Phytotaxa 181 (2): 096–109
www.mapress.com/phytotaxa/

Article

ISSN 1179-3155 (print edition)
PHYTOTAXA
ISSN 1179-3163 (online edition)

http://dx.doi.org/10.11646/phytotaxa.181.2.3

Overview of *Xanthoparmelia* taxa from South Korea including the description of two new species (Parmeliaceae, Ascomycota)

UDENI JAYALAL[1], PRADEEP K. DIVAKAR[2], SANTOSH JOSHI[1], SOON OK OH[1], JUNG A KIM[1] & JAE-SEOUN HUR[1,3]

[1]*Korean Lichen Research Institute, Sunchon National University, Sunchon 540–742, Korea*
[2]*Departamento de Biología Vegetal II, Facultad de Farmacia, Universidad Complutense de Madrid, Plaza de Ramón y Cajal s/n, 28040 Madrid, Spain*
[3]*Author for correspondence, email:jshur1@sunchon.ac.kr*

Abstract

In the genus *Xanthoparmelia*, species boundaries are based on morphological and chemical features such as the presence and/or absence of secondary metabolites, diagnostic reproductive structures, isidia morphology, and color of lower surface. Two new species of *Xanthoparmelia* are described from South Korea, *X. kolriana* with cylindrical isidia containing atranorin and salazinic acid as major components in the medulla together with cortical usnic acid, while *X. volcanicola* is characterised by a red coloured medulla, and subglobose isidia. The characteristics of *Xanthoparmelia* species and their distribution in South Korea are outlined and an identification key given. Additionally, we used ITS ribosomal DNA sequences to assess the monophyly of *Xanthoparmelia* species from South Korea. Our results reveal that traditionally circumscribed species were not recovered as monophyletic clades. Further, we here show that ITS is insufficient to estimate a well-supported phylogenetic hypothesis, but suggests that traditional taxonomy may not reflect natural groups. This communication provides an important framework for future studies assessing species boundaries in *Xanthoparmelia* species in South Korea.

Key words: ITS rDNA, molecular phylogeny, new species, endemic species, character distribution, pigmented medulla, volcanic rock

Introduction

The genus *Xanthoparmelia* belongs to the large family Parmeliaceae (Crespo *et al.* 2010, Eriksson *et al.* 2004, Lumbsch & Huhndorf 2007), with over 800 accepted species world-wide (Blanco *et al*. 2004). Of these at least 600 species have a yellow green upper surface and contain cortical usnic or isousnic acids (Blanco *et al.* 2005). The first synopsis of *Xanthoparmelia* was published by Hale in 1990. This synopsis included 406 species mainly from South Africa and Australia region. Subsequently many additional species have been recognized in Australasia (Elix 2003a, 2007, Elix *et al.* 1986, 2000, Elix & Kantvilas 2009, Galloway 2007), South Africa (Nash & Elix 1987, Elix 1999, 2002), North America (Nash & Elix 2004), South America (Nash *et al.* 1995, Eliasaro & Adler 2002) and Asia (Divakar & Upreti 2005, Kurokawa 1989a, 1989b, 1989c, Sharma & Kurokawa 1990).

Early molecular studies carried out by Crespo *et al.* (2001) revealed that species from the genera *Xanthoparmelia*, *Neofuscelia*, *Paraparmelia* and *Chondropsis* were recovered together within a single large clade. On the basis of these findings, the older generic name of *Chondropsis* was transferred to the genus *Xanthoparmelia* by Hawksworth and Crespo (2002). Subsequently, also the genera *Almbornia, Karoowia, Namakwa, Neofuscelia, Omphalodiella, Paraparmelia, Placoparmelia* and *Xanthomaculina* were synonymized with *Xanthoparmelia* (Elix 2003b, Blanco *et al.* 2004, Thell *et al*. 2006, Amo de Paz *et al*. 2010 a, b).

Although *Xanthoparmelia* species occur commonly throughout Asia, specimens from Asia have been poorly represented in molecular phylogenetic analyses to date. Twenty-eight *Xanthoparmelia* species have been recorded for China, including Hong Kong (Wei 1991, Aptroot & Sipman 2001), nine for Japan (Harada *et al.* 2004), two for Thailand (Wolseley *et al*. 2002) and three species for Taiwan (Wei 1991). *Xanthoparmelia* is particularly well represented in the Korean Peninsula, while only three species have been recorded for North Korea, including *X. subramigera* (Gyeln.)

