

Three Sorediate Species of the Genus *Usnea* (Parmeliaceae, Ascomycota) New to Taiwan

Yoshihito Ohmura¹, Chung-Kang Lin² and Pi-Han Wang³

¹ Department of Botany, National Museum of Nature and Science,
4–1–1 Amakubo, Tsukuba, Ibaraki 305–0005, Japan
E-mail: ohmura-y@kahaku.go.jp

² Department of Botany, National Museum of Natural Science, Taichung, 404, Taiwan
E-mail: kang@mail.nmns.edu.tw

³ Department of Life Sciences, Tunghai University, Taichung, 40704, Taiwan
E-mail: phwang@thu.edu.tw

Abstract. *Usnea bicolorata*, *U. hakonensis*, and *U. pycnoclada* are reported as new to Taiwan. Their morphology, chemistry, and ecological features are discussed.

Key words: flora, lichenized fungi, *Usnea*, secondary substances, soralia, taxonomy.

Introduction

The genus *Usnea* (Parmeliaceae, Ascomycota) consists of ca. 300 species, and is widely distributed from polar zones to tropical area (Kirk *et al.*, 2008). Diagnostic features of the genus include a fruticose thallus with a cortex, medulla, and a cartilaginous central axis, and the presence of usnic acid in the cortex. Monophyly of the genus has been confirmed by molecular phylogenetic methods using the taxa having these synapomorphic features (Articus, 2002; Ohmura, 2002; Ohmura & Kanda, 2004; Wirtz *et al.*, 2006), although Articus (2002) elevated several infrageneric groups to generic level (i.e., *Dolicousnea*, *Eumitria*, *Neuropogon*, and *Usnea*).

The *Usnea* flora of Taiwan was primarily summarized by Ohmura (2001) who revised the former studies in this area made by Zahlbruckner (1933), Motyka (1936–1938), and Asahina (1956, 1963, 1965a, 1965b, 1967a, 1967b, 1967c, 1967d, 1968a, 1968b, 1969a, 1969b, 1969c, 1969d, 1970, 1972a, 1972b). Subsequently two additional species and one variety were also reported from Taiwan (Aptroot *et al.*, 2002; Clerc, 2004). The total number of *Usnea* taxa in Taiwan is 35 species and one variety up to date.

In 2008, the first author carried out joint field surveys in Taiwan with the third author. In addition, the second author has collected ca. 400 specimens of Taiwanese *Usnea* during a period between 1990 and 2008. Some of these specimens are identified as *U. bicolorata* Motyka, *U. hakonensis* Asahina, and *U. pycnoclada* Vain., which had not been previously reported from Taiwan. The purpose of this study is to discuss their morphology, chemistry, and ecological feature, and to provide descriptions based on the Taiwanese materials.

Materials and Methods

This study is based on ca. 500 specimens of Taiwanese *Usnea* deposited in the herbaria of National Museum of Nature and Science, Tokyo, Japan (TNS) (ca. 100 specimens) and National Museum of Natural Science, Taichung, Taiwan (TNM) (ca. 400 specimens).

Morphological observations were made using a dissecting microscope or a bright field microscope. The diameter of branch was measured using a well-developed thicker branch. The ratios of thickness of the cortex, medulla, and axis for the branch were measured following the method

of Clerc (1984). The minimum-*average*-maximum values of them are shown in the description. Cross sections of thallus were cut by hand with a razor blade, and observed after mounting in GAW (glycerin: ethanol: water, 1 : 1 : 1).

Lichen substances were examined using thin layer chromatography (TLC) (Culberson & Johnson, 1982). Solvent B system (hexane: methyl tert-butyl ether: formic acid, 140: 72: 18) was used for all TLC analyses.

Results and Discussion

Usnea bicolorata Motyka, Lich. Gen. *Usnea* Stud. Monogr., Pars Syst. 2: 336, 1937. (Fig. 1)

Type: Africa centralis, in montibus Kivu, de Witte s. n. (herbarium, not traced).

