are probably recalcitrant, so not suitable for conventional seed-banking, and should not be allowed to be dried before sowing since this can be expected to kill them. Experience at Ngel Nyaki (*Matthesius et al., 2011*) shows that it is possible to raise hundreds of seedlings in nurseries and to establish them in natural forest.

DISCUSSION

The discovery of a threatened, new species to science from surviving natural habitat in the Cameroon Highlands is not unusual. At most of the six locations from which we here describe *Deinbollia onanae,* additional new or resurrected species to science, all highly localised, range-restricted and threatened with extinction, have been documented in recent years. At Ngel Nyaki in Nigeria a point endemic *Memecylon* species (*H.M. Chapman* 744) as yet undescribed is present (pers. comm. R.D. Stone to Hazel Chapman), while at Mt Kupe for example, *Coffea montekupensis* Stoffelen (*Stoffelen et al., 1997*) and more recently the new species and genus to science *Kupeantha kupensis* Cheek & Sonké (*Cheek et al., 2018a*). At Bali Ngemba, *Leptonychia kamerunensis* Engler & K. Krause (*Cheek et al., 2013*), *Psychotria babatwoensis* Cheek (*Cheek et al., 2009*) and *Allophylus ujori* Cheek (*Cheek & Etuge, 2009b*), at Mt Oku and the Ijim Ridge *Kniphofia reflexa* Marais (*Maisels et al., 2000*), *Scleria cheekii* Bauters (*Bauters et al.,* 2018), while at Dom, the endemic epiphytic sedge *Coleochloa domensis* Musaya & D.A Simpson (*Muasya et al., 2010*). No additional such new species are known from the Adamaoua location, probably because it is less completely sampled than the preceeding four.

However, *Deinbollia onanae* is exceptional among these aforementioned species in that it is a new species of tree predominantly of montane forest. The many other newly discovered for science, resurrected or rediscovered plant species of the Cameroon Highlands have been overwhelmingly either been herbs or shrubs or are derived from submontane habitats (800–2000 m altitude).

Montane Forest Trees of the Cameroon Highlands

The Cameroon Highlands extend through four tropical African countries. Beginning in the south on the volcano island of Bioko (Equatorial Guinea) they continue on the mainland with the Mount Cameroon active volcano, heading NNE along a major fault, forming the ridges, plateaux and isolated peaks of the Bakossi Mts and Mt Kupe, Muanenguba, Bamboutos Mts, the Lebialem and Bamenda Highlands, Mt Oku, Tchabal Mbabo, then heading eastwards and forming the lower and drier Adamaoua Highlands which extend into the Central African Republic. Two westward extending arms from the central section in Cameroon extend into Nigeria, forming the Obudu and Mambilla Plateaux. The altitudinal division between montane and submontane forest is well-marked in the Cameroon Highlands. Most species of montane tree only occur above the 2000 m contour and not below it (Table 3), while tree species from the submontane forest belt rarely exceed the 2000 m contour (*Cheek et al., 1996; Cheek et al., 2000; Cheek et al., 2004*), although some species of tree, like *Deinbollia onanae* can occur on either side of the 2000 m contour. Since most of the Cameroon Highlands do not ascend above 2000 m alt., montane forest is not ubiquitous along their length. Moreover, even where altitude is sufficient to support it and where it formerly occurred, montane forest has seen massive clearance for agriculture, and has been totally lost at the Bamboutos Mountains of West Region Cameroon (*Ngoufou,1992*). Indeed, the Bamenda Highlands of Cameroon, long since cleared of their montane forest, are now known in Cameroon as “The grasslands” because they are blanketed in secondary grassland, perpetuated by fire. It has been estimated that as much as 96.5% of the original montane forest of the Bamenda Highlands has been lost (*Cheek et al.,* 2000: 49-50). The tallest mountain in the range, Mt Cameroon (4040 m), despite its height and lack of human activity above 2000 m alt., has surprisingly little forest above this contour due to the free-draining nature of its predominantly volcanic cinder substrate (*Thomas & Cheek, 1992; Cheek et al., 1996; Cable & Cheek, 1998*). The single largest block of montane forest that survives by far in the Cameroon Highlands is that at Mt Oku and the Ijim Ridge (Kilum-Ijim) where about 70 km^2 has been estimated to survive and to have a measure of protection. Here it extends from the 2000 m contour to the summit at 3011 m alt. (*Cheek et al., 2000:* 20). Elsewhere in the Cameroon Highlands, such as at Mt Kupe, Muanenguba, Bali-Ngemba, Ngel Nyaki and Dom, surviving patches of montane forest consists of only a few hectares, although an area of 40 km^2 of forest has been recorded at Dutsin Dodo and Gangirwal mountain within the Gashaka Gumti National Park of Nigeria (H.M. Chapman pers. obs. 2000)

