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New higher taxa in the lichen family Graphidaceae (lichenized Ascomycota: Ostropales) based on a three-gene skeleton phylogeny

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Abstract

We provide an updated skeleton phylogeny of the lichenized family Graphidaceae (excluding subfamily Gomphilloideae), based on three loci (mtSSU, nuLSU, *RPB2*), to elucidate the position of four new genera, *Aggregatorygma*, *Borinquenotrema*, *Corticorygma*, and *Paratopeliopsis*, as well as the placement of the enigmatic species *Diorygma erythrellum*, *Fissurina monilifera*, and *Redingeria desseiniana*. Based on the resulting topology, in addition to three tribes described previously, we recognize four further tribes in the subfamily Graphidoideae: *Acanthothecieae* Lumbsch, Kraichak & Lücking, *Diploschisteae* (Zahlbr.) Lumbsch, Kraichak & Lücking, *Leptotremateae* Lumbsch, Kraichak & Lücking, and *Wirthiotremateae* Lumbsch, Kraichak & Lücking. The phylogenetic position of *Aggregatorygma* and *Borinquenotrema* was not resolved with support, whereas *Corticorygma* forms part of Acanthothecieae, supported sister to *Acanthothecis*, and *Paratopeliopsis* belongs in Thelotremateae, unsupported sister to *Leucodecton*. *Diorygma erythrellum* is confirmed as a member of the *Diorygma-Thalloloma* clade, while *Fissurina monilifera*, inspite of its myriotremoid ascomata, belongs in *Fissurina* s.str. *Redingeria dessiniana*, although resembling the genus *Phaeographopsis*, is supported sister to *R. glaucoglyphica*. *Topeliopsis darlingtonii* forms the sister group to *Gintarasia megalophthalma*. Consequently, *T. darlingtonii* and the closely related *T. elixii* are recombined in *Gintarasia* as *Gintarasia darlingtonii* (Frisch & Kalb) Lumbsch, Kraichak & Lücking, and *G. elixii* (Frisch & Kalb) Lumbsch, Kraichak & Lücking.

Key words: Brazil, classification, Diploschistaceae, Puerto Rico, *Xalocoa*.

Introduction

The lichenized fungal family Graphidaceae now includes the previously separated families Graphidaceae, Thelotremataceae, Gomphillaceae, and Solorinellaceae (Rivas Plata *et al.* 2012a). Molecular data support four distinct clades within the emended family, classified as subfamilies Fissurinoideae, Gomphilloideae, Graphidoideae, and Redonographoideae (Rivas Plata *et al.* 2012a; Lücking *et al.* 2013). These do not correspond to

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tribe as a whole, but tendencies to have an internal anatomy, ascospores, and chemistry similar to tribe Thelotremateae are apparent. Most of the genera included in this tribe were previously assigned to tribe Thelotremateae s.lat., but further analyses showed that they are not closely related (Lücking *et al.* 2013; Rivas Plata *et al.* 2013).

Generic delimination in this tribe, including resurrection of the genus *Asteristion*, is currently under revision and will be dealt with in a forthcoming publication.

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References

Acharius, E. (1803) *Methodus qua omnes detectos lichenes secundum organa carpomorpha ad genera, species et varietates redigere atque observationibus illustrare tentavit*. F.D.D. Ulrich, Stockholm.
http://dx.doi.org/10.5962/bhl.title.79411

Aptroot, A., Diederich, P., Sérusiaux, E. & Sipman, H.J.M. (1997) Lichens and lichenicolous fungi from New Guinea. *Bibliotheca Lichenologica* 64: 1–220.
http://dx.doi.org/10.1017/s0024282997000613

Archer, A.W. (2009) Graphidaceae. *Flora of Australia* 57 (Lichens 5): 84–194.

Caceres, M.E.S., Aptroot, A., Parnmen S. & Lücking, R. (2104) Remarkable diversity of the lichen family *Graphidaceae* in the Amazon rain forest of Rondônia, Brazil. *Phytotaxa* 189(1): 87–136.
http://dx.doi.org/10.11646/phytotaxa.189.1.8

Clements, F.E. (1909) *The Genera of Fungi.* New York.
http://dx.doi.org/10.5962/bhl.title.54501

Drummond, A.J. & Rambaut, A. (2007) BEAST: Bayesian evolutionary analysis by sampling trees. *BMC Evolutionary Biology* 7: 214.
http://dx.doi.org/10.1186/1471-2148-7-214

Eschweiler, F.G. (1824) *Systema lichenum, genera exhibens rite distincta, pluribus novis adaucta*. Nürnberg, pp. 1–26.