Thallus fruticose, erect, up to 6 cm long, grayish green with reddish pigment in parts, jet black at the base; branching anisotomic-dichotomous; branches matt on the surface, lacking pseudocyphellae and maculae, terete, uninflated, gradually tapering, with many fibrils and lateral branches, 1.3–1.4–1.5 mm in diameter; lateral branches cylindrical at the base; papillae sparse, hemispherical; soralia common, formed mainly on lateral branches, developed from the top of eroded papillae, more or less discrete, rounded in shape or confluenting each other to form irregular mass of asexual propagules, larger than branch diameter, sessile to slightly stipitate, cortical margin reflexed as growing, concave at the top with granular soredia and rarely with isidiomorphs. **Cortex** 8.6–9.4–10.2% of the radius, *florida*-type plectenchymatous (see Ohmura, 2001); hyphae leptodermatous, secreting red pigment in the cell wall in part, with oblong lumina. **Medulla** dense, 24.2–28.6–32.9% of the radius, hyphae near the cortex thickened and secreting red pigment in the cell wall. **Axis** solid, 17.1–24.2–31.3% of the diameter, I–. **Apothecia** not seen.

Chemistry. Usnic, barbatic, protocetraric, and salazinic (\pm) acids.

The distinguishing features of *U. bicolorata*

are (1) erect thallus with anisotomic-dichotomous branching (Fig. 1a), (2) jet black base (Fig. 1b), (3) uninflated branches, (4) concave soralia with granular soredia and few isidiomorphs (Fig. 1c), (5) the presence of red pigment secreting in the hyphal cell wall in the medulla near the cortex [“subcortical” in Swinscow & Krog (1979)] (Fig. 1d & e), and (6) the presence of barbatic and protocetraric acids as major substances.

Although Motyka (1937) designated the type specimen of *U. bicolorata* in “Institut de Parc Nationaux Belges, Bruxelles”, Swinscow and Krog (1979) noted that the existence of type specimen could not be traced. We identified Taiwanese specimens as *U. bicolorata* following the description of Swinscow and Krog (1979).

Taiwanese specimens (Y. Ohmura 6099 and 6112) have the *florida*-type cortex which is seen in the sect. *Usnea* [e.g. *U. florida* (L.) F.H. Wigg.] (Fig. 1e). However, the subcortical red pigmentation in the medulla has never been known in the sect. *Usnea*. Further study based on molecular phylogenetic analysis is necessary to clarify the taxonomic position of this species.

Three chemical races have been known in this species: race 1, containing usnic, protocetraric, alectorialic (\pm), salazinic (\pm), and barbatic (\pm) acids; race 2, containing usnic, alectorialic, and barbatic acids; and race 3, containing usnic, norstictic, galbinic, and salazinic acids (Swinscow & Krog, 1979; Stevens, 1999). All Taiwanese specimens belong to the race 1. Stevens (1999) described *U. bicolorata* var. *australiensis* G. N. Stevens based mainly on the different chemistry (race 3) from *U. bicolorata* var. *bicolorata* (races 1 and 2). She also pointed out the consistent presence of isidiomorphs on soralia in *U. bicolorata* var. *australiensis*. Since chemistry and amount of isidiomorphs are variable in some species of the genus *Usnea*, the relationship between these taxa should be carefully examined in further study.

Usnea bicolorata resembles *U. fragilesceus* Lyngé, *U. fulvoviregens* (Räsänen) Räsänen, *U. glabrescens* (Vain.) Vain., and *U. wasmuthii* Räsänen in having a jet black base of thallus and