 Accepted by Thorsten Lumbsch: 27 Aug. 2014; published: 1 Oct. 2014

Acknowledgments

We thank Jack Elix for valuable advice and comments on HPLC chromatograms, Ms. Min-Hye Jeong for the HPLC analysis and Ms. Jung Shin Park for providing data on some localities. We also thank two anonymous reviewers for valuable comments and suggestions that improved the manuscript. This work was supported by a grant from the Korean National Research Resource Center Program (NRF-2014M3A9B8002115), and the Korean Forest Service Program (KNA 2014) through the Korea National Arboretum. PKD thanks the Spanish Ministerio de Ciencia e Innovación (CGL2010-21646/BOS) and Comunidad Autónoma de Madrid (REMEDINAL S-2009/AMB-1783) for financial support.

References

Ahti, T., Brodo, I.M. & Noble, W.J. (1987) Contributions to the lichen flora of British Columbia, Canada. *Mycotaxon* 28: 91–97.

Ahti, T. & Hawksworth, D.L. (2005) *Xanthoparmelia stenophylla*, the correct name for *X. somloënsis*, one of the most widespread usnic acid containing species of the genus. *Lichenologist* 37: 363–366. http://dx.doi.org/10.1017/s0024282905015197

Akaike, H. (1974) A new look at the statistical model identification. *IEEE Transactions on Automatic Control* 19: 716–723. http://dx.doi.org/10.1109/TAC.1974.1100705

Amo de Paz, G., Crespo, A., Elix, J.A. & Lumbsch, H.T. (2010a) Additional morphological diversity in *Xanthoparmelia*: *Placoparmelia* and *Omphalodiella* belong to this monophyletic clade. *Bryologist* 113: 376–386. http://dx.doi.org/10.1639/0007-2745-113.2.376

Amo de Paz, G., Elix, J.A., Blanco, O., Lumbsch, H.T. & Crespo, A. (2010b) The genus *Karoowia* (Parmeliaceae, Ascomycota) includes unrelated clades nested within *Xanthoparmelia*. *Australian Systematic Botany* 23: 173–184.

Aptroot, A. & Sipman, H.J.M. (2001) New Hong Kong lichens, ascomycetes and lichenicolous fungi. *Journal of the Hattori Botanical Laboratory* 91: 317–343.

Blanco, O., Crespo, A. & Elix, J.A. (2005) Two new species of *Xanthoparmelia* (Ascomycota: *Parmeliaceae*) from Spain. *Lichenologist* 37: 97–100. http://dx.doi.org/10.1017/S0024282905014829

Blanco, O., Crespo, A., Elix, J.A., Hawksworth, D.L. & Lumbsch, H.T. (2004) A molecular phylogeny and a new classification of parmelioid lichens containing *Xanthoparmelia*–type lichenan (Ascomycota: Lecanorales). *Taxon* 53: 959–975. http://dx.doi.org/10.2307/4135563

Cho, S. & Lee, Y.N. (1980) Studies on Parmeliae in Mt. Deokyoo Area. *Korean Journal of Mycology* 8: 149–157.

Crespo A., Blanko, O. & Hawksworth, D.L. (2001) The potential of mitochondrial DNA for establishing phylogeny and stabilizing generic concepts in the parmeloid lichens. *Taxon* 50: 807–819. http://dx.doi.org/10.2307/1223708

Crespo, A., Divakar, P.K. & Hawksworth, D.L. (2011) Generic concepts in parmelioid lichens, and the phylogenetic value of characters used in their circumscription. *Lichenologist* 43: 511–535. http://dx.doi.org/10.1017/S0024282911000570

Crespo, A., Kauff, F., Divakar, P.K., Prado, R.D., Pérez-Ortega, S., Amo, G., Ferencova, Z., Blanco, O., Roca-Valiente, B., Núñez-Zapata, J., Cubas, P., Argüello, A., Elix, J.A., Esslinger, T.L., Hawksworth, D.L., Millanes, A., Molina M.C., Wedin, M., Ahti, T., Aptroot, A., Barreno, E., Bungartz, F., Calvelo, S., Candan, M., Cole, M., Ertz, D., Goffinet, B., Lindblom, L., Lücking, R., Lutzoni, F., Mattsson, J.E., Messuti, M.I., Miadlikowska, J., Piercey-Normore, M., Rico, V.J., Sipman, H.J.M., Schmitt, I., Spribille, T., Thell, A., Thor, G., Upreti, D.K. & Lumbsch, H.T. (2010) Phylogenetic generic classification of parmelioid lichens (Parmeliaceae, Ascomycota) based on molecular, morphological and chemical evidence. *Taxon* 59: 1735–1753.

