



Revisiting the phylogeny of Ocellularieae, the second largest tribe within Graphidaceae (lichenized Ascomycota: Ostropales)

EKAPHAN KRAICHAK¹, SITTIPORN PARNMEN², ROBERT LÜCKING¹, EIMY RIVAS PLATA¹, ANDRÉ APTROOT³, MARCELA E. S. CÁCERES⁴, DAMIEN ERTZ⁵, ARMIN MANGOLD⁶, JOEL A. MERCADO-DÍAZ⁷, KHWANRUAN PAPONG⁸, DRIES VAN DEN BROECK⁵, GOTHAMIE WEERAKOON⁹ & H. THORSTEN LUMBSCH¹

¹Science & Education, The Field Museum, 1400 South Lake Shore Drive, Chicago, Illinois 60605-2496, U.S.A.; email: rlucking@fieldmuseum.org, erivasplata@fieldmuseum.org, tlumbsch@fieldmuseum.org

²Toxicology and Biochemistry Section, Department of Medical Sciences, Ministry of Public Health, Nonthaburi 11000 Thailand; email: sparnmen@gmail.com

³ABL Herbarium, G.v.d.Veenstraat 107, NL-3762 XK Soest, The Netherlands; email: andreaproot@gmail.com

⁴Departamento de Biociências, Universidade Federal de Sergipe, CEP: 49500-000, Itabaiana, Sergipe, Brazil; email: mscaceres@hotmail.com

⁵Department of Bryophytes-Thallophytes, Botanic Garden Meise, Nieuwelaan 38, 1860 Meise, Belgium; email: damiens.ertz@br.fgov.be, dries.van.den.broeck@br.fgov.be

⁶Ossastrasse 6, D-12045 Berlin, Germany; email: arminmangold@gmail.com

⁷International Institute of Tropical Forestry, USDA Forest Service, Ceiba St. 1201, Jardín Botánico Sur, Río Piedras; email: joel_pr19@hotmail.com

⁸Department of Biology, Faculty of Science, Maharakham University, Kantarawichai, Maha Sarakham Province 44150, Thailand; khwanruanpapong@gmail.com

⁹Department of Botany, University of Sri Jayawardenepura, Sri Lanka; email: gothamiew@yahoo.com

Abstract

We present an updated 3-locus molecular phylogeny of tribe Ocellularieae, the second largest tribe within subfamily Graphidoideae in the Graphidaceae. Adding 165 newly generated sequences from the mitochondrial small subunit rDNA (mtSSU), the nuclear large subunit rDNA (nuLSU), and the second largest subunit of the DNA-directed RNA polymerase II (*RPB2*), we currently distinguish 218 species among the sequenced material, including the outgroup. This corresponds to almost half the species at this point recognized within this tribe. The newly generated sequences include 23 newly described species and one newly described genus published elsewhere in this volume. For the first time, *Sarcographina cyclospora* Müll. Arg., in spite of its distinctly lirellate ascomata, is shown to belong in tribe Ocellularieae, as strongly supported sister to *Ocellularia inturgescens* (Müll. Arg.) Mangold. The following six new combinations are proposed: *Melanotrema lynceodes* (Nyl.) Rivas Plata, Lücking & Lumbsch, *Ocellularia curranii* (Vain.) Kraichak, Lücking & Lumbsch, *O. khasiana* (Patw. & Nagarkar) Kraichak, Lücking & Lumbsch, *O. cinerea* (Müll. Arg.) Kraichak, Lücking & Lumbsch, *O. erodens* (R. C. Harris) Kraichak, Lücking & Lumbsch, and *O. laeviuscula* (Nyl) Kraichak, Lücking & Lumbsch. Further, the new name *Ocellularia hernandeziana* Kraichak, Lücking & Lumbsch is introduced for *Myriotrema ecorticatum*. The nomenclatural status of the name *Ocellularia microstoma* is clarified.

