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## Use of vegetative characters in the identification of species of *Salacia* (Celastraceae)

J. B. HALL & J. M. LOCK

### SUMMARY

The authors describe the woody-stem anatomy of 13 taxa of *Salacia* in Ghana. Four main anatomical types are recognized and a new terminology is proposed. The taxonomic use of stem anatomy and of exudates is discussed. A paper chromatogram of extracts of dried leaves is presented. A key to *Salacia* in Ghana is given, based on stem structure and shoot morphology.

### RÉSUMÉ

Les auteurs décrivent l'anatomie des tiges ligneuses de 13 taxons de *Salacia* du Ghana. Ils reconnaissent quatre types anatomiques et proposent une nouvelle terminologie. L'emploi en taxonomie des critères tirés de l'anatomie de la tige et des exsudats est discuté. Un chromatogramme sur papier d'extraits de feuilles sèches est présenté. Une clé, basée sur la structure de la tige et sur la morphologie des pousses, est rédigée pour les espèces de *Salacia* se trouvant au Ghana.

Recently a floristic survey has been carried out in the closed-canopy forests of Ghana which has led to a new classification of these forests (Hall & Swaine, 1974). Lists of all species present were obtained for 155 sample plots each measuring 25 m × 25 m, scattered through the forest zone. The survey showed that the family *Celastraceae* (consisting here of genera formerly segregated in the *Hippocrateaceae*), though less abundant than *Rubiaceae*, is well represented, being of comparable importance to *Annonaceae*, *Apocynaceae*, *Caesalpiniaceae*, *Euphorbiaceae*, *Papilionaceae* and *Sterculiaceae*. Up to 7 species of *Celastraceae* were found in a plot, and the family was absent from only 6 plots. Although present in all forest types, it is relatively more abundant in drier forest (Fig. 1).

Of all the above-mentioned families, the *Celastraceae* has presented the greatest difficulties in identification. This is partly because, despite the work of Hallé (1962), the family in West Africa is still not well-known taxonomically. With two exceptions, moreover, the family consists of lianes which are seldom obtained in flower. Shade-leaves on the sterile shoots collected in the forest understorey are often more variable in shape, larger, thinner and more strongly toothed than sun-leaves, which are associated with inflorescences. Matching such sterile shoots with flowering herbarium material is, however, usually possible (provided a sufficient range of material is