Divakar, P.K. & Upreti, D.K. (2005) *Parmelioid lichens in India (A revisionary study)*. Bishen Singh Mahendra Pal Singh, India.

Ekman, S. (1999) PCR optimization and troubleshooting, with special reference to the amplification of ribosomal DNA in lichenized fungi. *Lichenologist* 31: 517–531. http://dx.doi.org/10.1017/s0024282999000675

Eliasaro, S. & Adler, M. (2002) *Flavoparmelia* and *Xanthoparmelia* (Parmeliaceae, lichenized Ascomycotina) of the Segundo Planalto of Paraná (Brazil). *Mitteilungen aus dem Institut für Allgemeine Botanik in Hamburg* 30–32: 25–34.

Elix, J.A. (1994) *Xanthoparmelia*. *Flora of Australia* 55: 201–308.

Elix, J.A. (1997) Further new species in the lichen family Parmeliaceae (Ascomycotina) from Australasia. *Mycotaxon* 65: 481–492.

Elix, J.A. (1999) New species of *Xanthoparmelia* (lichenized Ascomycotina, Parmeliaceae) from South Africa. *Mycotaxon* 73: 51–61.

http://dx.doi.org/10.1006/lich.2002.0383
Elix, J.A. (2002) New species of *Xanthoparmelia* (lichenized Ascomycotina, Parmeliaceae) from Africa. *Lichenologist* 34: 283–291. http://dx.doi.org/10.1006/lich.2002.0383
Elix, J.A. (2003a) New species and new records of *Xanthoparmelia* (lichenized Ascomycota, Parmeliaceae) from Western Australia. *Lichenologist* 35: 291–299. http://dx.doi.org/10.1016/s0024-2829(03)00040-9
Elix, J.A. (2003b) The lichen genus *Paraparmelia*, a synonym of *Xanthoparmelia* (Ascomycota, Parmeliaceae). *Mycotaxon* 87: 395–403.
Elix, J.A. (2007) A new species of *Xanthoparmelia* (Parmeliaceae, lichenized Ascomycota) from Australia. *Australasian Lichenology* 61: 30–31.
Elix, J.A., Johnston, J. & Armstrong, P.M. (1986) A revision of the lichen genus *Xanthoparmelia* in Australasia. *Bulletin of the British Museum (Natural History, Botany)* 15: 1–192.
Elix, J.A. & Kantvilas, G. (2009) Further new species of *Xanthoparmelia* (Parmeliaceae, Ascomycota) from Tasmania. *Bibliotheca Lichenologica* 99: 123–132.
Elix, J.A., Louwhoff, S.H.J.J. & Molina, M.C. (2000) Two new species of *Xanthoparmelia* (lichenized Ascomycotina, Parmeliaceae) from Australia containing norlobaridone. *Mycotaxon* 74: 499–503.
Eriksson, O.E., Baral, H.O., Currah, R.S., Hansen, K., Kurtzman, C.P., Rambold, G. & Laessøe, T. (2004) Outline of Ascomycota–2004. *Myconet* 10: 1–99.
Galloway, D.J. (2007) *Xanthoparmelia*. Flora of New Zealand: Lichens. Rev. 2nd ed. pp. 1896–1972.
Gardes, M. & Bruns, T.D. (1993) ITS primers with enhanced specificity for basidiomycetes. Applications for the identification of mycorrhizae and rusts. *Molecular Ecology* 2: 113–118. http://dx.doi.org/10.1111/j.1365-294x.1993.tb00005.x
Gutierrez, G., Blanco, O., Divakar, P.K., Lumbsch, H.T. & Crespo, A. (2007) Patterns of group I intron presence in nuclear SSU rDNA of the lichen family Parmeliaceae. *Journal of Molecular Evolution* 64: 181–195. http://dx.doi.org/10.1007/s00239-005-0313-y
Hale, M.E. (1974) *Bulbothrix*, *Parmelina*, *Relicina*, and *Xanthoparmelia*, four new genera in the Parmeliaceae. *Phytologia* 28: 479–490.
Hale M.E. (1987) Additions to the *Xanthoparmelia* Flora of Southern Africa (Lichenized Ascomycotina: Parmeliaceae). *Mycotaxon* 29: 251–266.
Hale, M.E. (1988) New Combinations in the Lichen Genus *Xanthoparmelia* (Ascomycotina). *Mycotaxon* 33: 401–406.
Hale, M.E. (1990) A Synopsis of the Lichen Genus *Xanthoparmelia* (Vainio) Hale (Ascomycotina, Parmeliaceae). *Smithsonian Contribution to Botany* 74: 1–241. http://dx.doi.org/10.5479/si.0081024x.74
Harada, H., Okamoto, T. & Yoshimura, I. (2004) A checklist of lichens and lichen–allies of Japan. *Lichenology* 2: 124–125.
Hawksworth, D.L. & Crespo, A. (2002) Proposal to conserve the name *Xanthoparmelia* against *Chondropsis* nom. Cons. (Parmeliaceae). *Taxon* 51:807. http://dx.doi.org/10.2307/1555046
Huelsenbeck, J.P. & Ronquist, F. (2001) MRBAYES: Bayesian inference of phylogenetic trees. *Bioinformatics* 17: 754–755. http://dx.doi.org/10.1093/bioinformatics/17.8.754
Huneck, S., Ri, J.D., Ahti, T. & Poelt, J. (1989) Zur Kenntnis der Flechtenflora von Korea. *Herzogia* 8: 177–185.
Hur, J.S., Koh, Y.J. & Harada, H. (2005) A checklist of Korean lichens. *Lichenology* 4: 91.
Jeon, H.S., Koh, Y.J. Lökös, L., Lee, Y.M., Byun, B.K. & Hur, J.S. (2009) Report on the lichen list of North Korea. *Korean Journal of Mycology* 37: 1–10.
Katoh, K. & Toh, H. (2008) Recent developments in the MAFFT multiple sequence alignment program. *Brief Bioinformatics* 9: 286–298. http://dx.doi.org/10.1093/bib/bbn013
Ko, M.J. (1992) *A taxonomic study of family Parmeliaceae and Physciaceae (lichens) in Mt. Chiri*. Thesis. Sookmyung Women's University, Seoul, Korea.
Krempelhuber, A. (1878) Lichenes, collecti in republica Argentina a Doctoribus Laentz et Hiemymus. *Flora* 61: 433–439.
Kurokawa, S. (1989a) Studies on Japanese species of *Xanthoparmelia* (Parmeliaceae) (1). *Journal of Japanese Botany* 64: 165–175.
Kurokawa, S. (1989b) Studies on Japanese species of *Xanthoparmelia* (Parmeliaceae) (2). *Journal of Japanese Botany* 64: 289–298.
Kurokawa, S. (1989c) New or noteworthy species of *Xanthoparmelia* (Parmeliaceae). *Annals of the Tsukuba Botanical Garden* 6: 21–25.
Kurokawa, S. (1991) Japanese species and genera of the Parmeliaceae. *Journal of Japanese Botany* 66: 152–159.
Leavitt, S.D., Johnson, L. & St Clair, L.L. (2011) Species delimitation and evolution in morphologically and chemically diverse communities of the lichen-forming genus *Xanthoparmelia* (Parmeliaceae, Ascomycota) in western North America. *American Journal of Botany* 98: 175–188. http://dx.doi.org/10.3732/ajb.1000230