The tree species diversity of the montane forest of the Cameroon Highlands is low (28 species, based on herbarium specimens, see Table 3) compared with submontane forest which has hundreds of species, and also in great contrast, montane forest contains few Cameroon Highland endemic tree species (only seven: 25% of the total, see Table 3). The majority of the canopy contains even fewer species. It was estimated that just ten species made up 90% of the montane forest canopy at Mt Oku and the Ijim Ridge, three of which are endemics (*Cheek et al.,*

*2000:*20). The majority of montane tree species of the Cameroon Highlands are widespread in montane forest in Africa (Afromontane) occurring also east of the Congo Basin in the rift mountains of East Africa and several, such as *Ilex mitis,* extend north to Ethiopia and south to South Africa. The East African montane forest is more species-diverse, and only a subset of its species extend west to the Cameroon Highlands, and an even smaller subset, just seven species, extend even further west from the Cameroon Highlands, to the Guinea Highlands (*Couch et al*., *2019:*54).

The high altitudinal range of *Deinbollia onanae* is unrivalled west of the Congo basin by any other species of the genus. Elsewhere in Africa it is matched only by *Deinbollia kilimandscharica* Taub., of mountains from Ethiopia to Malawi, reported to achieve 2250 m elevation in Tanzania (*Davies & Verdcourt, 1998*). Most species of the genus in tropical Africa are lowland forest shrubs, in the Cameroon Highlands only *Deinbollia oreophila* also occurs regularly at altitude over 800 m, and is largely confined to the submontane forest band being recorded from (880–)1000–1900(–2050) m altitude where it is often relatively frequent (*Cheek & Etuge, 2009*). We postulate based on their shared morphological characters that these two may be sister species (see results above) that have segregated between two adjacent altitudinally based vegetation types in a similar way to certain clades of bird species in the Cameroon Highlands such as the Turaco (*Njabo & Sorensen, 2009*). This hypothesis needs testing. It would most readily done by a comprehensive species-level molecular phylogenomic study of *Deinbollia* as has been achieved in several other genera, such as *Nepenthes* L.f. (*Murphy et al., 2020*).

The fruits of *Deinbollia onanae* are similar to those of other species of the genus, i.e., fleshy, indehiscent and large-seeded, suggesting that the now intermittent distribution of this species, along a line c. 570 km along peaks of the Cameroon Highland line, was likely due to dispersal in the gut by animals. Chimpanzees (*Pan troglodytes ellioti*) and putty-nose monkeys (*Cercopithecus nictitans*) are known to disperse the species at one location however these species do not cross from one forest patch to another, especially when as now these patches can be separated by tens of kilometres of secondary grassland .Formerly the range of *Deinbollia onanae* may have once been more continuous along the mountain range than today, but it was likely greatly reduced when forest was cleared for agriculture as reported above.