Key words: *Ampliotrema*, *Glaucotrema*, phylogenetic resolution, *Redingeria*, *Reimnitzia*, *Rhabdodiscus*, *Sarcographina*, *Stegobolus*, supermatrix

Introduction

The two largest families of lichenized ascomycetes are the crustose Graphidaceae and the predominantly foliose and fruticose Parmeliaceae. With a recent increase in species discovery, mainly in tropical regions, Graphidaceae

characterize these clades and eventually give them formal generic status. In addition, it becomes apparent that, at least in this clade, nuLSU and also *RPB2* provide a better resolution at species and species group level than mtSSU; on the other hand, the proportion of sequences routinely obtained for taxa within this clade indicates that nuLSU and particularly *RPB2* sequencing often fails. The highlighted cases suggest that especially within *Ocellularia* s.lat., additional data from these two loci may help to better resolve this clade and then either define subgenera or even additional genera.

Acknowledgements

Data obtained for this study were gathered as part of several projects funded by the National Science Foundation: *TICOLICHEN* (DEB 0206125 to The Field Museum; PI Robert Lücking), *Phylogeny and Taxonomy of Ostropalean Fungi, with Emphasis on the Lichen-forming Thelotremaaceae* (DEB 0516116 to The Field Museum; PI H. T. Lumbsch; Co-PI R. Lücking), *Neotropical Epiphytic Microlichens—An Innovative Inventory of a Highly Diverse yet Little Known Group of Symbiotic Organisms* (DEB 715660 to The Field Museum; PI R. Lücking), and *ATM—Assembling a taxonomic monograph: The lichen family Graphidaceae* (DEB-1025861 to The Field Museum; PI T. Lumbsch, CoPI R. Lücking). Fred Barrie is thanked for nomenclatural advice.

References

- Adanson, M. (1763) *Familles des Plantes*. Vol. II. Paris.
- Aptroot, A. (2014) New fertile isidiate Graphidaceae from the Solomon Islands. *Phytotaxa* 189(1): 82–86.
<http://dx.doi.org/10.11646/phytotaxa.189.1.7>
- 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.
- Cáceres, M.E.S., Santos Viera, T., Santos De Jesus, L. & Lücking, R. (2012). New and interesting lichens from the Caxiuanã National Forest in the Brazilian Amazon. *The Lichenologist* 44: 807–812.
<http://dx.doi.org/10.1017/s0024282912000412>
- 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>
- Fée, A.L.A. (1825) *Essai sur les Cryptogames des Écorces Exotiques Officinales*. Paris.
- Ferraro, L.I., Lücking, R., Aptroot, A. & Cáceres, M.E.S. (2014) New Graphidaceae from northern Argentina. *Phytotaxa* 189(1): 137–146.
<http://dx.doi.org/10.11646/phytotaxa.189.1.9>
- Frisch, A., Kalb, K. & Grube, M. (2006) Contributions towards a new systematics of the lichen family Thelotremaaceae. *Bibliotheca Lichenologica* 92: 1–556.
- Hale, M.E. (1974) Morden-Smithsonian Expedition to Dominica: The lichens (Thelotremaaceae). *Smithsonian Contributions to Botany* 16: 1–46.
<http://dx.doi.org/10.5479/si.0081024x.16>
- Hale, M.E. (1978) A revision of the lichen family Thelotremaaceae in Panama. *Smithsonian Contributions to Botany* 38: 1–60.
<http://dx.doi.org/10.5479/si.0081024x.38>
- Hale, M.E. (1980) Generic delimitation in the lichen family Thelotremaaceae. *Mycotaxon* 11: 130–138.
- Hale, M.E. (1981) A revision of the lichen family Thelotremaaceae in Sri Lanka. *Bulletin of the British Museum (Natural History)*, *Botany Series* 8: 227–332.
- Hall, T.A. (1999) BioEdit: a user-friendly biological sequence alignment and analysis program for Windows 95/98/NT. *Nucleic Acids Symposium Series* 41: 95–98.
- 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 Thelotremaaceae. *Mycotaxon* 79: 319–328.
- Kalb, K. & Jia, Z.F. (2014) New species of Graphidaceae from Zhejiang Province, China. *Phytotaxa* 189(1): 147–152.
<http://dx.doi.org/10.11646/phytotaxa.189.1.10>