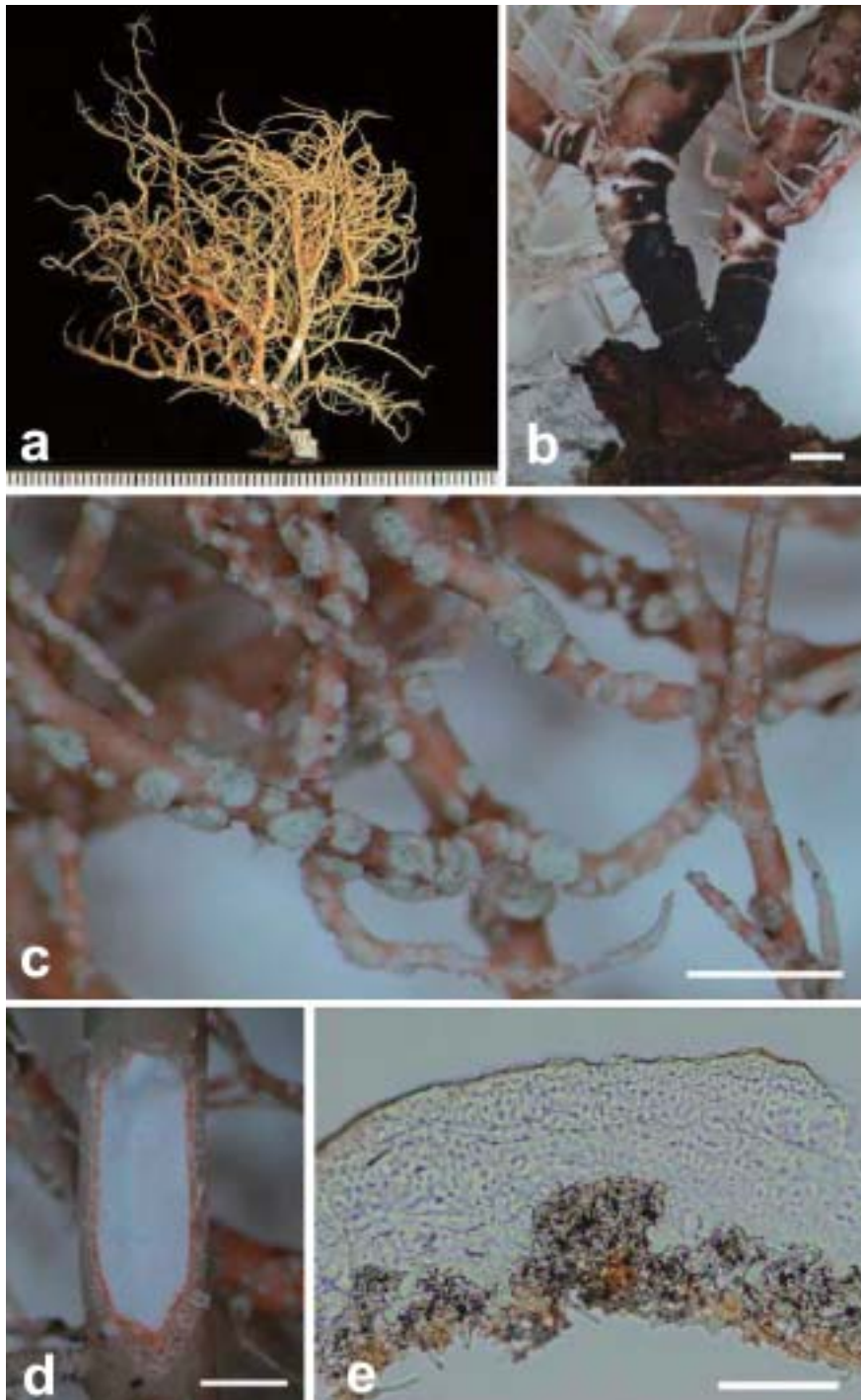


Fig. 1. Morphology of *Usnea bicolorata* (Y. Ohmura 6099, TNS). a, thallus. b, jet black base of thallus. c, concave soralia having granular soredia and few isidiomorphs. d, subcortical red pigment in the medulla. e, *flori-da*-type cortex. Scales=1 mm (a–d) and 100 μ m (e).

concave soralia with granular soredia. However, it is readily distinguished from them by the presence of subcortical red pigment in the medulla. It also resembles *U. dorogawensis* Asahina in having subcortical red pigment in the medulla, from which it can be distinguished by the uninflated branches, the jet black base of thallus, and the presence of protocetraric and barbatic acids. *Usnea bicolorata* may be confused with *U. rubicunda* Stirt. and *U. rubrotincta* Stirt. in having partly red pigmented thallus. However, the red pigmentation of *U. rubicunda* and *U. rubrotincta* occur in the cortex, while that of *U. bicolorata* occurs in subcortical part of medulla.

In Taiwan, *U. bicolorata* is found on bark of *Pinus* at elevation around 2600 m of Mt. Dasheue. This species has been also recorded from Africa and Australia (Motyka, 1936–1938; Swinscow and Krog, 1979; Stevens, 1999).

Specimens examined. Taiwan, Nantou Co., Mt. Dasheue, on bark of *Pinus* sp., elevation 2595 m, September 2, 2008, Y. Ohmura 6099 and 6112 (TNS, TNM).

Usnea hakonensis Asahina, Lich. Jpn. 3: 77, 1956. (Fig. 2)

Holotype: Japan, Honshu, Prov. Sagami, Hakone, lakeside of Ashinoko, July 15, 1952, M. Togashi s. n. (TNS!). Chemistry: usnic, norstictic, protocetraric, and salazinic acids, and unidentified substances (US1 and US2) (Ohmura, 2001).

