Phytotaxa 181 (3): 151–162
www.mapress.com/phytotaxa/

Article

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

http://dx.doi.org/10.11646/phytotaxa.181.3.3

On the systematic position of the genus *Timmiella* (Dicranidae, Bryopsida) and its allied genera, with the description of a new family Timmiellaceae

YUYA INOUE[1, 3] & HIROMI TSUBOTA[2]

[1]*Department of Biological Science, Graduate school of Science, Hiroshima University, Kagamiyama 1–3–1, Higashi-hiroshima-shi, Hiroshima-ken 739–8526, Japan.*

[2]*Miyajima Natural Botanical Garden, Graduate School of Science, Hiroshima University, Mitsumaruko-yama 1156–2, Miyajima-cho, Hatsukaichi-shi, Hiroshima-ken 739–0543, Japan.*

[3]*Author for correspondence (jujainoue@hiroshima-u.ac.jp)*

Abstract

Based on our molecular phylogenetic analysis of haplolepideous mosses with concatenated sequences of chloroplast *rps4* and *rbcL* genes, a new family Timmiellaceae is erected to accommodate the genera *Timmiella* and *Luisierella*, both of which have been formerly included in the family Pottiaceae. The family Timmiellaceae is resolved as a second-branching clade together with *Distichium* (Distichiaceae) within the Dicranidae (haplolepideous moss) lineages and phylogenetically distinct from the Pottiaceae. Reassessment of morphological characters suggests that a combination of the characters: 1) adaxially bulging and abaxially flat leaf surfaces, 2) sinistrorse or straight peristomes, when present, and 3) sinistrorsely arranged operculum cells is unique to Timmiellaceae and discriminates it from other haplolepideous moss families.

Introduction

The genus *Timmiella* (De Notatis 1865: 100) Limpricht (1888: 590) is a haplolepideous moss which has been placed in the family Pottiaceae Schimper (1856: 24) since it was first described as a section of the genus *Trichostomum* Bruch in Müller (1829: 396) by De Notaris (1865). Although many authors have placed the genus in the subfamily Trichostomoideae (Schimper 1860: 141) Brotherus (1902: 381) of the Pottiaceae (Limpricht 1888, Brotherus 1902, 1924a, Hilpert 1933, Chen 1941, Podpěra 1954, Saito 1975, Corley *et al.* 1981, Walther 1983), the systematic position of the genus has been questioned because of its unique morphological characters [e.g. denticulate to dentate leaf margins, bistratose lamina, adaxially bulging and abaxially flat lamina, and sinistrorse peristomes (twisted to the left when viewed from the side)]. These characters indicate that it has a different evolutionary line from the other genera of Trichostomoideae as noted by Saito (1975). Based on cladistic analysis using morphological characters, Zander (1993) established the subfamily Timmielloideae Zander (1993: 68) with its sole genus *Timmiella*.

Recent molecular phylogenetic studies have suggested the exclusion of *T. anomala* (Bruch & Schimper 1842: 196) Limpricht (1888: 592) or *T. crassinervis* (Hampe 1860: 456) Koch (1950: 11) from the Pottiaceae and their repositioning as an early-diversing clade within the Dicranidae Ochyra (2003: 104) (haplolepideous mosses) (La Farge *et al.* 2000, 2002, Werner *et al.* 2004, Hedderson *et al.* 2004, Tsubota *et al.* 2004, Wahrmund *et al.* 2009, 2010, Cox *et al.* 2010). However, *Timmiella* was retained as a member of the Pottiaceae because of its morphological affinity to the family, especially the distinctive twisted peristome (Zander 2006, 2007). No taxonomic changes had been made based on the monophyletic groupings because the phylogenetic position of the genus in the early-diversing haplolepideous mosses remained to be fully resolved.

In the present study, the phylogenetic position and taxonomic treatment of *Timmiella* and its allied genera are reassessed based on phylogenetic analysis with concatenated sequences of chroloplast ribosomal protein S4 (*rps4*) and ribulose 1,5-bisphosphate carboxylase/oxygenase large subunit (*rbcL*) genes. We also discuss morphological characters that support the monophyly inferred from our analysis.