Fée, A.L.A. (1825) *Essai sur les cryptogames des écorces exotiques officinales*. Paris. vii.xiv, 1–167 pp.

Frisch, A. & Kalb, K. (2006b) The lichen *Topeliopsis*, additions and corrections. *Lichenologist* 38: 37–45.
http://dx.doi.org/10.1017/s0024282905005530

Frisch, A., Kalb, K. & Grube, M. (2006) Contributions towards a new systematics of the lichen family Thelotremataceae. *Bibliotheca Lichenologica* 92: 1–556.

Hall, T.A. (1999) BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. *Nucleic Acids Symposium Series* 41: 95–98.

Hue, A. (1891) Lichenes exoticos a professore W. Nylander descriptos vel recognitos et in herbario musei Parisiense pro maxima parte asservatos in ordine systematico deposuit. *Nouvelles Archives du Muséum d'Histoire Naturelle* [Sér. 3] *3*: 33–120.

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

Kalb, K. (2001) The lichen genus *Topeliopsis* in Australia and remarks on Australian Thelotremataceae. *Mycotaxon* 79: 319–328.

Kalb, K., Staiger, B. & Elix, J.A. (2004) A monograph of the lichen genus *Diorygma* - a first attempt. *Symbolae Botanicae Upsalienses* 34(1): 133–181.

Kantvilas, G. & Vězda, A. (2000) Studies on the lichen family Thelotremataceae in Tasmania. The genus *Chroodiscus* and its relatives. *Lichenologist* 32: 325–357.
http://dx.doi.org/10.1006/lich.2000.0274

Katoh, K. & Toh, M. (2005) MAFFT Version 5: improvement in accuracy of multiple sequence alignment. *Nucleic Acids Research* 33: 511–518.
http://dx.doi.org/10.1093/nar/gki198

Kauff, F. & Lutzoni, F. (2002) Phylogeny of Gyalectales and Ostropales (Ascomycota, Fungi): among and within order relationships based on nuclear ribosomal RNA small and large subunits. *Molecular Phylogenetics and Evolution* 25: 138–156.
http://dx.doi.org/10.1016/s1055-7903(02)00214-2

Knight, C. & Mitten, W. (1860) Contribution to the Lichenographia of New Zealand; being an Account, with Figures, of some New Species of Graphidaceae and allied Lichens. *Transactions of the Linnean Society, London* 23: 101–106.
http://dx.doi.org/10.1111/j.1096-3642.1860.tb00124.x

Kraichak, E., Parnmen, S., Lücking, R., Rivas Plata, E., Aptroot, A., Cáceres, M.E.S., Ertz, D., Mangold, A., Mercado-Díaz, J.A., Papong, K., Van den Broeck, D., Weerakoon, G. & Lumbsch, H.T. (2014) Revisiting the phylogeny of Ocellularieae, the second largest tribe within Graphidaceae (lichenized Ascomycota: Ostropales). *Phytotaxa* 189(1): 52–81.
http://dx.doi.org/10.11646/phytotaxa.189.1.6

Leighton, W.A. (1869) The Lichens of Ceylon, collected by G. H. K. Thwaites. *Transactions of the Linnean Society, London* 27: 161–185.
http://dx.doi.org/10.1111/j.1096-3642.1870.tb00210.x

Liu, Y.J., Whelen, S. & Hall, B.D. (1999) Phylogenetic relationships among ascomycetes: evidence from an RNA polymerase II subunit. *Molecular Biology and Evolution* 16: 1799–1808.
http://dx.doi.org/10.1093/oxfordjournals.molbev.a026092

Lücking, R., Parnmen, S. & Lumbsch, H.T. (2012) *Mangoldia*, a new lichen genus in the family Graphidaceae (Ascomycota: Ostropales). *Phytotaxa* 69: 1–5.