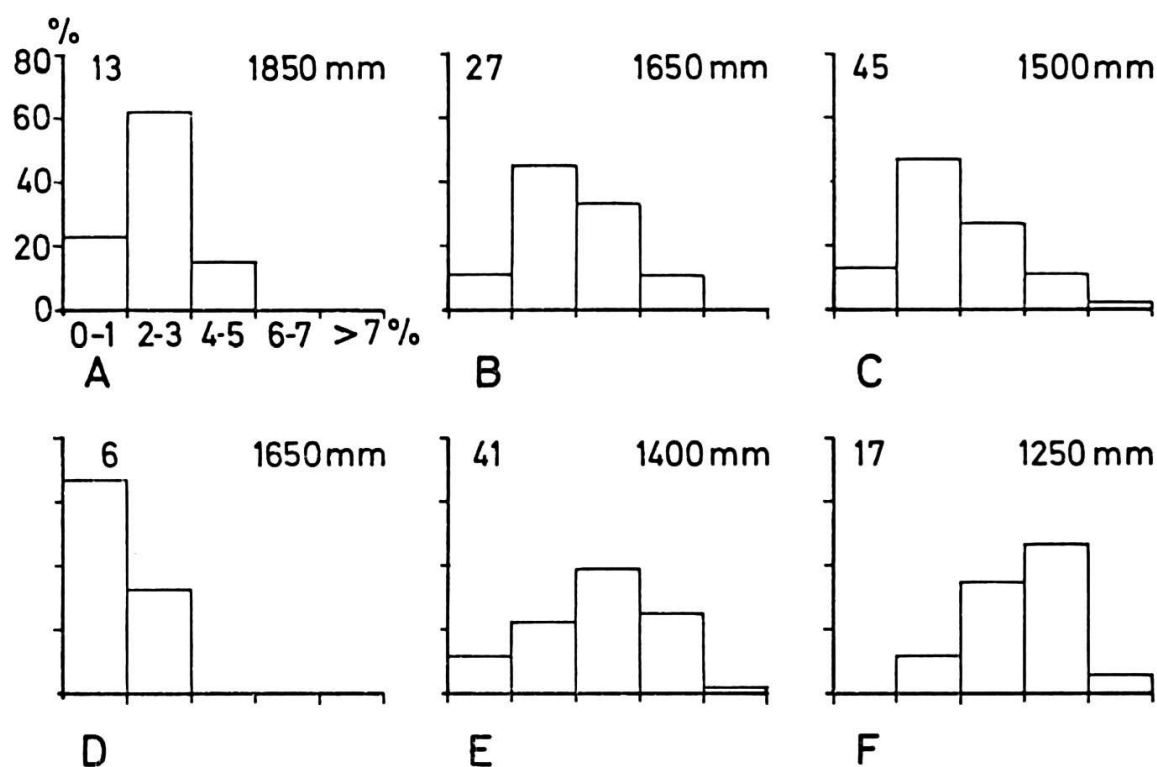


Fig. 1. — Occurrence of *Celastraceae* in six major forest types in Ghana (Hall & Swaine, 1974). The horizontal axis shows *Celastraceae* occurrence class, i.e. the number of species in a 625 m<sup>2</sup> sample plot as a percentage of total species in that plot. The vertical axis gives for each forest type the percentage of plots in which each *Celastraceae* occurrence class was found. Figure in top left corner of each histogram is number of plots sampled in that type; figure in top right corner is mode for mean annual rainfall. Forest types: A, wet evergreen; B, moist evergreen; C, moist semideciduous; D, upland evergreen; E, dry semideciduous; F, southern marginal.

considered) using characters such as twig ornamentation, colour and venation pattern of the leaves, presence or absence of gutta canals in the shoot, and so on. The structure of the woody stem presents many further useful characters.

Forest *Celastraceae* resemble *Combretum* spp. in their woody, scandent habit, and opposite, simple, penninerved leaves with stipules absent or minute. *Celastraceae* can be distinguished, however, by the more-or-less toothed leaf margin, absence of scales and the usual absence of hair. Within *Celastraceae* (former *Hippocrateaceae*) branching in the capsular-fruited genera is always opposite and decussate, the branches growing from the axils of foliage leaves or scale leaves; in the baccate-fruited genera (*Salacia* and *Salacighia*) branching is almost always alternate, and the branches are typically subtended by scale leaves following a 2/5 phyllotaxy.

#### Stem anatomy in *Salacia*

Hallé (1962) found in the capsular-fruited genera that woody-stem anatomy was of great value in their classification. In *Salacia* he reported that, according to species, the wood could be cylindrical and normal, or divided into concentric bands

by anomalous phloem rings, or deeply grooved by radial phloem-filled furrows. Hallé noted, however, that information was available for too few species to enable valid taxonomic conclusions to be drawn. He described woody-stem anatomy for ten of the *Salacia* species which occur in Ghana, four of these descriptions being derived from Obaton (1960). It is noteworthy that the same types of anomaly were recognised by Schenck (1893) in *Salacia* from the South American tropics. Schenck further observed that in some species with the first type of anomaly the phloem rings are complete, in others they are incomplete, while in yet others they consist only of isolated strands of phloem giving a structure similar to that of lianescent species of *Strychnos*. Obaton (1960) noted the occurrence of such phloem strands in the West African *Salacia zenkeri*, and Hallé found this arrangement also in species of *Salacighia*. At least in West Africa, intermediates between strands and rings do not seem to occur, and hence it seems justifiable to regard strand structure as a distinct type: this may be termed *lacunose* from its appearance in transverse section. The following terms are proposed for the four types of woody-stem anatomy in West African *Salacia*:

Proposed term	Previously used terms	
	Hallé (1962)	Schenck (1893)
Normal	Normal cylindrique	—
Annular	Anomalies concentriques	Wiederholte Cambiumbildung
Lacunose	Anomalies concentriques	Wiederholte Cambiumbildung
Sulcate	Type silloné à base 5	Gefurchter Holzkörper

A summary of the stem anatomy of the ten species of *Salacia* described by Hallé (1962) together with that of 13 further species here described for the first time is given in Table 1; some species are illustrated in Figure 2.