Usnea hakonensis f. *inactiva* Asahina, Lich. Jpn. 3: 77, 1956. Lectotype: Japan, Honshu, Prov. Sagami, Hakone, Lakeside of Ashinoko, July 15, 1952, M. Togashi s. n. (TNS!). Chemistry: usnic acid and unidentified substances (US1 and US2) (Ohmura, 2001).

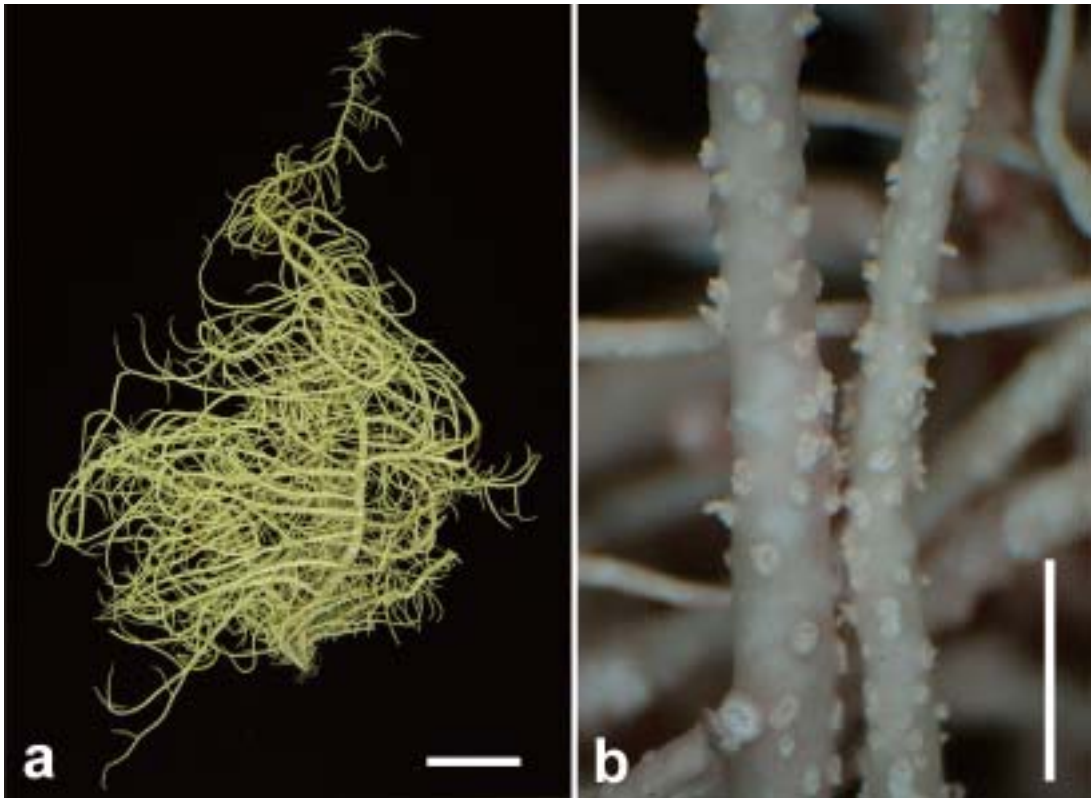


Fig. 2. Morphology of *Usnea hakonensis* (H. Kashiwadani 55009B1, TNS). a, thallus. b, soralia with isidomorphs. Scales=1 cm (a) and 1 mm (b).

Thallus fruticose, erect, up to 8 cm long, grayish green when fresh, chestnut brown in herbarium specimen, concolorous with thallus or black at the base; branching anisotomic-dichotomous; branches glossy on the surface, lacking pseudocypbellae and maculae, terete, inflated, gradually tapering, with many fibrils and lateral branches, 0.7–1.1–1.6 mm in diameter; lateral branches constricted at the base; papillae sparse or absent, hemispherical to verrucose; soralia common, formed mainly on lateral branches, developed from the top of eroded papillae, more or less discrete, rounded, smaller than branch diameter, sessile to distinctly stipitate, cortical margin not reflexed, convex at the top often with many isidiomorphs, lacking granular soredia. **Cortex** 6.8–9.9–11.4% of the radius, *ceratina*-type plectenchymatous; hyphae pachydermatous, lacking red pigment, with oblong or turbinate lumina. **Medulla** lax to moderate in density, 22.9–29.0–34.5 % of the radius, lacking red pigment. **Axis** solid, 17.6–22.4–31.4% of the diameter, I–. **Apothecia** not seen.

Chemistry. Usnic and norstictic acids, US1 (Rf class 2, lower than salazinic acid), and US2 (Rf class 2, higher than salazinic acid) (see Ohmura, 2001).