Leavitt, S.D., Lumbsch, H.T.. Stenroos, S. & Clair, L.L. (2013) Pleistocene Speciation in North American Lichenized Fungi and the Impact of Alternative Species Circumscriptions and Rates of Molecular Evolution on Divergence Estimates. *PLoS ONE* 8(12): e85240. http://dx.doi.org/10.1371/journal.pone.0085240

Lim, K.M., Yamamoto, Y. Harada, H., Lee, Y.M., Koh, Y.J. & Hur, J.S. (2006) New record of *Karoowia saxeti* (Stizenb.) Hale in South Korea. *Mycobiology* 34: 148–150. http://dx.doi.org/10.4489/MYCO.2006.34.3.148

Lumbsch, H.T. & Huhndorf, S.M. (Ed.) (2007) Outline of Ascomycota – 2007. *Myconet* 13: 1–58.

Moon, K.H. (1999) Lichens of Mt. Sorak in Korea. *Journal of the Hattori Botanical Laboratory* 86: 187–220.

Nash III, T.H. & Elix, J.A. (2004) *Xanthoparmelia*. *In*: Nash III, T.H.; Ryan, B.D., Diederich, P., Gries, C., Bungartz, F. (Eds). *Lichen flora of the greater Sonaran Desert region*. Vol. II. Tempe, AZ, Lichens unlimited, Arizona State University. pp. 566–605.