Although closely-related species are often similar in stem anatomy, as is the case with *Salacia nitida*, *S. whytei* and *S. staudtiana*, and also with *S. debilis* and *S. erecta*, stem anatomy seems on the whole less well correlated with other characters in *Salacia* than in the capsular-fruited genera of *Celastraceae*. There does not, for example, seem to be a close relationship between the two species *S. howesii* and *S. zenkeri*, known to have lacunose wood, and neither seems close to *Salacighia*. *S. nitida* and *S. camerunensis* are closely similar in most respects—they are, indeed, frequently confused—but the former has sulcate and the latter annular wood. Another sulcate species, *S. lateritia*, is, despite its unique papillose lower leaf surface (Plate I) certainly more closely related to *S. pyriformis*, with annular wood, than it is to *S. nitida*.

Considerable variation, as noted in Table 1, exists within the annular group. One subtype is represented by *S. elegans* (Fig. 2A) in which the phloem rings are very narrow, irregular, numerous and incomplete. Another subtype is exemplified by *S. erecta* (Fig. 2E) which resembles *Agelaea* (*Connaraceae*) in its broad, complete rings and lobed, eccentric stem section. Thirdly, *S. leptoclada* (Fig. 2C) represents a subtype in which the rings are joined into a network by oblique and radial bands of phloem. Unfortunately these subtypes are linked by numerous intermediates.

