Chemistry, taxonomy and ecology of the potentially chimpanzee-dispersed *Vepris teva* sp.nov. (Rutaceae) endangered in coastal thicket in the Congo Republic

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Continuing a survey of the chemistry of species of the largely continental African genus *Vepris*, we investigate a species previously referred to as *Vepris* sp. 1 of Congo. From the leaves of *Vepris* sp. 1 we report six compounds. The compounds were three furoquinoline alkaloids, kokusaginine (**1**), maculine (**2**), and flindersiamine (**3**), two acridone alkaloids, arborinine (**4**) and 1-hydroxy-3-methoxy-10-methylacridone (**5**), and the triterpenoid, ß-amyrin (**6**). Compounds **1**-**4** are commonly isolated from other *Vepris* species, compound **5** has been reported before once, from Malagasy *Vepris pilosa,* while this is the first report of ß-amyrin from *Vepris.* This combination of compounds has never before been reported from any species of *Vepris.* We test the hypothesis that *Vepris* sp.1 is new to science and formally describe it as *Vepris teva*, unique in the genus in that the trifoliolate leaves are subsessile, with the median petiolule far exceeding the petiole in length. Similar fleshy-leathery 4-locular syncarpous fruits are otherwise only known in the genus in *Vepris glaberrima* (formerly the monotypic genus *Oriciopsis* Engl.), a potential sister species, but requiring further investigation to confirm this phylogenetic position. We briefly characterise the unusual and poorly documented Atlantic coast equatorial ecosystem, where *Vepris teva* is restricted to evergreen thicket on white sand, unusual in a genus usually confined to evergreen forest. This endemic-rich ecosystem with a unique amphibian as well as plants, extends along the coastline from the mouth of the Congo River to southern Rio Muni, a distance of about 1000 km, traversing five countries. We map and illustrate *Vepris teva* and assess its extinction risk as Endangered (EN B1ab(iii)+B2ab(iii)) using the IUCN 2012 standard. Only three locations are known, and threats include port and oil refinery construction and associated activities, with only one protected location, the Jane Goodall Institute's Tchimpounga Reserve. Initial evidence indicates that the seeds of *Vepris teva* are dispersed by chimpanzees, previously unreported in the genus

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ABSTRACT.

Continuing a survey of the chemistry of species of the largely continental African genus *Vepris*, we investigate a species previously referred to as *Vepris* sp. 1 of Congo.

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We test the hypothesis that *Vepris* sp.1 is new to science and formally describe it as *Vepris teva*, unique in the genus in that the trifoliolate leaves are subsessile, with the median petiolule far exceeding the petiole in length. Similar fleshy-leathery 4-locular syncarpous fruits are otherwise only known in the genus in *Vepris glaberrima* (formerly the monotypic genus *Oriciopsis* Engl.), a potential sister species, but requiring further investigation to confirm this phylogenetic position.

We briefly characterise the unusual and poorly documented Atlantic coast equatorial ecosystem, where *Vepris teva* is restricted to evergreen thicket on white sand, unusual in a genus usually confined to evergreen forest. This endemic-rich ecosystem with a unique amphibian as well as plants, extends along the coastline from the mouth of the Congo River to southern Rio Muni, a distance of about 1000 km, traversing five countries. We map and illustrate *Vepris teva* and assess its extinction risk as Endangered (EN B1ab(iii)+B2ab(iii)) using the IUCN 2012 standard. Only three locations are known, and threats include port and oil refinery construction and associated activities, with only one protected location, the Jane Goodall Institute's Tchimpounga Reserve. Initial evidence indicates that the seeds of *Vepris teva* are dispersed by chimpanzees, previously unreported in the genus

Key words. Alkaloids, Jane Goodall Foundation**,** *Oriciopsis,* TotalEnergies SA, triterpenoids, white sand habitat.

INTRODUCTION

91 As part of a series of studies of the chemistry of *Vepris* led by the first author, material from a
92 Congolese *Vepris* previously referred to in field studies as *Vepris sp.* 1 of Pointe Noire was
93 investigated. In this paper we present the chemical results, compare the taxon morphologically
94 within *Vepris,* test the hypothesis that this taxon is new to science and formally name it as *Vepris*
95 *teva* Cheek. We also present data on its ecology in coastal thicket on white sand, a poorly known
96 and highly threatened ecosystem on the equatorial Atlantic coast of Africa. Initial field
97 observations suggest that the seeds of *Vepris teva* are dispersed by chimpanzees.
98
99 *Vepris* Comm. ex A. Juss. (Rutaceae-Toddalieae), is a genus with 91 accepted species, 23 in
100 Madagascar and the Comores and 68 in Continental Africa with one species extending to Arabia
101 and another endemic to India (Plants of the World Online, continuously updated). The genus was
102 last revised for tropical Africa by *Verdoorn (1926).* Founded on the Flore du Cameroun account
103 of *Letouzey (1963a),* nine new species were recently described from Cameroon (*Onana &*
104 *Chevillotte 2015; Cheek et al., 2018a; Onana et al., 2019; Cheek & Onana 2021; Cheek, Hatt,*
105 *Onana 2021*), taking the total in Cameroon to 25 species, the highest number for any country
106 globally. The greatest concentration of *Vepris* species in Cameroon is within the Cross-Sanaga
107 Interval (*Cheek et al., 2001*) with 15 species of *Vepris* of which nine are endemic to the Interval.
108 The Cross-Sanaga has the highest species and generic diversity per degree square in tropical
109 Africa (*Barthlott et al., 1996; Dagallier et al., 2020*) including endemic genera such as
110 *Medusandra* Brenan (Peridiscaceae, *Breteler et al., 2015; Soltis et al., 2007*). By comparison,
111 neighbouring Gabon has just eight species, seven species of *Vepris* listed in the Gabon checklist
112 (*Sosef et al., 2006*) and *V. lecomteana.* (Pierre) Cheek & T. Heller. Meanwhile, just one species,
113 *Vepris lecomteana* is listed for Congo-Brazzaville (*Plants of the World Online, continuously*
114 *updated*), illustrating how under-recorded the Flora of this biodiverse country is. However, it is
115 almost certain that additional species for this country are represented in the Paris herbarium, P.,
116 but we have not been able to access this during the pandemic. Several Cameroon species are
117 threatened (*Onana & Cheek, 2011*) and in one case considered globally extinct (*Cheek et al.,*
118 *2018a*), although only two currently appear on the IUCN Red List: *Vepris lecomteana* (Pierre)
119 Cheek & T. Heller (Vulnerable, *Cheek, 2004*) and *Vepris trifoliolata* (Eng.) Mziray (Vulnerable,
120 *World Conservation Monitoring Centre, 1998*). In other parts of Africa species are even more
121 highly threatened, e.g., the Critically Endangered *Vepris laurifolia* (Hutch. & Dalziel) O.
122 Lachenaud & Onana of Guinea-Ivory Coast (formerly *V. felicis* Breteler, *Cheek 2017a;*
123 *Lachenaud & Onana, 2021*).
124
125 In continental Africa, *Vepris* are easily recognised. They differ from all other Rutaceae because
126 they have digitately (1–)3(–5)-foliolate (not pinnate) leaves, and unarmed (not spiny) stems. The
127 genus consists of evergreen shrubs and trees, predominantly of tropical lowland evergreen forest,
128 but with some species extending into submontane forests and some into drier forests and
129 woodland. *Vepris* species are often indicators of good quality, relatively undisturbed evergreen
130 forest since they are not pioneers. New species are steadily coming to light (*Cheek et al., 2019*).
131
132 Species of *Vepris* in Africa extend from South Africa, e.g. *Vepris natalensis* (Sond.) Mziray, to
133 the Guinean woodland in the fringes of the Sahara Desert (*Vepris heterophylla* (Engl.)
134 Letouzey). *Mziray (1992)* subsumed the genera *Araliopsis* Engl.*, Diphasia* Pierre*, Diphasiopsis*
135 Mendonça, *Oricia* Pierre, *Oriciopsis* Engl., *Teclea* Delile, and *Toddaliopsis* Engl. into *Vepris*,
136 although several species were only formally transferred subsequently (e.g., *Harris, 2000;*