Accepted by Lars Söderström: 23 Aug. 2014; published: 3 Oct. 2014

in both adaxial and abaxial surfaces in *Distichium*, whereas in *Timmiella* + *Luisierella* they are restricted to adaxial surface.

The family Distichiaceae was originally proposed by Schimper (1860) to include *Distichium* and *Eustichium* Bruch & Schimper (1849: 159) [= *Bryoxiphium* Mitten (1869: 24)], and later Limpricht (1887) placed *Distichium* in Ditrichaceae Limpricht (1887). Due to its universal acceptance, Magill (1977) proposed Ditrichaceae as a conserved name against Distichiaceae and Ceratodontaceae Schimper (1860), and this proposal was adopted in the Berlin Code (Greuter *et al.* 1988). From our study, the resultant tree suggests that *Distichium* should be treated as a distinct family from the other genera of Ditrichaceae. The family name Distichiaceae can be used to accommodate *Distichium*, because Distichiaceae and Ditrichaceae are heterotypic synonyms and either can be adopted as correct names when they are considered distinct from each other (Art 14.6, in ICN, Melbourne, McNeill *et al.* 2012).

Taxonomy

Based on phylogenetic and morphological distinctions from the other haplolepideous moss families, we concluded that *Timmiella* and *Luisierella* are excluded from Pottiaceae and warrant accommodation within a new family. However, from the results no final decision regarding the order within which these families are accommodated can be made. Further analyses based on increased taxa, especially polyphyletic families such as Dicranaceae Schimper (1856: 11), Ditrichaceae and Oncophoraceae Stech (2008: 14), are necessary for further resolution.

Timmiellaceae Y.Inoue & H.Tsubota, *stat. nov.*

Timmielloideae R.H.Zander, Bull. Buffalo Soc. Nat. Sci. 32: 68. 1993.

Type: *Timmiella* (De Not.) Limpr., Laubm. Deutch. 1: 590. 1888. [based on *Trichostomum* sect. *Timmiella* De Not., Comment. Soc. Crittog. Ital. 2: 100. 1865.]

Included genera: *Timmiella* (De Not.) Limpr. and *Luisierella* Thér. & P.de la Varde

Diagnosis: Plants acrocarpous; leaves incurved and tubulose when dry, spreading when moist, leaf cell surfaces adaxially bulging and abaxially flat; peristomes straight to sinistrorse or absent, operculum cells sinistrorsely arranged.

Acknowledgements

We thank Prof. R. D. Seppelt for providing valuable herbarium specimens for our molecular studies, for reading the manuscript and for his helpful comments; Dr. J. Kučera for providing valuable herbarium specimens for our molecular studies; curators of TNS for the loan of specimens; Dr. T. Suzuki and Mr. Y. Tateishi for field research assistance in Japan; Dr. M. Shimamura for giving instruction in techniques for SEM observation and helpful suggestions; Dr. T. Katagiri for his helpful comments on the manuscript; and Mr. A. Sadamitsu for helping us to design some primers. This study is partly supported by KAKENHI 23770089 to HT and 19570088 to Dr. H. Deguchi. Sequencing for this study was carried out at the Analysis Center of Life Science, Natural Science Center for Basic Research and Development, Hiroshima University.

References

Arnott, G.A.W. (1825) *Disposition Méthodique des Espèces de Mousses*. J. Tastu, Paris, iv + 72 pp.

Bescherelle, É. (1892) Étude sur le genre *Eustichia* (Brid.) C. Mueller. *Journal de Botanique (Morot)* 6: 177–186.

Bridel, S.É. (1806) *Muscologia Recentiorum Supplementum 1*. C. G. Ettinger, Gotha, viii + 272 pp.

Bridel, S.É. (1826) *Bryologia Universa 1*. J. A. Barth, Leipzig, xlvi + 856 pp + ii.

Brotherus, V.F. (1902) Pottiaceae. *In*: Engler, A. & Prantl, K. (Eds.) *Natürlichen Pflanzenfamilien 1 teil, 3 abteilung, 1 hälfte*. Wilhelm Engelmann, Leipzig, pp. 380–439.