- 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](http://dx.doi.org/10.1016/s1055-7903(02)00214-2)
- Lendemer, J.C. & Harris, R.C. (2014) Seven new species of Graphidaceae (Lichenized Ascomycetes) from the Coastal Plain of southeastern North America. *Phytotaxa* 189(1): 153–175.
<http://dx.doi.org/10.11646/phytotaxa.189.1.11>
- 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. (2014) Three new species of thelotremoid Graphidaceae from tropical Africa. *Phytotaxa* 189(1): 176–179.
<http://dx.doi.org/10.11646/phytotaxa.189.1.12>
- 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>
- Lumbsch, H.T., Ahti, T., Altermann, S., Amo De Paz, G., Aptroot, A., Arup, U., Bárcenas Peña, A., Bawingan, P.A., Benatti, M.N., Betancourt, L., Björk, C. R., Boonpragob, K., Brand, M., Bungartz, F., Cáceres, M. E. S., Candan, M., Chaves, J.L., Clerc, P., Common, R., Coppins, B.J., Crespo, A., Dal-Forno, M., Divakar, P.K., Duya, M.V., Elix, J.A., Elvebakk, A., Fankhauser, J.D., Farkas, E., Ferraro, L.I., Fischer, E., Galloway, D.J., Gaya, E., Giralt, M., Goward, T., Grube, M., Hafellner, J., Hernández M., J.E., Herrera Campos, M.A., Kalb, K., Kärnefelt, I., Kantvilas, G., Killmann, D., Kirika, P., Knudsen, K., Komposch, H., Kondratyuk, S., Lawrey, J.D., Mangold, A., Marcelli, M.P., McCune, B., Ines Messuti, M., Michlig, A., Miranda González, R., Moncada, B., Naikatini, A., Nelsen, M.P., Øvstedal, D.O., Palice, Z., Papong, K., Parnmen, S., Pérez-Ortega, S., Printzen, C., Rico, V. J., Rivas Plata, E., Robayo, J., Rosabal, D., Ruprecht, U., Salazar Allen, N., Sancho, L., Santos De Jesus, L., Santos Vieira, T., Schultz, M., Seaward, M.R.D., Sérusiaux, E., Schmitt, I., Sipman, H.J.M., Sohrabi, M., Söchting, U., Zeuthen Søgaard, M., Sparrius, L.B., Spielmann, A., Spribille, T., Sutjaritturakan, J., Thammathaworn, A., Thell, A., Thor, G., Thüs, H., Timdal, E., Truong, C., Türk, R., Umaña Tenorio, L., Upreti, D.K., Van Den Boom, P., Vivas Reubelta, M., Wedin, M., Will-Wolf, S., Wirth, V., Wirtz, N., Yahr, R., Yeshitela, K., Ziemmeck, F., Wheeler, T. & Lücking, R. (2011b) One hundred new species of lichenized fungi: a signature of undiscovered global diversity. *Phytotaxa* 18: 1–127.
- Lumbsch, H.T., Kraichak, E., Parnmen, S., Rivas Plata, E., Aptroot, A., Cáceres, M.E.S., Ertz, D., Feuerstein, S.C., Mercado-Díaz, J.A., Staiger, B., Van den Broeck, D. & Lücking, R. (2014) New higher taxa in the lichen family Graphidaceae (lichenized Ascomycota: Ostropales) based on a three-gene skeleton phylogeny. *Phytotaxa* 189(1):39–51.
<http://dx.doi.org/10.11646/phytotaxa.189.1.5>
- Magnusson, A.H. & Zahlbruckner, A. (1944) Hawaiian lichens. II. The families Lecideaceae to Parmeliaceae. *Arkiv för Botanik* 31A(6): 1–109.
- Mangold, A., Elix, J.A. & Lumbsch, H.T. (2007) *Ocellularia* species with a cone-shaped columella in Australia. *Bibliotheca Lichenologica* 96: 193–208.
- Mangold, A., Martín, M.P., Lücking, R. & Lumbsch, H.T. (2008a) Molecular phylogeny suggests synonymy of Thelotremataceae within Graphidaceae (Ascomycota: Ostropales). *Taxon* 57: 476–486.
- Mangold, A., Elix, J.A. & Lumbsch, H.T. (2008b) *Ocellularia wirthii* (Ascomycota, Ostropales), eine neue Art aus Neusüdwesten, Australien. *Sauteria* 15: 363–369.
- Mangold, A., Elix, J.A. and Lumbsch, H.T. (2009) Thelotremataceae. pp. 195–420 in: P. M. McCarthy (Ed.): *Flora of Australia Volume 57. Lichens 5*. ABRIS and CSIRO Publishing, Canberra and Melbourne. xx + 687 pages.
- Mangold, A., Lücking, R. & Lumbsch, H.T. (2014) New species of graphidoid and thelotremoid Graphidaceae from Australia. *Phytotaxa* 189(1): 180–185.
<http://dx.doi.org/10.11646/phytotaxa.189.1.13>
- 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>
- Mercado-Díaz, J.A., Lücking, R. & Parnmen, S. (2014) Two new genera and twelve new species of Graphidaceae from Puerto Rico: a case for higher endemism of lichenized fungi in islands of the Caribbean? *Phytotaxa* 189(1): 186–203.