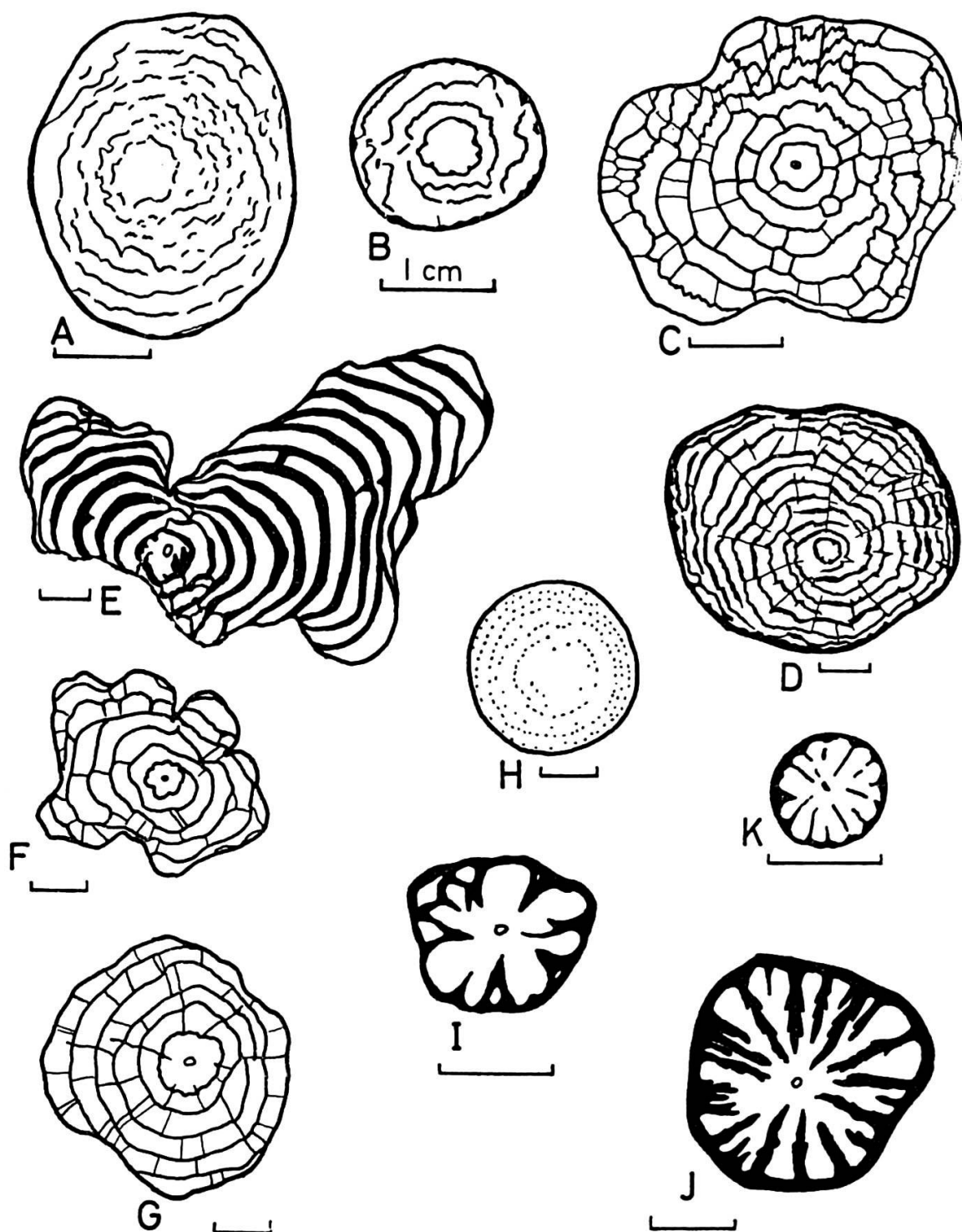


Fig. 2. — Woody-stem anatomy of 11 representative species of *Salacia* in transverse section (phloem black, xylem white). Annular wood: A, *S. elegans*, GC 44197; B, *S. togoica*, GC 42810; C, *S. leptoclada*, GC 43768; D, *S. lomensis*, GC 43797; E, *S. erecta*, GC 43828; F, *S. cerasifera*, GC 44515; G, *S. sp. aff. gabunensis*, GC 44102. Lacunose wood: H, *S. howesii*, GC 44324. Sulcate wood: I, *S. lateritia*, GC 44175; J, *S. staudtiana* var. *leonensis*, GC 44113; K, *S. whytei*, GC 44723. (For reference to collecting numbers, see Table 1.)

Name	Reference	Wood type	Notes
<i>S. alata</i> De Wild. var. <i>alata</i>	GC 43487	A	To 15 cm diam., intermediate between <i>S. erecta</i> and <i>S. leptoclada</i> .
<i>S. camerunensis</i> Loes.	GC 44564	A	To 2 cm diam., 1-2 rings only.
<i>S. cerasifera</i> Welw. ex Oliv.	GC 44515	A	Deeply lobed outline; netted phloem.
<i>S. cornifolia</i> Hooker fil.	Obaton, GC 36330	A	Similar to <i>S. cerasifera</i> .
<i>S. debilis</i> (G. Don) Walp.	GC 43519	A	Similar to <i>S. erecta</i> .
<i>S. elegans</i> Welw. ex Oliv.	GC 44197	A	Toothed-leaved form (GC 44197) similar to entire form (Hallé).
<i>S. erecta</i> (G. Don) Walp.	GC 43828	A	Deeply lobed outline; wide phloem rings.
<i>S. sp. aff. gabunensis</i> Loes.	GC 44102	A	Phloem $\pm$ concolorous with wood.
<i>S. howesii</i> Hutch. & Moss	GC 44324	L	Growth rings and parenchyma bands present.
<i>S. ituriensis</i> Loes.	GC 43889	A	Similar to <i>S. sp. aff. gabunensis</i> .
<i>S. lateritia</i> N. Hallé	GC 44175	S	To 2 cm diameter.
<i>S. leptoclada</i> Tul. (syn. <i>S. baumanii</i> Loes.)	GC 43768	A	Network of phloem, darker than wood.
<i>S. lomensis</i> Loes.	GC 43797	A	Similar to <i>S. alata</i> , but wood of inner 2-3 rings darker.
<i>S. miegei</i> N. Hallé	GC 36279	A	Similar to <i>S. pyriformis</i> , but red latex in phloem.
<i>S. nitida</i> (Bentham) N. E. Br.	GC 44605 Obaton	S	Stem outline grooved, to 3 cm diameter.
<i>S. oliverana</i> Loes. var. <i>adiopodoumella</i> N. Hallé	GC 44743 Hallé	A	Similar to <i>S. erecta</i> , but phloem rings narrower and with red latex.
<i>S. pallescens</i> Oliv.	Hallé	N	Erect shrub.
<i>S. pyriformis</i> (G. Don) Steudel (syn. <i>S. owabiensis</i> Hoyle)	GC 43771 Hallé	A	Similar to <i>S. erecta</i> but less lobed and much gutta in phloem.
<i>S. staudtiana</i> Loes. var. <i>leonensis</i> Loes. (syn. <i>S. tshopoensis</i> De Wild.)	GC 44113 Obaton	S	Stem outline rounded, to 3 cm diameter. Not annular as stated by Obaton.
<i>S. togoica</i> Loes.	GC 42810	A	Similar to <i>S. elegans</i> ; slender.
<i>S. uregaensis</i> Wilczek var. <i>aurantiaca</i> N. Hallé	Hallé	N	Erect shrub.
<i>S. whytei</i> Loes.	GC 44723	S	Similar to <i>S. nitida</i> ; slender.
<i>S. zenkeri</i> Loes.	Obaton	L	Similar to <i>S. howesii</i> .