CONCLUSIONS

Such cases as *Deinbollia onanae* underline the urgency for publishing further discoveries while species still survive, since threats to such rare species are often clear and current, putting these species at high risk of extinction. About 2000 new species of vascular plant have been discovered by science each year for the last decade or more (*Cheek et al., 2020*). Until species are delimited and known to science, it is more difficult to assess them for their conservation status and so the possibility of protecting them is reduced (*Cheek et al., 2020*). Documented extinctions of plant species are increasing, e.g. *Oxygyne triandra* Schltr. of Cameroon is now known to be globally extinct (*Cheek et al., 2018b*) as is *Afrothismia pachyantha* Schltr. (*Cheek et*

al., 2019). In some cases species appear to be extinct even before they are known to science, such as *Vepris bali* Cheek, once sympatric with *Deinbollia onanae* at Bali Ngemba (*Cheek et al., 2018c*), and elsewhere, *Nepenthes maximoides* Cheek (*King & Cheek, 2020*). Most of the >800 Cameroonian species in the Red Data Book for the plants of Cameroon are threatened with extinction due to habitat clearance or degradation, especially of forest for small-holder and plantation agriculture e.g. oil palm, following logging (*Onana & Cheek, 2011*). Efforts are now being made to delimit the highest priority areas in Cameroon for plant conservation as Tropical Important Plant Areas (TIPAs) using the revised IPA criteria set out in *Darbyshire et al.,* (*2017*). This is intended to help avoid the global extinction of additional endemic species such as the Endangered *Deinbollia onanae* which will be included in the proposed IPA s of Mt Kupe, Bali Ngemba, Kilum-Ijim and Dom.

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Table 1(on next page)

Characters separating *Deinbollia onanae* from *D. grandifolia, D. maxima and D. pinnata.*

Characters taken from *Fouilloy & Hallé* (*1973*) and *Keay* (*1958*).

1
2

	Deinbollia grandifolia	*Deinbollia maxima*	*Deinbollia onanae*	*Deinbollia pinnata*
Leaves	(5–)7-10-jugate	4–6-jugate	(2–)8–11-jugate	(2–)5–9-(-12)-jugate
Leaf rhachis adaxial surface	Rounded	Rounded	Flattened, with margins angled-winged, midline with raised ridge	Flattened, with margins angled-winged, midline with raised ridge
Indumentum of abaxial surface of leaflet	Glabrous, or with a few scattered inconspicuous hairs	Glabrous, or with a few scattered inconspicuous hairs	Softly hairy with numerous translucent, patent hairs	Glabrous, or with a few scattered inconspicuous hairs
Leaflet width	5–8 cm	6–8(–10) cm	(2.1–)2.5–4 cm	2.3–7.5(–10) cm
N°s pair of secondary nerves (distal leaflets)	12–14(–16)	8 – 10	(12–)17–18	6-12
Fruit breadth, indumentum	1.5 cm, glabresecent	Dimensions unknown, glabresecent	1.3-1.5 cm, tomentose	2 cm, glabrous

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Table 2(on next page)

The more significant differences between *Deinbollia onanae* and *Deinbollia oreophila*.

Data on *Deinbollia oreophila* from (*Cheek & Etuge, 2009*)

Table 2:
Characters separating *Deinbollia onanae* and *Deinbollia oreophila.*

Characters for *Deinbollia oreophila* taken from *Cheek & Etuge* (*2009*).

	Deinbollia oreophila	*Deinbollia onanae*
Height at maturing	0.8–3(–5) m	(4–)5–10(–15) m
Stem indumentum	Glabrous	Simple hairy, sparse to dense, glabrescent.
Lenticels	Highly conspicuous, bright white, contrasting with epidermis	Inconspicuous, grey-brown, concolorous with epidermis
Length of leaves (flowering stems)	25–63 cm	(14–)60–70 cm
Number of leaflets per leaf (flowering stems)	(4–)6–8(–10)	(4–)16–23
Width of leaflets (flowering stems).	(3–)5.5–9(–10.2) cm	(2.1–)2.5–4 cm
N° secondary nerves each side of midrib	(7–)9–14(–17)	(15–)17–18
Indumentum of lower surface of leaf blade	Glabrous	Inconspicuously sparsely simple hairy on secondary nerves and midrib
Sepals	Orbicular, margins glabrous	Ovate, margins hairy
Petals	Oblong or obovate, base cuneate; adaxial appendage surface glabrous	Rhombic or spatulate, basal claw (stalk); adaxial appendage surface hairy
Staminal filaments of male flowers	Proximal half glabrous.	Entire length densely hairy.
Ovary of female flowers	3-lobed, surface with very sparse, stout hairs	2-lobed, densely hair with fine hairs
Altitudinal range	(880–)1000–2050 m	(1400–)2050–2200 m

Table 3(on next page)

The 28 montane forest trees of the Cameroon Highlands.