Nash III, T.H., Gries, C. & Elix, J.A. (1995) A Revision of the Lichen Genus *Xanthoparmelia* in South America. *Bibliotheca Lichenologica* 56: 1–157.

Nash III, T.H. & Elix, J.A. (1987) New species and new reports in the Parmeliaceae (lichenized Ascomycotina) from South Africa and Australia. *Mycotaxon* 29: 467–476.

Nylander, J.A.A., Wilgenbusch, J.C., Warren, D.L. & Swofford, D.L. (2007) AWTY (Are We There Yet?): a system for graphical exploration of MCMC convergence in Bayesian phylogenetics. *Bioinformatics* 24: 581–583. http://dx.doi.org/10.1093/bioinformatics/btm388

Orange, A, James, P.W. & White, F.J. (2010) *Microchemical methods for the identification of lichens.* 2nd ed. London: British Lichen Society. pp. 1–101.

Park, Y.S. (1990) The macrolichen flora of South Korea. *Bryologist* 93: 130–131. http://dx.doi.org/10.2307/3243619

Posada, D. (2008) JModelTest: phylogenetic model averaging. *Molecular Biology and Evolution* 25: 1253–1256. http://dx.doi.org/10.1093/molbev/msn083

Rambaut, A. (2009) FigTree 1.2.2 [computer program]. Website http:// tree.bio.ed.ac.uk/software/figtree/.

Schoch, C.L., Seifert, K.A., Huhndorf, S., Robert, V., Spouge, J.L., Levesque, C.A., Chen, W. & Fungal Barcoding Consortium (2012) ribosomal internal transcribed spacer (ITS) region as a universal DNA barcode marker for Fungi. *Proceedings of the National Academy of Sciences* 109: 6241–6246. http://dx.doi.org/10.1073/pnas.1117018109

Sharma, L.R. & Kurokawa, S. (1990) Species of *Xanthoparmelia* in Nepal. *Journal of Japanese Botany* 65: 58–60.

Stamatakis, A. (2006) RAxML-VI-HPC: maximum likelihood-based phylogenetic analyses with thousands of taxa and mixed models. *Bioinformatics* 22: 2688–2690. http://dx.doi.org/10.1093/bioinformatics/btl446

Stamatakis, A., Hoover, P. & Rougemont, J. (2008) A rapid bootstrap algorithm for the RAxML Web Servers. *Systematic Biology* 57: 758–771. http://dx.doi.org/10.1080/10635150802429642

Talavera, G. & Castresana, J. (2007) Improvement of phylogenies after removing divergent and ambiguously aligned blocks from protein sequence alignments. *Systematic Biology* 56: 564–577. http://dx.doi.org/10.1080/10635150701472164

Thell, A., Feuerer, T., Elix, J.A. & Kärnefelt, I. (2006) A contribution to the phylogeny and taxonomy of *Xanthoparmelia* (Ascomycota,P armeliaceae). *Journal of the Hattori Botanical Laboratory* 100: 797–807.

Wang, X.Y., Koh, Y.J. & Hur, J.S. (2008) Taxonomic study on the lichen genus *Xanthoparmelia* (Ascomycotina, Parmeliaceae) in Korea. *Mycobiology* 36: 203–210. http://dx.doi.org/10.4489/MYCO.2008.36.4.203

Wei, J.C. (1991) *An enumeration of lichens in China*. International Academic Publishers, Beijing.

White, T.J., Bruns, T.D., Lee, S. & Taylor, J. (1990) Amplification and direct sequencing of fungal ribosomal DNA genes for phylogetics. *In*: Innis, M.A., Gelfand, D.H., Sninsky, J.J. & White, T.J. (Eds.) *PCR Protocols: a Guide to Methods and Applications*. Academic Press, San Diego, USA, pp. 315–321. http://dx.doi.org/10.1016/B978-0-12-372180-8.50042-1

Wolseley, P.A., Aguirre-Hudson, B. & McCarthy, P.M. (2002) Catalogue of the lichens of Thailand. *Bulletin of the Natural History Museum, London* (*Botany*) 32: 13–59. http://dx.doi.org/10.1017/s0968044602000038

Yoshimura, I., Kinoshita, Y., Yamamoto, Y., Huneck, S. & Yamada, Y. (1994) Analysis of secondary metabolites from lichen by high performance liquid chromatography with a photodiode array detector. *Phytochemical Analysis* 5: 197–205. http://dx.doi.org/10.1002/pca.2800050405