Table 1. — Woody-stem anatomy of Ghana *Salacia*. Reference is to collecting number for Ghana specimen, or to Hallé (1962) or to Obaton (1960). Wood types are: A, annular; L, lacunose; N, normal; S, sulcate. Wood anatomy is not yet known for the following two species which occur in Ghana, viz. *S. chlorantha* Oliv. and *S. columna* N. Hallé.

### Exudates

It is well-known that many, but not all, species of *Celastraceae* contain gutta-percha canals, whose contents form clear, glistening, "resinous threads" when the organ in which they occur is broken. This character is particularly useful because it is constant, and can readily be observed in both fresh and dry material. The following two further exudates are less familiar.

A yellow powdery material, which appears to be a form of gutta (Ding Hou, 1964), exudes from the cut stems of *S. nitida* and *S. staudtiana*, supporting the close affinity between these species that is suggested by other characters.

Red sticky latex exudes from the cut phloem of many lianes in the families *Connaceae*, *Euphorbiaceae* and especially *Papilionaceae*. Such latex has now been found in three otherwise distantly related species of *Salacia*: *S. oliverana*, *S. miegei* and an unidentified non-gutta species (Breteler nos. 1895 and 2449) from Cameroun.

### Leaf phenolics

Chromatograms were prepared as follows. Dry leaves were powdered and extracted with cold methanolic hydrochloric acid. The extract was then spotted onto chromatographic paper and run in 15% aqueous acetic acid. Spots, representing various unidentified phenolic compounds, were observed and marked under ultraviolet light both before and after fuming with ammonia.

Figure 3 illustrates the use of this technique as an aid to identification. It had been considered that specimens from plots 134, 131, 142, 139, 112, and 136 were morphologically fairly uniform and that they showed points of resemblance to *Salacia togoica* (S. T. in Fig. 3). Chromatography showed, firstly, that none of these specimens is referable to *S. togoica* and, secondly, that the specimen from plot 131 had been misplaced. Further morphological comparison showed that the odd specimen is *S. sp. aff. gabunensis*, and that the rest are *S. cornifolia*.

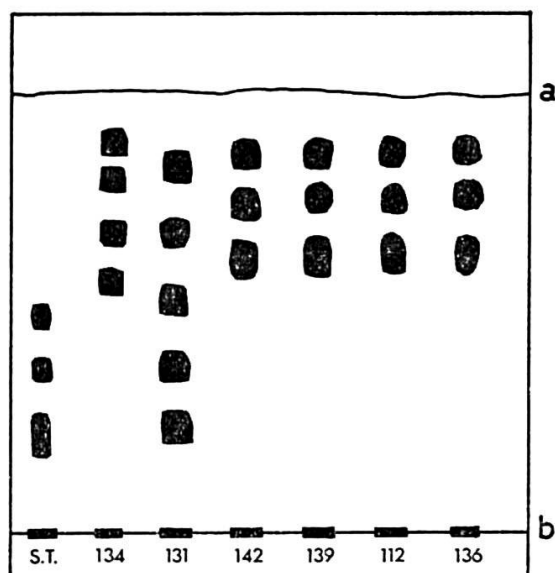


Fig. 3. — Paper chromatogram of extracts of dried leaves of *Salacia togoica* (S. T.) and of six other numbered samples (for methods see text above). Samples 134, 142, 139, 112, and 136 are very similar and are *S. cornifolia*; sample 131 is different and is *S. sp. aff. gabunensis*. a: solvent front; b: initial spots of samples.