<http://dx.doi.org/10.11646/phytotaxa.189.1.14>

- Meyer, G.F.W. (1825) *Nebestunden meiner Beschaeftigungen im Gebiete der Pflanzenkunde. Erster Theil*. Göttingen.
- 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*.
- Montagne, C. (1845) *Plantae cellulares quas in insulis Philippinensibus a cl. Cuming collectas recensuit observationibus nonnullis descriptionibusque illustravit. London Journal of Botany* 4: 1–6.
- Müller, J. (1882) Lichenologische Beiträge 16. *Flora* 65: 483–490, 499–505, 515–519.
- Müller, J. (1887) Lichenologische Beiträge 26. *Flora* 70: 268–273, 283–288, 316–322, 336–338, 396–402, 423–429.
- Müller, J. (1891a) Lichenes Bellendenici a cl. M. F. Bailey, Gouvernment Botanist, ad Bellenden Kerr Australiae orientalis lecti et sub numeris citatis missi. *Hedwigia* 30: 47–56.
- Müller, J. (1891b) Lichenes Brisbaneenses a cl. F. M. Bailey, Gouvernment Botanist, prope Brisbane (Queensland) in Australia orientali lecti. *Nuovo Giornale Botanico Italiano* 23: 385–404.
- Müller, J. (1892) Lichenes exotici. *Hedwigia* 31: 276–288.
- Overeem, C. (1922) Verzeichnis der in Niederländisch Ost-Indien bis dem Jahre 1920 gefundenen Myxomycetes, Fungi und Lichenes. *Bulletin du Jardin Botanique de Buitenzorg* 4: 1–146.
- Papong, K., Lücking, R., Kraichak, E., Parmen, S., von Konrat, M. & Lumbsch, H.T. (2014a) Twenty-three new species in the lichen family Graphidaceae from New Caledonia (Ostropales, Ascomycota). *Phytotaxa* 189(1): 204–231.
<http://dx.doi.org/10.11646/phytotaxa.189.1.15>
- Papong, K., Mangold, A., Lücking, R. & Lumbsch, H.T. (2014b) New species and new records of thelotremoid Graphidaceae (Ascomycota: Ostropales) from Thailand. *Phytotaxa* 189(1): 232–244.
<http://dx.doi.org/10.11646/phytotaxa.189.1.16>
- Parmen, 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>
- Patwardhan, P.G. & Kulkarni, C.R. (1977) A contribution to our knowledge of the lichen flora of India. I. Family Thelotremataceae. *Kawaka* 5: 1–17.
- Pelaez, R.N., Moncada, B. & Lücking, R. (2014) High diversity of *Ocellularia* (Ascomycota: Graphidaceae) in the Colombian Llanos, including two species new to science. *Phytotaxa* 189(1): 245–254.
<http://dx.doi.org/10.11646/phytotaxa.189.1.17>
- 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>
- Poengsungnoen, V., Manoch, L., Mongkolsuk, P. & Kalb, K. (2014a) New species of Graphidaceae from Loei Province, Thailand. *Phytotaxa* 189(1): 255–267.
<http://dx.doi.org/10.11646/phytotaxa.189.1.18>