Data mainly from *Cheek et al.,* (*2000*), updated with subsequent literature e.g. *Kenfack* (*2011*), *Cheek & Ngolan* (*2007*), *Cheek et al.,* (*2017*) and *POWO* (*2019*)

1

Currently accepted species name	Former name used in Cameroon Highlands, if any (e.g. *Cheek et al., 2000*)	Endemic to Cameroon Highlands (Y/N)	Occurring also below 2000 m alt. (Y/N)	Species forming 90% of the canopy (Y/N)	Forest edge species = E Infrequent species = R
Astropanax abyssinica (A.Rich.)Seem.	*Schefflera abyssinica (*A.Rich.)Harms	N	N	Y	
Astropanax mannii (Hook.f.)Seem.	*Schefflera mannii* (Hook.f.)Harms	Y	N	Y	
Prunus africana (L.)Kalkman	*Pygeum africanum* Hook.f.	N	N	Y	
Syzygium staudtii (Engl.)Mildbr.	*Syzygium guineense* subsp. *bamendae* F.White	N	N	Y	
Myrsine melanophloeos (L.)Sweet	*Rapanea melanophloeos* (L.)Mez	N	N	Y	
Oldeania alpina (K.Schum.)Stapleton	*Arundinaria alpina* K.Schum.	N	N	Y	
Carapa oreophila Kenfack	*Carapa grandiflora* Sprague	Y	N	Y	
Bersama abyssinica Fresen.		N	N	Y	
Ixora foliosa Hiern		Y	N	Y	
Clausena anisata (Willd.)Benth,		N	Y	Y	
Nuxia congesta Fresen.		N	N	N	E
Lasiosiphon glaucus Fresen.	*Gnidia glauca* (Fresen.) Gilg	N	N	N	E
Hypericum revolutum Vahl subsp. *revolutum*		N	N	N	E
Maesa lanceolata G.Don		N	N	N	E
Alsophila dregei (Kunze)R.M.Tryon	*Cyathea dregei* Kunze	N	N	N	E
Podocarpus latifolius (Thunb.)Mirb.		N	Y	N	R
Croton		N	Y	N	R

macrostachyus Delile					
Albizia gummifera (J.F.Gmel)C.A.Smith		N	Y	N	R
Cassipourea malosana (Baker)Alston		N	N	N	R
Brucea antidysenterica J.F.Mill.		N	N	N	R
Ilex mitis (L.)Radlk.		N	N	N	R
Neoboutonia mannii Benth. & Hook.f.	*Neoboutonia glabrescens* Prain	N	Y	N	R
Olea capensis subsp. *macrocarpa* (C.H.Wright)I.Verd.	*Olea capensis*	N	N	N	R
Eugenia gilgii Engl. & Brehmer		Y	N	N	R
Agarista salicifolia (Lam.)G.Don	*Agauria salicifolia* (Lam.)Oliv.	N	N	N	R
Dovyalis cameroonensis Cheek & Ngolan	*Dovyalis sp.nov.*	Y	N	N	R
Ternstroemia cameroonensis Cheek	*Ternstroemia polypetala* Melch.	Y	Y	N	R
Deinbollia onanae Cheek	*Deinbollia sp. 2*	Y	Y	N	R

Figure 1

Deinbollia onanae.

(A**)** habit, flowering branch; (B**)** detail from a large leaf showing apex and distal leaves (adaxial surfaces) and second leaf from the base (abaxial surface); (C) male flower lateral view; (D) male flower, petals and sepals removed to show the extra staminal disc and androecium; (E) base of D (male flower) showing the vestigial gynoecium and disc cut to show notches holding filament bases; (F**)** petal, adaxial surface, male flower; (G) female flower, lateral view; (H**)** female flower (with 3 sepals, 2 petals and anterior stamens removed) to show gynoecium and disc; (I**)** stamen from female flower; (J**)** petal, adaxial surface, of female flower with stamen. A, C-J from *de Wilde et al.* 4553 (K); B from *Cheek* 13436 (K). Drawn by Andrew Brown.