Key to *Salacia* in Ghana based on characters of woody stem and dried shade shoots

1. Gutta canals present: elastic threads seen when leaf is broken . . . . . 2  
 Gutta canals absent: no elastic threads . . . . . 10
2. Leaves coarsely toothed, with teeth reaching or exceeding 1 mm . . . . . 3  
 Leaves subentire or slightly toothed . . . . . 5
3. Young twigs closely verrucose . . . . . *S. chlorantha*  
 Young twigs smooth . . . . . 4
4. Leaves to 15 × 5 cm; phloem rings narrow, interrupted, without red latex  
*S. elegans* (typical form)  
 Leaves to 25 × 12 cm; phloem rings wide, containing red latex . . . . . *S. miegei*
5. Twigs with corky wings to 0.5 mm wide; leaves closely and minutely papillose below;  
 wood sulcate . . . . . *S. lateritia*  
 Twigs without corky wings; leaves completely glabrous; wood (where known) annular . . . . . 6
6. Young twigs thin-barked, more-or-less smooth . . . . . 7  
 Young twigs more-or-less closely verrucose . . . . . 9
7. Leaves large, c. 15 cm long; lateral nerves strong, c. 6 per side, well-marked and  
 ascending, lamina thickish; phloem rings wide, continuous, without red latex  
*S. pyriformis*  
 Leaves less than 12 cm long; lateral nerves less strong, 8-10 per side; lamina rather  
 thin; phloem rings not as above . . . . . 8
8. Phloem rings continuous and joined into a network, containing red latex; stem outline  
 deeply lobed . . . . . *S. oliverana*  
 Phloem rings narrow, interrupted, lacking red latex; stem outline not lobed  
*S. elegans* (subentire form)
9. Leaves obtuse, not exceeding 10 cm . . . . . *S. lomensis*  
 Leaves acuminate, to 18 cm long . . . . . *S. columna* var. *akeassii*
10. Erect shrubs; wood cylindrical, normal; branchlets often opposite . . . . . 11  
 Lianes; wood anomalous; branchlets alternate (ex. *S. camerunensis*) . . . . . 12
11. Leaf lamina thin, sharply serrate, dark green . . . . . *S. pallescens*  
 Leaf lamina thick, subentire, yellow-green . . . . . *S. uregaensis* var. *aurantiaca*
12. Wood sulcate; granular yellow exudate from cut phloem of woody stem (ex. *S. whytei*) . . . . . 13  
 Wood annular or lacunose; yellow exudate absent . . . . . 15
13. Leaves discolourous, yellow-green below; phloem rays yellowish, paler than wood  
*S. staudtiana* var. *leonensis*  
 Leaves almost concolorous, mid-green below; phloem rays brownish, darker than  
 wood . . . . . 14
14. Leaves to 18 cm long, elliptic, cuneate at base, nerves impressed above; stem to 3 cm  
 diam., inner bark yellow-orange . . . . . *S. nitida*  
 Leaves to 12 cm long, ovate to elliptic, rounded at base, nerves not impressed; stem to  
 1 cm diam., inner bark red-brown . . . . . *S. whytei*
15. Wood lacunose; shoots sometimes pubescent . . . . . 16  
 Wood annular; shoots always glabrous . . . . . 17
16. Twigs and underside of leaves densely and softly pubescent; twigs not lenticellate,  
 olive-brown . . . . . *S. howesii*  
 Shoot glabrous; twigs densely lenticellate, reddish-brown . . . . . *S. zenkeri*
17. Leaves distinctly toothed; twigs conspicuously 4-ridged and tuberculate; petiole  
 margin crisped . . . . . 18  
 Leaves subentire, or where toothed (*S. camerunensis*) twigs not as above; petiole  
 margin seldom crisped . . . . . 21