The distinguishing features of *U. hakonensis* are (1) erect thallus with anisotomic-dichotomous branching (Fig. 2a), (2) inflated branches which are glossy on the surface and with few papillae, (3) rounded soralia which are convex at the top often with many isidiomorphs (Fig. 2b), and (4) the presence of unidentified substances (US1 and US2) as major substances.

Two chemical races have been known in this species: race 1, containing usnic, norstictic acids, US1, US2, salazinic (\pm), protocetraric (\pm) acids, and atranorin (\pm); and race 2, containing usnic acid, US1, US2, and atranorin (\pm). All Taiwanese specimens belong to the race 1.

Usnea hakonensis resembles *U. cornuta* Krb., *U. dasaea* Stirt., and *U. pygmoidea* (Asahina) Y. Ohmura very much in having the inflated branches with round soralia which are less than branch diameter. However, it is distinguished from them

by the presence of unidentified substances (US1 and US2).

Usnea hakonensis has been known only from Japan so far (Ohmura, 2001). The distribution now includes Taiwan, where it grows on bark of *Pinus* and *Prunus* at elevation around 2000 m.

Specimens examined. Taiwan. Taichung Co.: Tashueshan Forest Park, Hopen, elevation about 2000 m, October 28, 2008, H. Kashiwadani 55008 (on decayed wood) and 55009B1 (on bark of *Prunus* sp.) (TNS). Nantou Co.: Haitienshih, Tantalindao of Hsini, on trunk of *Pinus* sp., elevation 2210 m, September 25, 1993, C. K. Lin 3305 (TNM).

Usnea pycnoclada Vain., Philipp. J. Sci. 4: 653, 1909. (Fig. 3)

Lectotype (selected here): Philippines, Luzon, Prov. Laguna, Mt. Banajao, Nov. 1907, H. M. Curran and M. L. Merritt, 8000 (TUR-V 833!). Chemistry: usnic, barbatic, and protocetraric acids (annotated by Drs. G. N. Stevens and P. Clerc).

Thallus fruticose, erect, up to 3 cm long, grayish-green when fresh, jet black at the base; branching anisotomic-dichotomous; branches slightly glossy on the surface, lacking pseudocypbellae and maculae, terete, inflated, tapering only near the apices, with many fibrils and lateral branches, 0.7–1.1–1.4 mm in diam.; lateral branches constricted at the base often with exposed medulla of the crack to form white annular rings; papillae sparse to common, hemispherical; soralia common, formed mainly on lateral branches, developed from the top of eroded papillae, more or less discrete, rounded in shape or confluent each other to form irregular mass of asexual propagules, larger than branch diam., distinctly stipitate, cortical margin reflexed, convex at the top often with isidiomorphs or rarely concave with granular soredia. **Cortex** 6.7–7.8–9.8% of the radius, *ceratina*-type plectenchymatous; hyphae pachydermatous, lacking red pigment, with oblong or turbinate lumina. **Medulla** lax, 23.2–28.1–31.5% of the radius, lacking red pigment. **Axis** solid, 23.1–28.3–34.1% of the di-