137   *Gereau, 2001; Cheek et al., 2009; Onana & Chevillotte, 2015*). Mziray's conclusions were
138   largely confirmed by the molecular phylogenetic studies of *Morton (2017)* but Morton's
139   sampling was limited, identifications appeared problematic (several species appear
140   simultaneously in different parts of the phylogenetic trees) and more molecular work would be
141   desirable. Morton studied about 14 taxa of *Vepris*, all from eastern Africa. More recently
142   *Appelhans & Wen (2020)* focussing on Rutaceae of Madagascar have found that the genus
143   *Ivodea* Capuron is sister to *Vepris* and that a Malagasy *Vepris* is sister to those of Africa.
144   However, the vast majority of the African species including all those of West and Congolian
145   Africa, remain unsampled leaving the possibility open of changes to the topology of the
146   phylogenetic tree when this is addressed.
147
148   Characteristics of some of the formerly recognised genera are useful today in grouping species.
149   The "araliopsoid" species have firm, subglobose, 4-locular fruit syncarpous with 4 external
150   grooves; the "oriciopsoid" soft, fleshy 4-locular syncarpous fruit; "oricioid" species are 4-locular
151   and apocarpous in fruit; the fruits of "diphasioid" species are laterally compressed in one plane,
152   bilocular and bilobed at the apex; while "tecleoid" species are unilocular in fruit and 1-seeded,
153   lacking external lobes or grooves. There is limited support for these groupings in Morton's study,
154
155   Due to the essential oils distributed in their leaves, and the alkaloids and terpenoids distributed in
156   their roots, bark and leaves, several species of *Vepris* have traditional medicinal value *(Burkill,*
157   *1997)*. Burkill details the uses, essential oils and alkaloids known from five species in west
158   Africa: *Vepris hiernii* Gereau (as *Diphasia klaineana* Pierre), *Vepris suaveolens* (Engl.) Mziray
159   (as *Teclea suaveolens* Engl.), *Vepris afzelii* (Engl.) Mziray (as *Teclea afzelii* Engl.), *Vepris*
160   *heterophylla* (Engl.) Letouzey (as *Teclea sudanica* A. Chev.) and *Vepris verdoorniana* (Exell &
161   Mendonça) Mziray (as *Teclea verdoorniana* Exell & Mendonça) (*Burkill, 1997*: 651–653).
162   Research into the characterisation and anti-microbial and anti-malarial applications of alkaloid
163   and limonoid compounds in *Vepris* is active and ongoing (e.g., *Atangana et al., 2017*), although
164   sometimes published under generic names no longer in current use, e.g. *Wansi et al., (2008)*.
165   Applications include as synergists for insecticides (*Langat, 2011*). *Cheplogoi et al., (2008)* and
166   *Imbenzi et al., (2014)* respectively list 14 and 15 species of *Vepris* that have been studied for
167   such compounds. A review of ethnomedicinal uses, phytochemistry, and pharmacology of the
168   genus *Vepris* was recently published by *Ombito et al., (2021),* listing 213 different secondary
169   compounds, mainly alkaloids and furo- and pyroquinolines, isolated from 32 species of the
170   genus, although the identification of several of the species listed needs checking. However, few
171   of these compounds have been screened for any of their potential applications. Recently, *Langat*
172   *et al., (2021)* have published three new acridones and reported multi-layered synergistic anti-
173   microbial activity from *Vepris gossweileri* (I.Verd.) Mziray, recently renamed as *Vepris africana*
174   (Hook.f ex Benth.) Lachenaud & Onana (*Lachenaud & Onana, 2021*).
175
176   **MATERIALS & METHODS**
177
178   **Taxonomy**
179   *The electronic version of this article in Portable Document Format (PDF) will represent a*
180   *published work according to the International Code of Nomenclature for algae, fungi, and plants*
181   *(ICN), and hence the new names contained in the electronic version are effectively published*
182   *under that Code from the electronic edition alone. In addition, new names contained in this work*

183 *which have been issued with identifiers by IPNI will eventually be made available to the Global*
184 *Names Index. The IPNI LSIDs can be resolved and the associated information viewed through*
185 *any standard web browser by appending the LSID contained in this publication to the prefix*
186 *"http://ipni.org/". The online version of this work is archived and available from the following*
187 *digital repositories: PeerJ, PubMed Central, and CLOCKSS.*

188 Fieldwork in the Republic of Congo resulting in the specimens and observations cited in this
189 paper was conducted with the collaboration and support of the CERVE (Centre d'Etudes sur les
190 Ressources Végétales) (currently named IRSEN (Institut de Recherche National en Sciences
191 Exactes et Naturelles, Brazzaville)-National Herbarium of Congo and Royal Botanic Gardens,
192 Kew beginning in 2010 under research permit (Autorisation de Recherche)
193 021/MRS/DGRST/DMAST (issued 2 Nov 2010), and the specimens were exported under
194 permit (Autorisation D'Exportation des Énchantillons Botaniques) number 003/CERVE/57/2011
195 (issued 4 Dec 2011). At the Royal Botanic Gardens, Kew, fieldwork was approved by the
196 Institutional Review Board of Kew entitled the Overseas Fieldwork Committee (OFC) for which
197 the registration number was OFC 490-3 – 490-6 (2010-2011). The most complete set of
198 duplicates for all specimens made was deposited at IEC, the remainder exported to K for
199 identification and distribution following standard practice.
200 The taxonomic study is based on herbarium specimens and observations of live material in
201 Congo-Brazzaville made by the second two authors and their colleagues in 2010–2012.
202 Herbarium citations follow Index Herbariorum (*Thiers et al., continuously updated*),
203 nomenclature follows *Turland et al., (2018)* and binomial authorities follow *IPNI (continuously*
204 *updated).* The methodology for the surveys in which the specimens were collected is given in
205 *Cheek & Cable (1997).* All specimens cited have been seen. Material of the suspected new
206 species was compared morphologically with material of all other species African *Vepris,*
207 principally at K, but also using material and images from BM, EA, BR, FHO, G, GC, HNG, P
208 and YA. Specimens at WAG were viewed on the Naturalis website
209 (https://bioportal.naturalis.nl/). The main online herbarium used during the study apart from that
210 of WAG was that of P (https://science.mnhn.fr/all/search). Herbarium material was examined
211 with a Leica Wild M8 dissecting binocular microscope fitted with an eyepiece graticule
212 measuring in units of 0.025 mm at maximum magnification. The drawing was made with the
213 same equipment using a Leica 308700 camera lucida attachment.
214
215 **Ecology**
216 Once *Vepris teva* was detected as being new to science, seemingly restricted to coastal white
217 sands (with other new and threatened species) in July 2011 we conducted desk-top studies using
218 Google Earth to find other areas of this poorly studied habitat where it survives in the Republic
219 of Congo. We visited these areas in Nov.-Dec. 2012, travelling by road from the northern border
220 with Gabon to the southern border with Angola (Cabinda) to visit targeted sites, but also ground-
221 truthing sites in different but adjoining habitats to test whether the species was indeed restricted
222 to the white sand habitat.
223
224
225 **Chemistry**
226 Samples were made from live plants (preferable to preserved material for chemical analysis)
227 cultivated from seed at the Royal Botanic Gardens, Kew which were associated with the