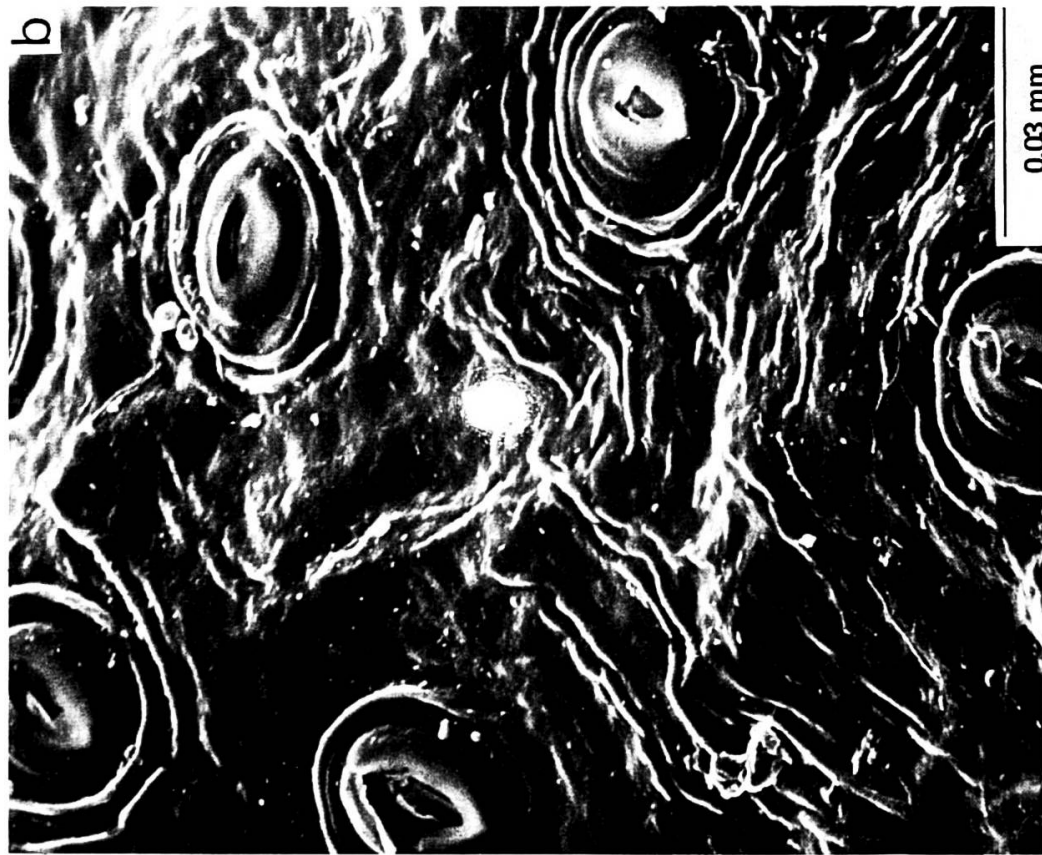
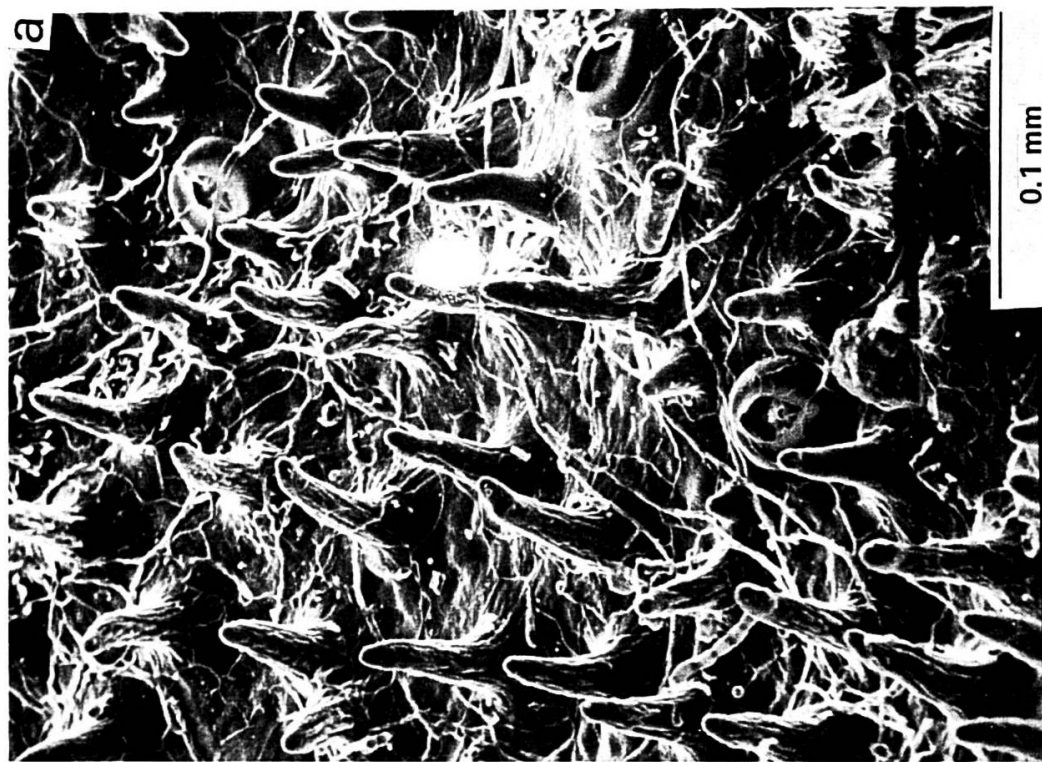
18. Petiole 5-10 mm long; leaves to 22 cm long; woody stem more-or-less cylindrical 19  
 Petiole 1-2 mm long; leaves to 15 cm long; old woody stem deeply lobed in section 20
19. Leaves pale greyish-green below; phloem rings darker than wood and wider than  
 phloem rays; stem surface lumpy . . . . . *S. alata* var. *alata*  
 Leaves mid-green below; phloem rays yellowish, concolorous with wood, same width  
 as phloem rays . . . . . *S. ituriensis*
20. Teeth 10-25 on each side of lamina; young twigs with ridges to 0.5 mm high and  
 prominent tubercles; leaves discolorous, drying yellow-brown below *S. debilis*  
 Teeth 20-40 on each side of lamina; young twigs with less pronounced ridges and  
 tubercles; leaves almost concolorous, drying greenish below . . . . . *S. erecta*
21. Leaves rather coarsely toothed; branching usually opposite; young twigs irregularly  
 wrinkled when dry; woody stems slender with only 1-2 rings; underbark brownish  
*S. camerunensis*  
 Leaves subentire; branching always alternate; woody stems developing several rings;  
 underbark usually yellow or orange . . . . . 22
22. Leaves large, often exceeding 20 cm, shiny below, not pressing flat; midrib yellow-  
 green below; twigs much flattened and often exceeding 4 mm wide below nodes;  
 without ridges; phloem rings almost concolorous with wood; bark rough with  