- Poengsungnoen, V., Manoch, L., Mongkolsuk, P., Boonpragob, K., Parmen, S., Lücking, R., Tehler, A. & Lumbsch, H.T. (2014b) Phylogenetic analysis reveals two morphologically unique new species in the genera *Astrochapsa* and *Nitidochapsa* (lichenized Ascomycota: Graphidaceae). *Phytotaxa* 189(1): 268–281.
<http://dx.doi.org/10.11646/phytotaxa.189.1.19>
- Redinger, K. (1933) Neue und wenig bekannte Flechten aus Brasilien. *Hedwigia* 73: 54–67.
- Rivas Plata, E. & Lumbsch, H.T. (2011) Parallel evolution and phenotypic divergence in lichenized fungi: a case study in the lichen-forming fungal family Graphidaceae (Ascomycota: Lecanoromycetes: Ostropales). *Molecular Phylogenetics and Evolution* 61: 45–63.
<http://dx.doi.org/10.1016/j.ympev.2011.04.025>
- 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. *MycKeys* 6: 55–94.
<http://dx.doi.org/10.3897/mycokeys.6.3482>
- Rivas Plata, E., Sipman, H.J.M. & Lücking, R. (2014) Five new thelotremoid Graphidaceae from the Philippines. *Phytotaxa* 189(1): 282–288.
<http://dx.doi.org/10.11646/phytotaxa.189.1.20>
- Sipman, H.J.M. (2014) New species of Graphidaceae from the Neotropics and Southeast Asia. *Phytotaxa* 189(1): 289–311.
<http://dx.doi.org/10.11646/phytotaxa.189.1.21>
- Sipman, H.J.M. & Aptroot, A. (1992) Results of a botanical expedition to Mount Roraima, Guyana. II. Lichens. *Tropical Bryology* 5: 79–108.
- Sipman, H.J.M., Lücking, R., Aptroot, A., Kalb, K., Chaves, J.L. & Umaña, L. (2012) A first assessment of the Ticolichen biodiversity inventory in Costa Rica and adjacent areas: the thelotremoid Graphidaceae (Ascomycota: Ostropales). *Phytotaxa* 55: 1–214.
- 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>
- Sutjaritturakan, J., Saipunkaew, W., Boonpragob, K. & Kalb, K. (2014) New species of Graphidaceae (Ostropales, Lecanoromycetes) from southern Thailand. *Phytotaxa* 189(1): 312–324.
<http://dx.doi.org/10.11646/phytotaxa.189.1.22>
- Vainio, E.A. (1921) Lichenes insularum Philippinarum III. *Annales Academiae Scientiarum Fennicae, Ser. A* 15(6): 1–368.
- 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.
- Weerakoon, G., Lücking, R. & Lumbsch, H.T. (2014) Thirteen new species of Graphidaceae (lichenized Ascomycota: Ostropales) from Sri Lanka. *Phytotaxa* 189(1): 331–347.
<http://dx.doi.org/10.11646/phytotaxa.189.1.24>
- Zahlbruckner, A. (1923) *Catalogus Lichenum Universalis* 2. Borntraeger, Leipzig.
- Zoller, S., Scheidegger, C & Sperisen, C. (1999) PCR primers for the amplification of mitochondrial small subunit ribosomal DNA of lichen-forming ascomycetes. *Lichenologist* 31: 511–516.
<http://dx.doi.org/10.1017/s0024282999000663>