228 herbarium collections *Mpandzou et al.* 1754 (IEC, K) collected with the authorisation of Herbier
229 National, Institut de Recherche National en Sciences Exactes et Naturelles (IRSEN formerly
230 CERVE, see permit references below), Cité Scientifique de Brazzaville. Two plants, grown from
231 seed, were cultivated in 3 inch (c. 8 cm) diam. plastic pots, using a free-draining potting medium
232 of 25% Coir (coconut husk fibre), 17% each of Seramis (baked expanded clay granules), medium
233 Perlite (amorphous volcanic glass) and fine bark, 12% loam and 12 % grit, with a slow-release
234 fertiliser. Plants were cultivated in a glasshouse in full light, with temperature maintained in the
235 range 21-25 deg. Celsius. The humidity goal is 70%, achieved by spraying over and damping
236 down the floor at least twice a day. Watering is usually once per day, and feeding twice a week
237 in summer, once in winter, with an additional weekly Kelp feed.
238 The plants grew very slowly, reaching only 15 cm in height, and not becoming reproductive,
239 even after ten years of cultivation, before they died in 2021. The cause of death is unknown. This
240 suggests that there is scope to develop an improved cultivation protocol. The RBG, Kew
241 reference number for this accession was 2019-14.
242
243 Spectroscopic and spectrometric analysis were conducted as follows: the FTIR spectra were
244 recorded using a Perkin-Elmer Frontier/Spotlight 200 spectrometer, and the acquired data used to
245 determine the functional groups present in the compounds. 1D and 2D NMR spectra were recorded
246 in $CDCl_3$ on a 400 MHz Bruker AVANCE NMR instrument at room temperature. Chemical shifts
247 (δ) are expressed in ppm and were referenced against the solvent resonances at δ_H 7.26 and δ_C
248 77.23 ppm for ^1H and ^{13}C NMR for $CDCl_3$. Accurate masses, for determination of molecular
249 formulae of the compounds, were recorded on a Thermo Scientific Orbitrap Fusion spectrometer.
250 Purity of compounds was monitored *via* thin layer chromatography (TLC) using pre-coated
251 aluminium-backed plates (silica gel 60 F_{254}, Merck) and compounds were visualised by UV
252 radiation at 254 nm and then using an anisaldehyde spray reagent (1% *p*-anisaldehyde:2% H_2SO_4:
253 97% cold MeOH) followed by heating. Final purifications used preparative thin layer
254 chromatography (Merck 818133) and gravity column chromatography that was carried out using
255 a 2 cm diameter column, which were packed with silica gel (Merck Art. 9385) in selected solvent
256 systems.
257
258
259 The leaves were freeze-dried and ground to fine powder using a blender. The dried leaves (37 g)
260 were successively extracted using methylene chloride (CH_2Cl_2) solvent to target non-polar and
261 semi-polar compounds and methanol solvent (MeOH) to target polar compounds. The CH_2Cl_2 and
262 MeOH extracts obtained were 1.7 g and 4.3 g respectively. The methylene chloride extract was
263 subjected to gravity column chromatography packed with a 1:1 blend of silica gel merck 9385
264 and eluted isocratically using 10% ethyl acetate in methylene chloride, collecting 35 mL. The
265 fractions were monitored using TLC and fractions with the same retention times were pooled.
266 Fractions 12–13 gave compound **5** which was determined to be 1-hydroxy-3-methoxy-10-
267 methylacridone (*Haensel & Cybulksi, 1978*). Fractions 14–18 gave compound **6** which was
268 determined to be ß-amyrin (*Okoye et al., 2014*). Fractions 23–25 gave compound **2** which was
269 determined to be maculine (*Vaquette et al., 1976*). Fractions 34–35 gave compound **4** which was
270 determined to be arborinine (*Haensel & Cybulksi, 1978*). Fractions 40–47 gave compound **3** which
271 was determined to be flindersiamine (*Vaquette et al., 1976*) and fractions 55–63 gave compound
272 **1** which was determined to be kokusaginine (*Pusset et al., 1991*).
273

274
275 **Extinction risk assessment**
276 Points were georeferenced using locality information from herbarium specimens. The map was
277 made using simplemappr *(Shorthouse, 2010).* The conservation assessment was made using the
278 categories and criteria of *IUCN (2012),* EOO was calculated with GeoCat (*Bachman et al.,*
279 *2011*). Threats were observed by the second two authors directly in the field in Republic of
280 Congo.
281
282 **RESULTS**
283
284 **Chemistry**
285 The structures of the alkaloids were determined based on comprehensive spectroscopic and
286 spectrometric analysis, and the spectra of the known compounds were compared to those
287 previously reported. The compounds were three furoquinoline alkaloids, kokusaginine (**1**)
288 (*Pusset et al., 1991*), maculine (**2**) (*Vaquette et al., 1976*) and flindersiamine (**3**) (*Vaquette et al.,*
289 *1976*), two acridone alkaloids, arborinine (**4**) (*Haensel & Cybulksi, 1978*) and 1-hydroxy-3-
290 methoxy-10-methylacridone (**5**) (*Haensel & Cybulksi, 1978*), and one triterpenoid, ß-amyrin (**6**)
291 (*Okoye et al., 2014*) (Fig. 1).
292 This combination of secondary compounds matches none of those reported from the 32 taxa of
293 *Vepris* that have been chemically investigated to date (*Ombito et al., 2021*). While compounds
294 **1–4** are relatively widespread in the investigated species, each having been recorded in 9–12
295 taxa, compound **5** is recorded only in one species, *Vepris pilosa* (Baker)I.Verd. (now a synonym
296 of *V. glomerata* (F.Hoffm.)Engl.). However, compounds **2 & 3** have not been recorded in *Vepris*
297 *glomerata*. Compound **6** has not been reported previously from *Vepris.* The chemical results
298 therefore do not conflict with the morphologically-based conclusion that *Vepris* sp. 1 is new to
299 science (see below).
300
301 **Morphology**
302 The morphological characteristics of *Vepris* sp. 1 are highly unusual within the genus. The
303 subsessile leaves of the fertile stems with the median petiolule far exceeding the petiolule in
304 length is unique within the genus. The leathery-walled, syncarpous, 4-loculed, and slightly lobed,
305 subverrucate fruits which have fleshy-juicy mesocarp surrounding the seeds are otherwise known
306 in only one species, *Vepris glaberrima,* formerly segregated as the monotypic genus *Oriciopsis*.
307 The two species share several unusual characters, such as numerous parallel, straight secondary
308 and intersecondary nerves, with few quaternary nerves, sparse oil glands and long median
309 petiolules, suggesting they are sister species. *Vepris* sp. 1 however differs greatly from the last
310 species in the characters indicated below in Table 1 and in the diagnosis below.
311
312
313 *Vepris teva* Cheek sp. nov. – Figs. 2 and 3.
314 *Type*. Republic of Congo, Kouilou, Port 8, along coast just northwest of Pointe Noire, near
315 Pointe Indienne, 4° 42´ 46.5"S, 11° 49´ 18.3"E, 10 m elev., fl. 23 Nov. 2011, *T. Kami et al.*1227
316 (holotype K000875074; isotypes EA, IEC, MO, P, US)
317
318 Syn. *Vepris* sp. 1 of Pointe Noire (*van der Burgt & Merklinger, 2012*).
319