Lücking, R., Tehler, A., Bungartz, F., Rivas Plata, E. & Lumbsch, H.T. (2013) Journey from the West: Did tropical Graphidaceae (lichenized Ascomycota: Ostropales) evolve from a saxicolous ancestor along the American Pacific coast? *American Journal of Botany* 100: 844–856.
http://dx.doi.org/10.3732/ajb.1200548

Lücking, R., Aptroot, A., Boonpragob, K., Cáceres, M.E.S., Ertz, D., Harris, R.C., Jia, Z.-F., Kalb, K., Kraichak, E., Lendemer, J.C., Mangold, A., Manoch, L., Mercado-Díaz, J., Moncada, B., Mogkulsuk, P., Papong, K., Parnmen, S., Peláez, R., Poengsunoen, V., Rivas-Plata, E., Saipunkaew, W., Sipman, H.J.M., Sutjaritturakan, J., van den Broeck, D., von Konrat, M., Weerakoon, G. & Lumbsch H.T. (2014) One hundred and seventy five new species of Graphidaceae: closing the gap or a drop in the bucket? *Phytotaxa* 189(1): 7–38.
http://dx.doi.org/10.11646/phytotaxa.189.1.4

Mangold, A., Martin, M.P., Lücking, R. & Lumbsch, H.T. (2008a) Molecular phylogeny suggests synonymy of Thelotremataceae within Graphidaceae (Ascomycota: Ostropales). *Taxon* 57: 476–486.

Mangold, A., Martín, M. P., Kalb, K., Lücking, R. & Lumbsch, H.T. (2008b) Molecular data show that Topeliopsis (Ascomycota, Thelotremataceae) is polyphyletic. *Lichenologist* 40: 39–46.
http://dx.doi.org/10.1017/s0024282908007366

Mangold, A., Elix, J.A. and Lumbsch, H.T. (2009) Thelotremataceae. *Flora of Australia Volume* 57: 195–420.

Mason-Gamer, R.J. & Kellogg, E.A. (1996) Testing for phylogenetic conflict among molecular data sets in the tribe Triticeae (Gramineae). *Systematic Biology* 45: 524–545.
http://dx.doi.org/10.2307/2413529

Massalongo, A.B. (1860) Esame comparativo di alcuni generi dei Licheni. *Atti del Reale Istituto Veneto di Scienze, Lettere et Arti, Series* 3(5): 247–276, 313–337.

Miadlikowska, J. & Lutzoni, F. (2000) Phylogenetic revision of the genus *Peltigera* (lichen-forming Ascomycota) based on morphological, chemical and large subunit nuclear ribosomal DNA data. *International Journal of Plant Science* 161: 925–968.
http://dx.doi.org/10.1086/317568

Miller, M.A., Pfeiffer, W. & Schwartz, T. (2010) Creating the CIPRES Science Gateway for inference of large phylogenetic trees. *Proceedings of the Gateway Computing Environments Workshop* (GCE): 1–8. New Orleans.
http://dx.doi.org/10.1109/gce.2010.5676129

Miquel, F.A.W. (1855). *Plantae Junghuhnianae. Leyden.*

Müller, J. (1887) Lichenologische Beiträge 26. *Flora* 70: 268–273, 283–288, 316–322, 336–338, 396–402, 423–429.

Nelsen, M., Lücking, R., Rivas Plata, E. & Mbatchou, J.S. (2010) *Heiomasia*, a new genus in the lichen-forming family Graphidaceae (Ascomycota: Lecanoromycetes: Ostropales) with disjunct distribution in Southeastern North America and Southeast Asia. *Bryologist* 113: 742–751.
http://dx.doi.org/10.1639/0007-2745-113.4.742

Norman, J.M. (1853) Conatus praemissus redactionis novae generum nunnullorum Lichenum. *Nytt Magazin for Naturvidenskapene* 7: 213–252.

Parnmen, S., Lücking, R. & Lumbsch, H.T. (2012) Phylogenetic classification at generic level in the absence of distinct phylogenetic patterns of phenotypical variation: A case study in Graphidaceae (Ascomycota). *PLOS One* 7(12): 1–13.
http://dx.doi.org/10.1371/journal.pone.0051392

Parnmen, S., Cáceres, M.E.S., Lücking, R. & Lumbsch, H.T. (2013) *Myriochapsa* and *Nitidochapsa*, two new genera in Graphidaceae (Ascomycota: Ostropales) for chroodiscoid species in the *Ocellularia* clade. *The Bryologist* 116: 127–133.
http://dx.doi.org/10.1639/0007-2745-116.2.127