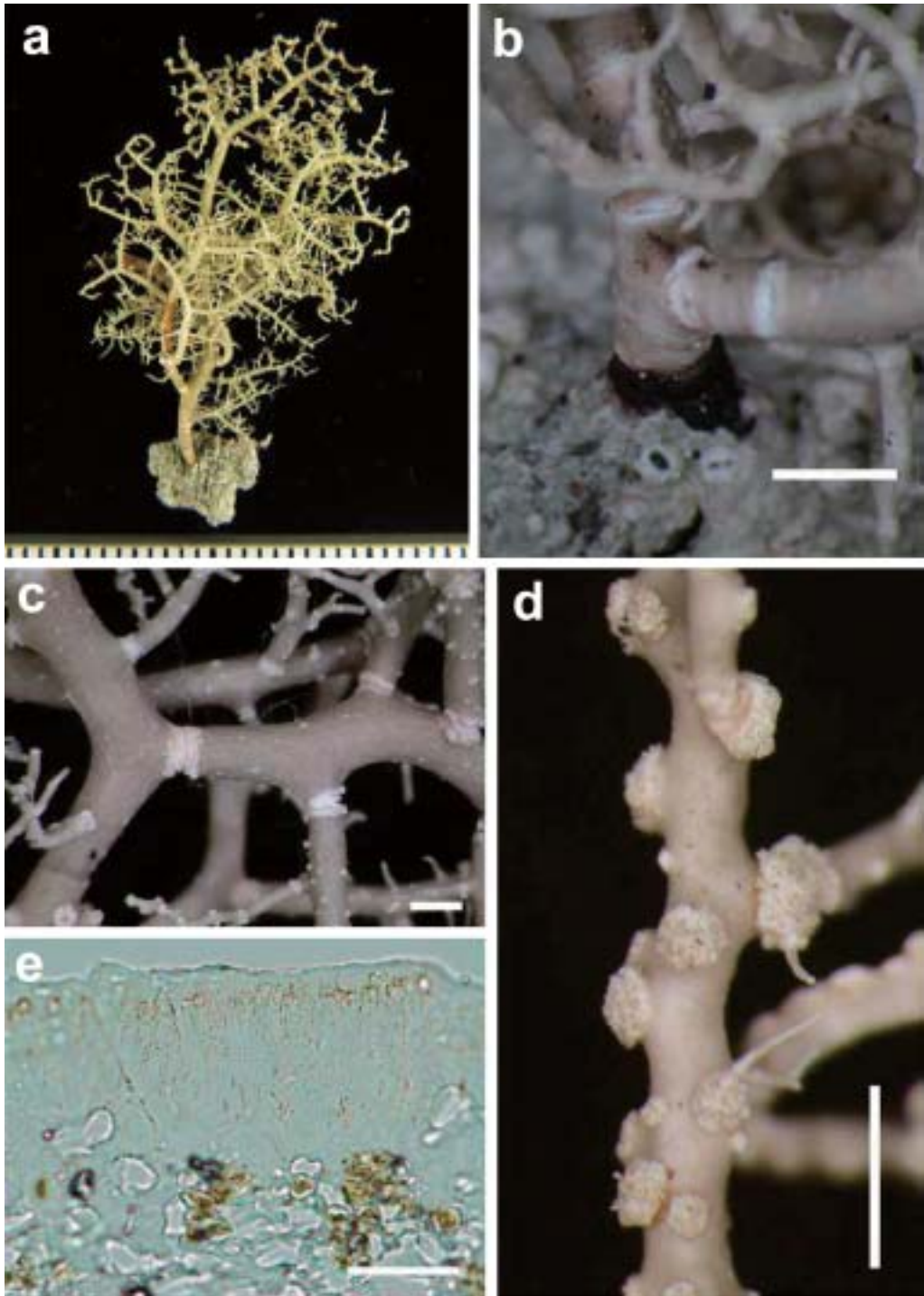


Fig. 3. Morphology of *Usnea pycnoclada*. a, thallus. b, jet black base of thallus. c, inflated branches with white annular rings. d, convex soralia which are distinctly stipitate. e, *ceratina*-type plectenchymatous cortex. (a, Y. Ohmura 6113, TNS; b, Y. Ohmura 6054B, TNS; c–e, Y. Ohmura 6054A, TNS). Scales=1 mm (a–d) and 50 μ m (e).

ameter, I–. **Apothecia** not seen.

Chemistry. Usnic, barbatic, protocetraric, and 4-*O*-demethylbarbatic (\pm) acids.

The distinguishing features of *U. pycnoclada* are (1) erect thallus with anisotomic-dichotomous branching (Fig. 3a), (2) jet black base of thallus (Fig. 3b), (3) inflated branches which are constricted at the base often with exposed medulla of the crack to form white annular rings (Fig. 3c), (4) convex soralia which are larger than branch diameter and distinctly stipitate (Fig. 3d), (5) the *ceratina*-type plectenchymatous cortex (Fig. 3e), and (6) the presence of barbatic and protocetraric acids as major substances.

When Wainio (1909) described *U. pycnoclada*, he cited two specimens in the protologue (H. M. Curran and M. L. Merritt 7999 and 8000). Only one specimen (no. 8000) is found in the herbarium of TUR-V while the other (no. 7999) is missing from the packet. The specimen of no. 8000 (TUR-V 833) agrees well with the protologue, and should be designated here as the lectotype according to Art. 9.2 of ICBN Vienna Code (McNeill et al., 2006).

Four chemical races have been known in this species: race 1, containing usnic, protocetraric, and barbatic acids; race 2, containing usnic, psoromic, and consporomic acid; race 3, containing usnic, barbatic, and psoromic acids; and race 4, containing usnic, norstictic, and stictic acids (Stevens, 1999). All Taiwanese specimens belong to the race 1.