320 Diagnosis: differs from all known trifoliolate species of *Vepris* in the median petiolule far
321 exceeding the petiole in length (usually by a factor of 2–4 times) on reproductive stems,
322 especially near the stem apex (vs. petiole exceeding petiolule in length in all other species). Most
323 similar to *Vepris glaberrima* (Engl.) J.B.Hall ex D.J. Harris in the soft, leathery-fleshy, 4-
324 loculed, and slightly lobed, subverrucate syncarpous fruit, differing in the inflorescences
325 exceeding the petiole in length (vs. shorter than the petioles), the secondary nerves (10–)11–16(–
326 18) on each side of the midrib (vs. 20–30), the leaflet apices shortly rounded-acuminate (vs.
327 long, acutely acuminate) and other characters shown in Table 1 above.
328
329
330 *Dioecious (probably) shrub* 0.5–1.5 m tall, moderately branched, glabrous apart from the
331 bracteole margins. Stems terete, internodes (0–)0.9–5.3(–7.5) cm long, (1.5–)2–3.5(–4) mm
332 diam. at lowest leafy node, epidermis glossy, medium brown, finely longitudinally striate, at
333 length splitting longitudinally, soon lenticellate, lenticels very sparse white, orbicular or elliptic,
334 often longitudinally divided in two, (0.3–)0.5–1.3(–2.25) x (0.2–)0.3–0.6(–0.9) mm.
335 *Leaves* alternate, trifoliolate (rarely unifoliolate), *median leaflet* usually slightly longer than
336 lateral leaflets, elliptic, less usually obovate-elliptic, (4.5–)5.5–10.6(–14.3) x (2–)2.7–3.5(–5.2)
337 cm, acumen broadly triangular (0.3–)0.4–0.9(–1) x 0.25–0.45 cm, apex rounded, base acute-
338 decurrent, secondary nerves (10–)11–16(–18) on each side of the midrib, arising at 50–80° from
339 the midrib, straight, united by a slightly looping inframarginal vein 0.6–1.2 mm from the margin
340 (Fig. 1A-C), tertiary nerves conspicuous on the abaxial but not adaxial surface, mainly parallel to
341 the secondary nerves, uniting transversely only in the outer part of the blade (Fig. 1B),
342 quaternary nerves inconspicuous; oil gland dots translucent in transmitted light, inconspicuous
343 on the adaxial surface, conspicuous but concolorous, raised on the abaxial surface (Fig. 1B & C),
344 (2–)4–7(–8) per mm², the diameter of the glands 0.1–0.225 mm; lateral leaflets as the median
345 leaflet, but (4.7–)5.5–8.7)–12.7) x (1.9–)2.2–3.4(–4.25) cm, base acute. Petiolules canaliculate,
346 those of fertile stems exceeding the petiole in length (Fig. 1 A&C), (0.3–)0.5–1.1(–1.6) cm long,
347 those of median leaflets much longer than the lateral; articulated at junction with the petiole.
348 Petiole canaliculate, those of fertile stems 0.15–0.4(–0.75) cm long, those of sterile stems (e.g.
349 *Mpandzou* 1653, IEC, K) much longer, 4–5.2 cm long. *Inflorescences* terminal, less usually
350 axillary in the most distal subapical node(s), thyrsoid, contracted, about as wide as long 0.4–0.85
351 cm diam., 5–20-flowered, main axis with 1–3 pairs of 1–3-flowered cymes ± evenly spaced from
352 the base; bracts quadrate-triangular, 0.5 x 0.8 mm. Pedicels each subtended by a second order
353 bract and two bracteoles, all ovate-triangular, 0.5–0.6 x 0.3 mm, margins sparingly minutely
354 simple hairy. *Female flowers* unknown, apart from parts persisting in fruit. Stigma discoid,
355 peltate, subsessile,1 mm diam. *Male flowers* with pedicel 1.2–1.5 x 0.5 mm, terete, widening to
356 0.8–1.2 mm wide below the sepals, lacking conspicuous glands.
357 *Calyx* with sepals 4, imbricate, erect, broader than long, transversely semi-elliptic, 0.4–0.7(–0.9)
358 x 1.1–1.6 mm, apex broadly rounded or rounded-obtuse. *Petals* 4, oblanceolate, concave, erect,
359 3.2–3.5 x 1.4–1.5 mm, apex obtuse, rounded or minutely retuse, margin membranous, central
360 part thickened with numerous raised oil-glands conspicuous on the abaxial surface. *Stamens* 8,
361 erect, free, slightly exceeding petals, subequal, the outer 4 with slightly longer filaments than the
362 inner 4,
363 filaments terete, 2.5–3.0 mm long, 0.4mm wide at base, narrowing gradually to 0.2 mm wide at
364 apex; anthers submedifixed, introrse to lateral dehiscence, oblong-ovate, 1–1.2 x 0.6 mm; disc
365 inconspicuous; ovary (pistillode) obclavate-4-angled/fluted, 3–3.1 x 1.2–1.3 mm, 0.7 mm wide at

366   apex, apex rounded with a slight central depression, in plan view 4-lobed (Fig. 1F) stigmas
367   punctate, minute; 4-locules each biovulate. *Fruit* in terminal clusters of (1–)2–4, yellow-orange,
368   subglobose or obovoid, apex rounded-slightly depressed, longitudinally 4-grooved to slightly
369   lobed, 11–14 x 11–13 mm, 4-locular but usually with 1–2 locules incompletely formed, 1–2(–4)-
370   seeded by abortion. Pericarp leathery, surface minutely wrinkled to slightly verrucate, 0.5–0.7
371   mm thick, endocarp bony 0.05 mm thick; mesocarp liquid, sweet to the taste. *Seed* encased in a
372   cartilaginous, vascular endocarp, ellipsoid, 4–4.5 x 2.4 x 1.8–2 mm (Fig. 1H).