Penn, O., Privman, E., Landan, G., Graur, D. & Pupko, T. (2010a) An alignment confidence score capturing robustness to guide-tree uncertainty. *Molecular Biology and Evolution* 27: 1759–67.
http://dx.doi.org/10.1093/molbev/msq066

Penn, O., Privman, E., Ashkenazy, H., Landan, G., Graur, D. & Pupko, T. (2010b) GUIDANCE: a web server for assessing alignment confidence scores. *Nucleic Acids Research* 38: W23–W28.
http://dx.doi.org/10.1093/nar/gkq443

Rivas Plata, E., Lücking, R. & Lumbsch, H.T. (2008) When family matters: an analysis of Thelotremataceae (Lichenized Ascomycota: Ostropales) as bioindicators of ecological continuity in tropical forests. *Biodiversity and Conservation* 17: 1319–1351.
http://dx.doi.org/10.1007/s10531-007-9289-9

Rivas Plata, E., Lücking, R., Sipman, H.J.M., Mangold, A., Kalb, K. & Lumbsch, H.T. (2010) A world-wide key to the thelotremoid *Graphidaceae*, excluding the *Ocellularia-Myriotrema-Stegobolus* clade. *Lichenologist* 42: 139–185.
http://dx.doi.org/10.1017/s0024282909990491

Rivas Plata, E., Lücking, R. & Lumbsch, H.T. (2012a) A new classification for the family Graphidaceae (Ascomycota: Lecanoromycetes: Ostropales). *Fungal Diversity* 52: 107–121.
http://dx.doi.org/10.1007/s13225-011-0135-8

Rivas Plata, E., Lücking, R. & Lumbsch, H.T. (2012b) Molecular phylogeny and systematics of the *Ocellularia* clade (Ascomycota: Ostropales: Graphidaceae). *Taxon* 61: 1161–1179.

Rivas Plata E., Parnmen, S., Staiger, B., Mangold, A., Frisch, A., Weerakoon, G., Hernández M.J.E., Cáceres, M.E.S., Kalb, K., Sipman, H.J.M., Common, R.S., Nelsen, M.P., Lücking, R. & Lumbsch, H.T. (2013) A molecular phylogeny of Graphidaceae (Ascomycota, Lecanoromycetes, Ostropales) including 428 species. *MycoKeys* 6: 55–94.
http://dx.doi.org/10.3897/mycokeys.6.3482

Staiger, B. (2002) Die Flechtenfamilie Graphidaceae. Studien in Richtung einer natürlicheren Gliederung. *Bibliotheca Lichenologica* 85: 1–526.

Stamatakis, A. (2006) RAxML-VI-HPC: Maximum-Likelihood-based phylogenetic analyses with thousands of taxa and mixed models. *Bioinformatics* 22: 2688–90.
http://dx.doi.org/10.1093/bioinformatics/btl446

Stamatakis, A., Ludwig, T. & Meier, H. (2005) RAxML-III: A fast program for maximum likelihood-based inference of large phylogenetic trees. *Bioinformatics* 21: 456–463.
http://dx.doi.org/10.1093/bioinformatics/bti191

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

Tibell, L. (1984) A reappraisal of the taxonomy of Caliciales. *Beiheft zur Nova Hedwigia* 79: 597–713.

Trevisan, V. (1853) *Spighe e Paglie* 1. Padova. 64 pp.

Tripp, E.A., Lendemer, J.C. & Harris, R.C. (2010) Resolving the genus *Graphina* Müll. Arg. in North America: new species, new combinations, and treatments for *Acanthothecis*, *Carbacanthographis*, and *Diorygma*. *Lichenologist* 42: 55–71.
http://dx.doi.org/10.1017/s0024282909990296

Van den Broeck, D., Lücking, R. & Ertz, D. (2014) Three new species of Graphidaceae from tropical Africa. *Phytotaxa* 189(1): 325–330.
http://dx.doi.org/10.11646/phytotaxa.189.1.23

Vilgalys, R. & Hester, M. (1990) Rapid genetic identification and mapping of enzymatically amplified ribosomal DNA from several Cryptococcus species. *Journal of Bacteriology* 172: 4238–4246.

Zoller, S., Scheidegger, C. & Sperisen, C. (1999) PCR primers for the amplification of mitochondrial small subunit ribosomal DNA of lichen-forming ascomycetes. *The Lichenologist* 31: 511–516.
http://dx.doi.org/10.1017/s0024282999000663