Usnea pycnoclada resembles *U. dorogawensis* and *U. glabrata* (Ach.) Vain. in having inflated branches and stipitate soralia which are larger than branch diameter. However, it is distinguished from *U. dorogawensis* by the absence of red pigment, and from *U. glabrata* by the convex soralia.

In Taiwan, *U. pycnoclada* is found on bark of *Pinus* at elevation 2200 to 2600 m. This species has been also recorded from Philippine, China (Prov. Yunnan), and Australia (Motyka, 1936–1938; Stevens, 1999).

Specimens examined. Taiwan. Nantou Co.: Mt. Dasheue, on bark of *Pinus* sp., elevation

2595 m, September 2, 2008, Y. Ohmura 6054A, 6054B, 6079, and 6113 (TNS, TNM); Nantzusienci, on trunk of *Pinus* sp., elevation 2250 m, October 14, 1993, S. Z. Chen 113 (TNM). Philippines. Luzon, Prov. Mountain, summit of Mt. Data, mossy oak forest, elevation about 2300 m, 1964, M. E. Hale and J. Banaag 25973 pr. p. (TNS).

Acknowledgements

We wish to express our thanks to Mr. M. H. Kao for his help during field surveys and Dr. H. Kashiwadani for providing valuable advice for this manuscript. This study was conducted as a part of research project “Biodiversity inventory in the Western Pacific region” organized by the National Museum of Nature and Science, and partly funded by the Grant-in-Aid for Young Scientists (B) of the Japan Society for the Promotion of Science (no. 21770097).

References

- Aptroot, A., L. B. Sparrius & M.-J. Lai, 2002. New Taiwan macrolichens. *Mycotaxon*, 84: 281–292.
- Articus, K., 2002. *Neuropogon* and the phylogeny of *Usnea* s. l. (Parmeliaceae, Lichenized Ascomycetes). *Taxon*, 53: 925–934.
- Asahina, Y., 1956. Lichens of Japan, vol. 3, genus *Usnea*. Research Institute for Natural Resources Shinjuku, Tokyo.
- Asahina, Y., 1963. Lichenologische notizen (§192). *Journal of Japanese Botany*, 38: 257–260.
- Asahina, Y., 1965a. Lichenologische notizen (§197). *Journal of Japanese Botany*, 40: 129–133.
- Asahina, Y., 1965b. Lichenologische notizen (§200). *Journal of Japanese Botany*, 40: 225–227.
- Asahina, Y., 1967a. Lichenologische notizen (§203). *Journal of Japanese Botany*, 42: 1–9.
- Asahina, Y., 1967b. Lichenologische notizen (§204). *Journal of Japanese Botany*, 42: 257–260, pl. V.
- Asahina, Y., 1967c. Lichenologische notizen (§205). *Journal of Japanese Botany*, 42: 289–294.
- Asahina, Y., 1967d. Lichenologische notizen (§206). *Journal of Japanese Botany*, 42: 321–326.
- Asahina, Y., 1968a. Lichenologische notizen (§§207–208). *Journal of Japanese Botany*, 43: 65–68.
- Asahina, Y., 1968b. Lichenologische notizen (§§211–212). *Journal of Japanese Botany*, 43: 495–498, pl.

XXIV.