5cm
A
10cm
B
1mm
E
G
C
5mm
D
H
I
J
1mm
1mm
F
©A.P.B

Figure 2

Deinbollia onanae.

Photo of the holotype: *Etuge* 3600 (holotypus K000593309). Photo by Xander van der Burgt.

Figure 3

Deinbollia onanae. Global distribution map. By Xander van der Burgt.

By Xander van der Burgt.

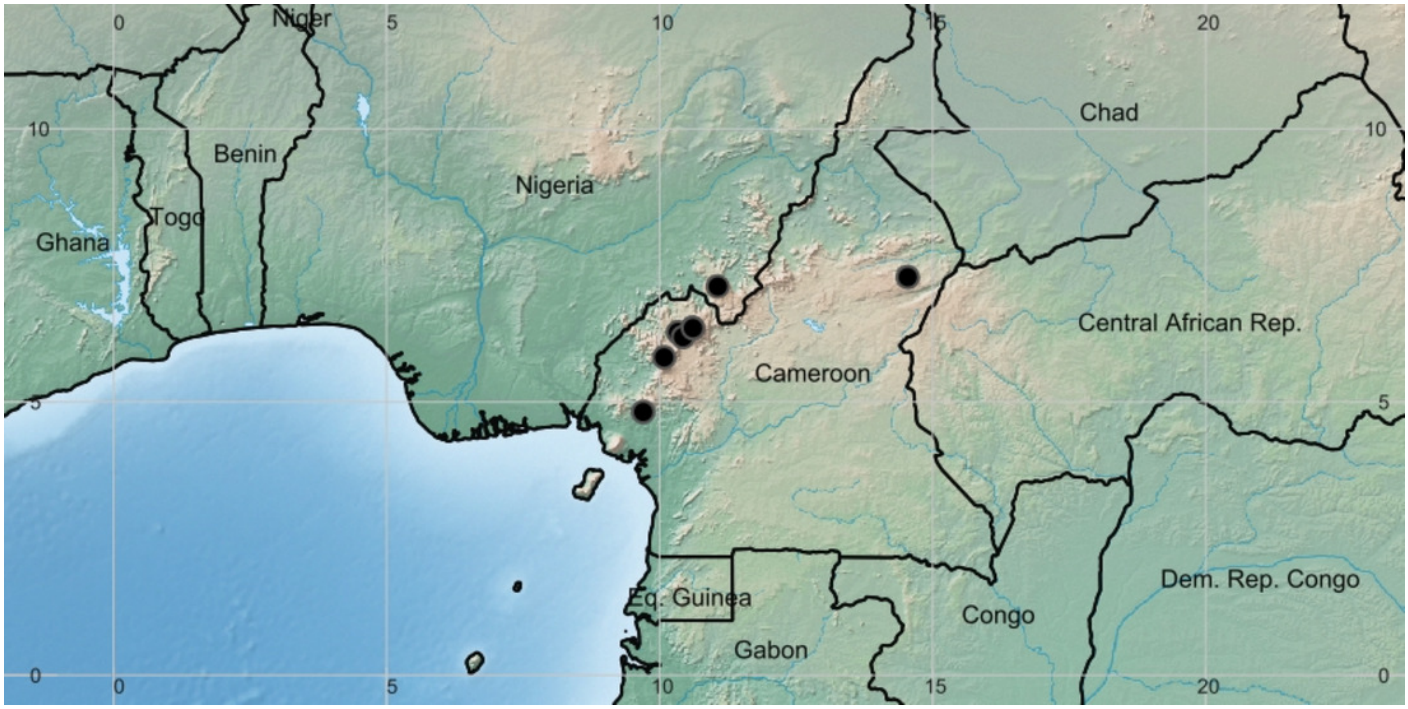

Figure 4

Figure 4: *Deinbollia onanae.*

Habit of tree in flower at Ngel Nyaki, Nigeria. Photo by Max Walters. Source: *Nickrent DL, Costea M, Barcelona JF et al.* (*2006* onwards)