374   **Distribution.** Republic of Congo, Kouilou Department, Tchimpounga to Djeno. Fig. 4

376   **Ecology. The evergreen thicket ecosystem on white sand on the Atlantic coast of Africa**
377   *Vepris teva* is restricted to the key vegetation type, thicket on white sand, that occurs in a coastal
378   ecosystem extending along the equatorial Atlantic coast of Africa in the southern hemisphere.
379   This ecosystem extends from the mouth of the Congo River in the Democratic Republic of
380   Congo, along the coast through Angolan Cabinda, Republic of Congo into southern Gabon, with
381   some areas thought to extend into Rio Muni of Equatorial Guinea. It extends discontinuously
382   along the coastline for about 1000 km and extends inland for between 100–3000 m, and is based
383   on old, partly dissected and flattened, highly leached white sand dunes that run parallel to the
384   coast, alternating with lower, wet or seasonally wet drainage areas often developing black peaty
385   soils, that can develop either swamp forest e.g. with *Alstonia congensis* Engl. trees and an
386   understorey of *Acrostichum aureum* L. or a wetland grassland community including Cyperaceae,
387   *Utricularia*, *Drosera*, Xyridaceae and *Stipularia africana* P.Beauv. Thicket develops on the top
388   of the ridges. In the ecotone transition areas, the shallow slopes between the thicket and wetland
389   area, a sparse grassland develops on the upper part of the white sand with *Chlorophytum,*
390   *Dissotis congolensis* (Cogn. ex Büttner) Jacq.-Fél., *Eulophia caricifolia* (Rchb.f.) Summerh., and
391   in the lower damper, seasonally inundated parts of the ecotone, grass species including
392   *Anadelphia hamata* Stapf, and herbs such as *Neurotheca corymbosa* Hua, both globally restricted
393   to this vegetation type.

395   On the seaward side of the dunes a sea-shore community including halophytes develops with
396   succulent species such as *Sansevieria longiflora* Sims, while in brackish inlets the Atlantic
397   mangrove community is formed, including *Rhizophora racemosa* G.Mey. On the landward side
398   of the ecosystem two substrates interface with the white sand, red-brown loam, and grey sand
399   which each have their own communities of grassland species. This ecosystem has rarely been
400   referred to in the literature. The best account is probably that by *Vande Weghe (2007)* regarding
401   the areas in southern Gabon. He refers to a sand-burrowing toad *Hemisus perretii* Laurent
402   (*Vande Weghe, 2007*: 250) that is restricted to this ecosystem. *Van der Burgt & Merklinger*
403   *(2012)* have characterised this ecosystem in the Republic of Congo after our studies in 2010–
404   2012, recognising the nine habitats referred to above, six of which have threatened, or
405   provisionally threatened plant species often restricted to this ecosystem. However, Critically
406   Endangered (CR) and Endangered (EN) species are reported only from two of the habitats: the
407   thicket (13 species) and sparse grassland on white sand habitats (2 species). The evergreen
408   thicket which is the habitat to which *Vepris teva* is restricted is only 2–3 m tall and consists of
409   shrubs, intermixed with very few emergent tree species e.g. *Hyphaene guineensis* Schumach. &
410   Thonn. and *Tessmannia dawei* J.Léonard, numerous climbers and several herbs,
411   characteristically:

412
413   Common shrubs: *Chrysobalanus icaco* subsp. *icaco* L., *Syzygium guineense* var. *guineense*
414   (Willd.) D C., *Ochna multiflora* DC, *Dalbergia grandibracteata* De Wild., *Manilkara lacera*
415   (Baker) Dubard, *Premna serratifolia* L., *Rytigynia dewevrei* Robyns, *Trichoscypha imbricata*
416   Engl., *Tricalysia coriacea* (Benth.) Hiern, *Vismia affinis* Oliv., *Psychotria kimuenzae* De Wild.,
417   *Psydrax moandensis* Bridson, *Thomandersia butayei* De Wild., *Baphia leptostemma* subsp.
418   *leptostemma* Baill. and *Leptactina mannii* Hook.f.,
419
420   Common climbers: *Pentarhopalopilia marquesii* (Engl.) Hiepko, *Uvaria versicolor* Pierre ex
421   Engl. & Diels, *Calycobolus cabrae* (De Wild. & T.Durand) Heine, *Jasminum kwangense* Liben
422   and
423   *Ancylobothrys scandens* (Schumach. & Thonn.) Pichon
424
425   Common herbs: *Pseuderanthemum lindavianum* De Wild. & T. Durand*, Coleus calaminthoides*
426   Baker and *Dracaena braunii* Engl.
427
428   The grassland is maintained by dry season fires which kill most or all woody plants (*Vande*
429   *Weghe, 2007*), none of which, curiously, appear fire-adapted. Such grassland fires were recorded
430   by us in Congo in July 2010. Owing to the sparsity of the herbs in the grassland, fires are not
431   intense due to the low fuel- load. It is sometimes possible for shrubs to establish in grassland.
432   *Chrysobalanus icaco* is a shrub which, once established, in the absence of fire, can spread
433   laterally to form a thicket in which other species of shrub and tree can colonise, leading towards
434   succession from grassland to thicket.
435
436   Among the endemic and highly threatened shrub species of this ecosystem, several apart from
437   *Vepris teva,* were found to be new to science. Of these, those recently published are *Dracaena*
438   *marina* Damen (*Damen et al., 2018*), *Baphia vili* Cheek (*Cheek et al., 2014*), *Salacia arenicola*
439   Gosline (*Gosline et al., 2014*). However, several additional species remain to be published.
440
441   **Local names and uses.** None are recorded.
442
443   **Etymology.** Named for Teva Kami, lead collector of the type specimen, who played a key role
444   in the discovery of this species and further research upon it concerning interactions with
445   chimpanzees (see below).
446
447   **Conservation.** *Vepris teva* is known from nine specimens and seven sight-records made
448   between July 2011-Feb. 2012. These equate to an area of occupation of 40 km^2 using the IUCN-
449   preferred 4 km^2 gridcells, and an extent of occurrence of 172 km^2. It is restricted to coastal
450   thicket on white sand habitat in Republic of Congo. This habitat is thought to extend along the
451   Atlantic coast from coastal DRC to southern Equatorial Guinea. Despite targetted surveys in this
452   habitat through most of this range especially in Congo, *Vepris teva* has only been found at three
453   of the more than eight locations studied. These are: 1) Pointe Noire at Point Indienne; 2) Djeno;
454   3) Tchimpounga. At the first location, the plants are threatened by an extension northward of the
455   port of Pointe Noire to accommodate export of rock phosphate, manganese, iron-ore for which
456   there is currently insufficient port capacity. Plants of *Vepris teva* are also threatened by cutting
457   of their coastal thicket habitat for charcoal and for clearance for housing. At the second location,