- Asahina, Y., 1969a. Lichenologische notizen (§§213–214). *Journal of Japanese Botany*, 44: 1–5, pl. I–IV.
- Asahina, Y., 1969b. Lichenologische notizen (§§215–216). *Journal of Japanese Botany*, 44: 33–39, pl. V–VII.
- Asahina, Y., 1969c. Lichenologische notizen (§§217–222). *Journal of Japanese Botany*, 44: 257–269.
- Asahina, Y., 1969d. Lichenologische notizen (§§223–225). *Journal of Japanese Botany*, 44: 353–360.
- Asahina, Y., 1970. Lichenologische Notizen (§235). *Journal of Japanese Botany*, 45: 129–133, pl. IV–VI.
- Asahina, Y., 1972a. Lichenologische Notizen (§§248–250). *Journal of Japanese Botany*, 47: 129–135.
- Asahina, Y., 1972b. Lichenologische Notizen (§251). *Journal of Japanese Botany*, 47: 257–260.
- Clerc, P., 1984. Contribution à la revision de la systématique des usnées (Ascomycotina, *Usnea*) d'Europe. I.—*Usnea florida* (L.) Wigg. emend. Clerc. *Cryptogamie Bryologie et Lichénologie*, 5: 333–360.
- Clerc, P., 2004. Notes on the genus *Usnea* Adanson. II. *Bibliotheca Lichenologica*, 88: 79–80.
- Culberson, C. F. & A. Johnson, 1982. Substitution of methyl tert.-butyl ether for diethyl ether in the standardized thin-layer chromatographic method for lichen products. *Journal of Chromatography*, 238: 483–487.
- Kirk, P. M., P. F. Cannon, D. W. Minter & J. A. Stalpers, 2008. Dictionary of the fungi, 10th edition. CAB International, Wallingford.
- McNeill, J., Barrie, F. R., Burdet, H. M., Demoulin, V., Hawksworth, D. L., Marhold, K., Nicolson, D. H., Prado, J., Silva, P. C., Skog, J. E., Wiersema J. H. & Turland, N. J. (eds.), 2006. International Code of Botanical Nomenclature (Vienna Code). Adopted by the Seventeenth International Botanical Congress Vienna, Austria, July 2005. Regnum Vegetabile 146. A. R. G. Gantner Verlag, Ruggell, Liechtenstein.
- Motyka, J., 1936–1938. Lichenum generis *Usnea* studium monographicum, Pars Systematica. Leopoli.
- Ohmura, Y., 2001. Taxonomic study of the genus *Usnea* (lichenized Ascomycetes) in Japan and Taiwan. *Journal of Hattori Botanical Laboratory*, 90: 1–96.
- Ohmura, Y., 2002. Phylogenetic evaluation of infrageneric groups of the genus *Usnea* based on ITS regions in rDNA. *Journal of Hattori Botanical Laboratory*, 92: 231–243.
- Ohmura, Y. & H. Kanda, 2004. Taxonomic status of section *Neuropogon* in the genus *Usnea* elucidated by morphological comparisons and ITS rDNA sequences. *Lichenologist*, 36: 217–225.
- Stevens, G. N., 1999. A revision of the lichen family Usneaceae in Australia. *Bibliotheca Lichenologica*, 72: 1–128.
- Swinscow, T. D. V. & H. Krog, 1979. The fruticose species of *Usnea* subgenus *Usnea* in east Africa. *Lichenologist*, 11: 207–252.
- Wainio, E. A., 1909. Lichenes insularum Philippinarum, I. *Philippine Journal of Science*, 4: 651–663.
- Wirtz, N., C. Printzen, L.G. Sancho & T. Lumbsch, 2006. The phylogeny and classification of *Neuropogon* and *Usnea* (Parmeliaceae, Ascomycota) revisited. *Taxon*, 55: 367–376.
- Zahlbruckner, A. 1933. Flechten der Insel Formosa (Fortsetzung und Schluß). *Feddes Repertorium specierum novarum regni vegetabilis* 33: 22–68.

台湾新産の粉芽を有するサルオガセ属 (ウメノキゴケ科, 子囊菌門) 3種

大村嘉人・林 仲剛・汪 碧涵

台湾産サルオガセ属の約500点の標本を検討した結果, *Usnea bicolorata* (ウチベニサルオガセ, 新称), *U. hakonensis* (ハコネサルオガセ), *U. pycnoclada* (コナフシサルオガセ, 新称) が本地域に産することが明らかとなった。ウチベニサルオガセは, 地衣体が灌木状で基部が黒色, 枝は膨らまず, 顆粒状の粉芽とわずかな裂芽状突起を伴う凹状の粉芽塊を持つ。地衣体内髄層部の皮層側に赤色色素があり, 髄層の化学成分にバルバチン酸, プロトセトラー酸を含む。本種はこれまでにアフリカとオーストラリアに分布していることが知られていた。ハコネサルオガセは, 地衣体が灌木状で基部が他の部位と同色または黒色。枝は膨らみ, 表面には光沢があり, わずかに乳頭状突起を伴う。粉芽塊は円形, 凸状で, 多数の裂芽状突起を伴う。髄層成分に未同定物質 (US1, US2) を含む。本種は日本からのみ知られていた。コナフシサルオガセは, 地衣体が灌木状で基部が黒色, 枝が膨らみ, 枝の節部は露出した髄層によってしばしば白い環状構造となる。粉芽塊は凸状で枝の直径よりも大きくなり, 粉芽塊の基部は枝表面から顕著に突出する。皮層組織は *Ceratina* タイプ。髄層成分にバルバチン酸とプロトセトラー酸を含む。本種はこれまでにフィリピン, 中国 (雲南省), オーストラリアから報告されていた。