 bright orange inner layer . . . . . *S. sp. aff. gabunensis*  
 Leaves usually less than 20 cm long, matt below, pressing flat; midrib often tinged  
 orange below; twigs often flattened below nodes but never wider than 3 mm; with  
 or without slight ridges; phloem rays much darker than wood, bark fairly smooth 23
23. Lateral nerves faint, not prominent below, concolorous with lamina below; leaves  
 less than 12 cm long . . . . . *S. leptoclada*  
 Lateral nerves prominent and darker than lamina below; leaves 12-20 cm long . . . 24
24. Leaves drying olive-brown below; lamina obscurely toothed; margins of petiole  
 meeting adaxially; twigs with two slight ridges on each side, and often with  
 scattered, white, raised dots . . . . . *S. cornifolia*  
 Leaves drying pale below; lamina obscurely toothed or entire; margins of petiole  
 open; twigs with or without ridges; without white dots . . . . . 25
25. Leaf margin obscurely toothed; twigs with two slight ridges on each side; phloem rings  
 continuous; wood outline deeply lobed; wood pores c. 0.2 mm diam. *S. cerasifera*  
 Leaf margin entire; twigs without ridges; phloem rings interrupted; wood outline  
 not lobed; wood pores c. 0.1 mm diam. . . . . *S. togoica*

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Scanning electron micrographs of lower leaf surface of (a) *Salacia luteritia* (GC 44175f) showing papillae (and also hyphae of phyllosphere fungi); and (b) *S. pyriformis* (GC 44878) showing smooth surface.