458   plants are threatened by the infrastructure and activities of the Total E&P Congo petro-chemical
459   plant (part of TotalEnergie S.A.), the installation of which appears to have destroyed much of the
460   habitat of *Vepris teva* at this location. Indirectly, Total, as the major employer at Djeno
461   attracting labour which requires local accommodation, appears to have stimulated an expansion
462   of urbanisation, resulting in *Vepris teva* habitat being parcelled for sale as house building plots
463   (Cheek pers. obs. 2012). At Tchimpounga, a reserve created by the Jane Goodall Foundation to
464   protect chimpanzees, *Vepris teva* uniquely appears protected and secure so long as this venture is
465   supported. In view of the EOO and AOO, and the threats stated, we here assess *Vepris teva* as
466   Endangered (EN B1ab(iii)+B2ab(iii)).
467
468   **Additional specimens and observations**
469   Republic of Congo, Dept. Kouilou, Tchimpounga, along coast NW of Pointe Noire, about 7 km
470   SE of the Kouilou River Bridge, in the Tchimpounga Chimpanzee Sanctuary, fl. 3 Dec. 2011, *T.*
471   *Kami et al.,*1356 (IEC, K000875073); Tchimpounga pointe 2 zone ex gorillon, fl. 5 Nov. 2012,
472   *Mpandzou et al.,*1641 (IEC, K000875078); Tchimpounga, bas-Kouilou, Bois de Singe, st. 6 Dec.
473   2012; *Mpandzou et al.,*1754 (IEC, K000875081); Tchimpounga, Point 1 zone de soleil, fl. 2
474   Nov. 2012, *T. Kami et al.,*1421 (BR, IEC, K000875083); Tchimpounga, Point 1 zone de soleil,
475   fl. 3 Nov. 2012, *T. Kami* 1437 *et al.,* (IEC, K000875082); **Pointe Noire,** Port 8, along coast just
476   northwest of Pointe Noire, near Pointe Indienne, 4° 42′ 46.5"S, 11 49 18.3E, 10 m elev., fl. 23
477   Nov. 2011, *T. Kami et al.,*1227 (holotype K000875074; isotypes EA, IEC, MO, P, US); Pointe
478   Noire, fr. 9 July 2011, *Mpandzou et al.,*1198 (IEC, K000875072, P); near Pointe Indienne, 24
479   Nov. 2011, Port Observations 36; ibid. 24 Nov. 2011, Port Observations 61; ibid, 25 Nov. 2011,
480   Port Observations 91; ibid. 26 Nov. 2011, Port Observations 128; 27 Nov. 2011, Port
481   Observations 215; **Djeno** a côté de Terminal de Djeno, fr. 6 Dec. 2012, *Mpandzou et al.,*1768
482   (IEC, K000875077); ibid., fr. 6 Dec. 2012, *Mpandzou et al.,*1754 (IEC, K000875081); Djeno,
483   near Total refinery, 15 Feb. 2012, Port Observations 309; ibid., 13 July 2011, Port Observations
484   303.
485
486   **Notes.** We first detected *Vepris teva* in July 2011, during the dry season environmental impact
487   studies for a proposed new port facility near the major existing port of Pointe Noire, Congo's
488   principal port and commercial centre. It was provisionally named as '*Vepris* sp. 1 of Pointe
489   Noire,' and considered likely to be new to science since it matched no other known species of the
490   genus in tropical Africa (*Cheek et al., 2011*). Further collections were made in a wet season
491   survey in Nov. and Dec. 2011. These surveys resulted in the discovery of many other rare
492   species, usually previously unknown to science, mainly confined to evergreen thicket on coastal
493   white sand. Consequently, surveys in Nov.-Dec. 2012 were made along the length of the
494   Congolese coastline to map the full national extent of this ecosystem and of its rare and
495   threatened species. It was discovered that unlike many of the coastal thicket species, *Vepris teva*
496   is restricted to only a small length of the coast, from Djeno in the south to Tchimpounga in the
497   north. At these three sites, wherever coastal thicket on white sand appears, *Vepris teva* can be
498   fairly frequent. However, when thicket become degraded or damaged, it is no longer present.
499   We believe that our surveys have detected all sites where this species survives in the Republic of
500   Congo. However, it is possible that additional individuals might survive in fragments of original
501   vegetation that were overlooked by us e.g within the greater area of the city of Pointe Noire, but
502   we consider this unlikely. Also, it is possible that the species might extend to Angola (Cabinda)
503   or southern Gabon which we were not able to visit during the studies referred to in this paper.

504 *Vepris teva* sometimes grows alongside another species of the genus, *Vepris africana* (formerly
505 *Vepris gossweileri*). The second species extends into Angola and to S.Tomé (*Lachenaud &*
506 *Onana, 2021*). The two species cannot be confused since the first is trifoliolate, while the second
507 is unifoliolate. No *Vepris* species other than these two have been found in coastal thicket on
508 white sand in Congo.

509

510 Our knowledge of the phenology of *Vepris teva* is restricted to two periods of the year – July
511 (dry season) and Nov.-Dec. (wet season). At both seasons plants were found in both flower and
512 fruit. All flowers collected are monomorphic and have well-developed stamens with pollen, and
513 are therefore supposed to be male. This is supported by our observation that while the fruits (the
514 undoubted products of female flowers) have a 1 mm diam. peltate, discoid stigma, peltate
515 stigmas have not been in any of the flowers which are therefore male. Since *Vepris* species have
516 been found to be dioecious wherever their reproductive strategies have been studied, we
517 conclude that female flowers remain to be discovered, although female plants (in fruit) have been
518 collected. There is a small possibility that *Vepris teva*, atypically in the genus, might have
519 hermaphroditic flowers.

520

521 *Vepris teva* grows very slowly from seed. Three plants cultivated at the Royal Botanic Gardens,
522 Kew from seed collected in 2011, reached only 15–25 cm tall after five years. By March 2020,
523 after 8.5 years, the plants had reached 30–45 cm tall, but none had shown signs of flowering. All
524 three of these plants showed the long petiole of sterile plants, and not the characteristic extremely
525 short petioles of reproductive individuals. Thus, the age of sexual maturity is likely to be at least
526 10 years in *Vepris teva.*

527

528 Because *Vepris teva* has a 4-locular syncarpous flower producing a soft fleshy fruit it would
529 formerly have been classified in the monotypic genus *Oriciopsis*, together with *V. glaberrima*
530 (*Letouzey, 1963b*: 79–80). The last species occurs in lowland evergreen forest at the junction of
531 Cameroon, C.A.R. and Gabon and is also a small, sparingly branched shrub. It is conceivable
532 that the two are sister species (see above). Four-locular syncarpous ovaries are also seen in the
533 formerly accepted genera *Araliopsis* and *Toddaliopsis,* but in these taxa the fruits are hard. The
534 former occurs in W-C Africa but is a large tree with digitately 5-foliolate leaves, the second a
535 tree of coastal E Africa with a subspiny, "nut-like" fruit.

536

537 *Vepris teva* appears unique and is easily recognisable in the genus and in its habitat because of
538 the combination of long petiolules with extremely short petioles on the fertile stems. The
539 petioles can be so contracted that they are almost invisible, and it then appears that there are
540 three simple, leaves, each on its own petiole (in fact leaflets on petiolules) at each node.

541

542

543 **Chimpanzee–mediated seed dispersal.**

544

545 During field surveys of the vegetation in which *Vepris teva* occurs, the last author tested the
546 hypothesis that the fruits might conform to the 'spat seed' syndrome characteristic of some
547 primate-dispersed plant species (*Sengupta et al., 2015; Dominy & Duncan, 2005*). When the
548 base of a fruit plucked from a shrub is sucked, the pleasantly sweet, watery mesocarp with the

549   seed(s) enters the mouth, the juice can be swallowed, and the slippery seed(s) in their
550   endocarp(s) spat out (Fig. 5).
551
552   One of the three known locations for *Vepris teva* is the Tchimpounga Reserve, co-managed by
553   the Jane Goodall Institute (*Jane Goodall Institute, 2018*) which focuses on chimpanzee
554   conservation and research of both rescued animals from captivity and hunting, and chimpanzees
555   indigenous to the coastal thicket ecosystem (see below). During field observations for doctoral
556   studies of fruit consumption by chimpanzees from tree species by the second author (2014–2020,
557   *Kami, 2021*), chimpanzees were observed to seemingly feed on the fruits of this species of
558   *Vepris* – evidenced by empty pericarps and separated, spat seeds of this species after they had
559   been in the vicinity of the fruiting shrubs. Chimpanzee seed dispersal of *Vepris teva* seems very
560   likely but more detailed studies are needed to confirm this.
561
562
563   **CONCLUSIONS**
564
565   The description of a known compound, ß-amyrin, for the first time in *Vepris*, is consistent with
566   previous research wherein nearly each species of the genus that is newly chemically investigated
567   contributes additional compounds, often those that are new to science (e.g., *Langat et al. 2021*).
568   The number of species of *Vepris* that have been chemically investigated is rising steadily,
569   numbers having doubled in the last seven years, with 15 species of *Vepris* reported as
570   investigated by *Imbenzi et al. (2014)* and 32 by *Ombito et al. (2021),* the last reporting 213
571   secondary compounds in five classes from *Vepris*. However, this represents only a third of the
572   known species diversity of the genus, which itself is increasing as taxonomists uncover
573   additional species new to science, 12 new species having been published since 2000, a c. 15%
574   increase in numbers for the genus, the recent novelties having been detected mainly in Cameroon
575   (e.g. *Onana & Chevillotte, 2015*). The range of biological activity shown by these compounds is
576   wide and has great potential to address current and future needs of humanity, from medical to
577   agricultural. However, screening for biological activity lags far behind discovery of compounds.
578
579   The case of *Vepris teva* illustrates the importance of uncovering and publishing species before
580   they become extinct and become lost forever, together with their potential applications for
581   humanity, in this case secondary compounds with potential e.g., as anti-microbials, natural
582   insecticides and in the case of ß-amyrin, recorded here for the first time in *Vepris,* strong anti-
583   inflammatory action (*Okoye et al., 2014*).
584
585   For last 15 years or more, about 2000 new species of flowering plant have been published by
586   scientists each year (*Cheek et al., 2020*), adding to the estimated 369 000 already documented
587   (*Nic Lughadha et al., 2016).* However, only 7.2% of species have been assessed for their threat
588   status and are included on the Red List using the *IUCN (2012)* standard (*Bachman et al., 2019*).
589   Newly discovered species, such as *Vepris teva*, reported in this paper, are likely to be threatened,
590   since widespread species tend to have been already discovered. There are notable exceptions to
591   this rule (e.g., *Vepris occidentalis* Cheek & Onana (*Cheek et al., 2019*) a species widespread in
592   West Africa from Guinea to Ghana). However, it is generally the more range-restricted,
593   infrequent species that remain unknown to science. This makes it urgent to find, document and
594   protect such species before they become extinct. Until species are described and known to
595   science, it is difficult to assess them for their IUCN conservation status and so the possibility of

596   protecting them is reduced (*Cheek et al., 2020*). Documented extinctions of plant species are
597   increasing, e.g., in coastal forest of Cameroon, *Oxygyne triandra* Schltr. is considered extinct at
598   its sole locality, the forest at Mabeta-Moliwe in the foothills of Mt Cameroon (*Cheek et al.,*
599   *2018b; Cheek & Williams 1999; Cheek, 1992), Inversodicraea bosii* (C.Cusset) Rutish. & Thiv.
600   at the Lobe Falls (*Cheek et al., 2017*) and in Gabon *Pseudohydrosme buettneri* Engl. (*Cheek et*
601   *al., 2021*) in coastal forest. There are also examples of species that appear to have become
602   extinct even before they are known to science, such as in Cameroon *Vepris bali* Cheek (*Cheek et*
603   *al., 2018a*), and in Gabon *Pseudohydrosme bogneri* (*Moxon-Holt & Cheek, 2021*). Human
604   pressures have been the cause of these extinctions in all these cases
605
606   In the Republic of Congo natural habitat is fortunately relatively extensive and intact, but in
607   some specialised ecosystems such as that with the evergreen thicket on white sand habitat
608   described above, to which *Vepris teva* is restricted, large areas have entirely disappeared and
609   others are set to follow them.
610
611   Further effort in prioritising high priority areas for plant conservation as Tropical Important Plant
612   Areas (TIPAs), using the revised IPA criteria set out in *Darbyshire et al., (2017)* is being
613   implemented in Guinea (*Couch et al., 2019*). TIPAs are also in progress in countries such as
614   Cameroon, Ethiopia, Mozambique and Uganda and might be extended elsewhere in Africa such
615   as to the Republic of Congo, to reduce the risk of future global extinctions of range-restricted
616   endemic species such as *Vepris teva.*
617
618

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Morphological characters separating *Vepris teva* from *Vepris glaberrima*

Characters	*Vepris teva*	*Vepris glaberrima*
Petiole length (cm)	0.14–0.4(–0.75)	4–10
Petiolule length (cm)	(0.3–)0.5–1.1(–1.6)	1.1–2.7
Median leaflet texture and dimensions (cm)	Coriaceous (4.5–)5.5–10.6(–14.3) x (2–)2.7–3.5(–5.2)	Papyraceous 7.5–18(–20) x 2.5–8.3
Acumen length (mm)	(3–)4–9(–10)	13–19(–20)
Oil gland dots on abaxial surface	Raised above surface, moderately conspicuous	Not visible
Petal length (mm)	3.3–3.5	4.8–5.1
Calyx lobe	Well-developed 0.4–0.7 mm long	Not developed
Fruit shape	Subglobose	Ovoid
Fruit size (mm)	11–14 x 11–13	20–25 x 16–20

Figure 1

Furoquinoline and acridone alkaloids isolated from *Vepris teva*

Furoquinoline alkaloids: kokusaginine (**1**), maculine (**2**), and flindersiamine (**3**). Acridone alkaloids: arborinine (**4**) and 1-hydroxy-3-methoxy-10-methylacridone (**5**).
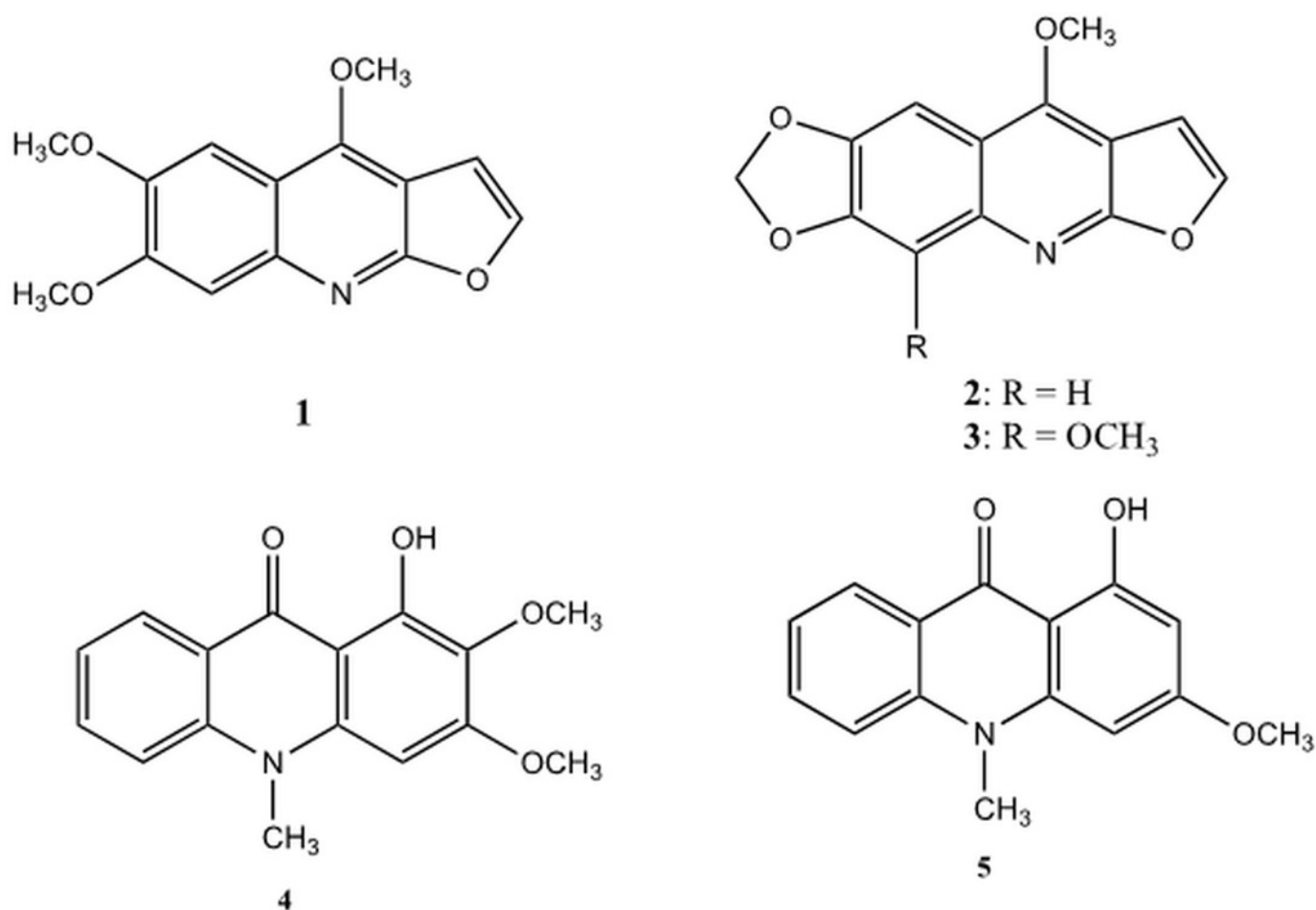
Figure 2

Vepris teva.

(A) Habit, fruiting stem; (B) detail of leaflet blade showing oil gland dots and nervation, lower surface of blade in foreground; (C) detail of male inflorescence; (D) male flower, side view; (E) as D, two petals removed to show stamens; (F) pistil of male flower, 4-lobed, viewed from above; (G) male flower, 2 petals and 3 stamens removed to show pistil; (H) mature fruit, side view (seed on right); (I) fruit, plan view; (J) fruit, transverse section, showing four locules, three aborted and one with seed. A & H-J from *Mpandzou et al.,* 1198, B & G from *Kami, T. et al* 1356; C-F from *Kami, T. et al.,* 1227. Drawn by Juliet Williamson, CC-BY-NC-ND.
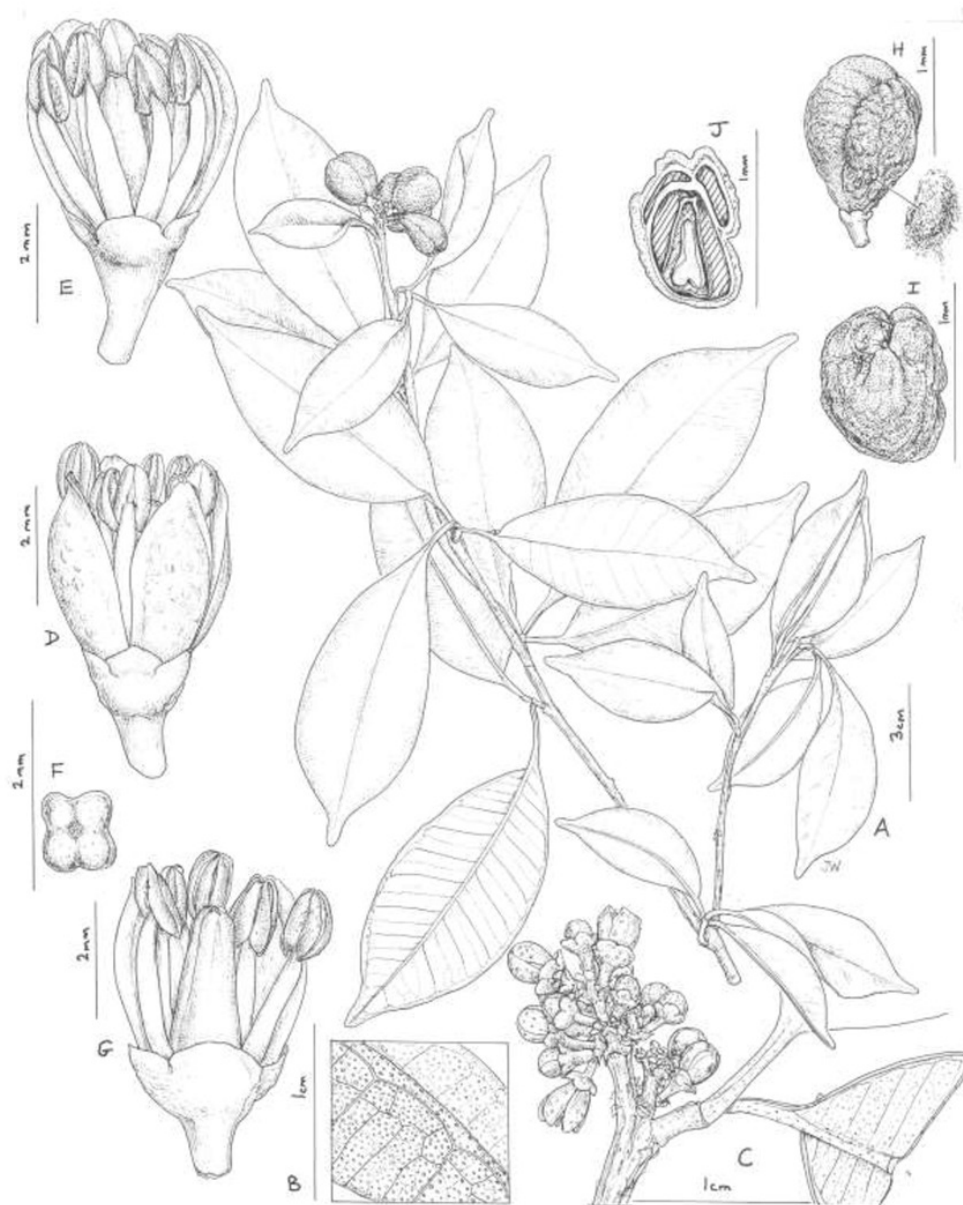
Figure 3

Vepris teva.

Shrub with mature (yellow) and immature (green) fruits. Note the sessile leaves. From *Mpandzou et al.,* 1198 (IEC, K). Photo by M. Cheek.

Figure 4

Vepris teva

Global distribution

Figure 5

Vepris teva.

The empty, leathery pericarp after juice abstraction and three spat seeds. Photo: M. Cheek