Brotherus, V.F. (1904) Catoscopiaceae. *In*: Engler, A. & Prantl, K. (Eds.) *Natürlichen Pflanzenfamilien 1 teil, 3 abteilung, 1 hälfte.*

Wilhelm Engelmann, Leipzig, pp. 629–631.

Brotherus, V.F. (1924a) Pottiaceae. *In*: Engler, A. & Prantl, K. (Eds.) *Natürlichen Pflanzenfamilien ed. 2, 10*. Wilhelm Engelmann, Leipzig, pp. 243–302.

Brotherus, V.F. (1924b) Eustichiaceae. *In*: Engler, A. & Prantl, K. (Eds.) *Natürlichen Pflanzenfamilien ed. 2, 10*. Wilhelm Engelmann, Leipzig, pp. 420–421.

Bruch, P. & Schimper, W.P. (1842) Fasc. 13–15. *Barbula*. *In:* Bruch, P., Schimper, W.P. & Gümbel, W.T. (Eds.) *Bryologia Europaea*. E. Schweizerbart, Stuttgart.

Bruch, P. & Schimper, W.P. (1846a) Fasc. 29–31. *Bartramidula*, *Hedwigia*, *Hedwigidium*, *Braunia*, *Anoectangium*, *Didymodon*, *Distichium*, *Discelium*, *Ceratodon*, *Trematodon*, *Campylostelium*, *Mnium*, *Desmatodon*, *Fontinalis*, *Bartramia*, *Barbula*, *Dichelyma*. *In*: Bruch, P., Schimper, W.P. & Gümbel, W.T. (Eds.) *Bryologia Europaea.* E. Schweizerbart, Stuttgart.

Bruch, P. & Schimper, W.P. (1846b) Fasc. 33–36. *Brachyodus*, *Anodus*, *Seligeria*, *Blindia*, *Stylostegium*, *Hymenostomum*, *Weisia*, *Rhabdoweisia*, *Gymnostomum*, *Eucladium*, *Angstroemia*, *Arctoa*, *Cynodontium*. *In*: Bruch, P., Schimper, W.P. & Gümbel, W.T. (Eds.) *Bryologia Europaea*. E. Schweizerbart, Stuttgart.

Bruch, P. & Schimper, W.P. (1849) Fasc. 42. *Ephemerum*, *Acaulon*, *Physcomitrella*, *Eustichium*, *Pottia*, *Orthotrichum*, *Fissidens*, *Grimmia*, *Hymenostomum*. *In*: Bruch, P., Schimper, W.P. & Gümbel, W.T. (Eds.) *Bryologia Europaea*. E. Schweizerbart, Stuttgart.

Buck, W.R. & Goffinet, B. (2000) Morphology and classification of mosses. *In*: Shaw, A.J. & Goffinet, B. (Eds.) *Bryophyte Biology*. Cambridge University Press, Cambridge, pp. 71–123.

Chen, P.C. (1941) Studien über die ostasiatischen Arten der Pottiaceae I & II. *Hedwigia* 80: 1–76, 141–322.

Corley, M.F.V., Crundwell, A.C., Düll, R., Hill, M.O. & Smith, A.J.E. (1981) Mosses of Europe and the Azores; an annotated list of species, with synonyms from the recent literature. *Journal of Bryology* 11: 609–689.
http://dx.doi.org/10.1179/jbr.1981.11.4.609

Cox, C.J., Goffinet, B., Wickett, N.J., Boles, S.B. & Shaw, A.J. (2010) Moss diversity: a molecular phylogenetic analysis of genera. *Phytotaxa* 9: 175–195.
http://dx.doi.org/10.11646/phytotaxa.9.1.10

Churchill, S.P. (1981) A phylogenetic analysis, classification and synopsis of the genera of the Grimmiaceae (Musci). *In*: Funk, V.A. & Brooks, D.R. (Eds.) *Advances in Cladiststics*. The New York Botanical Garden, New York, pp. 127–144.

De Notaris, G. (1865) Cronaca della briologia Italiana. *Commentario della Società Crittogamologica Italiana* 2: 89–113.

Deguchi, H. (1987) *Luisierella* (Pottiaceae, Musci), a moss genus with a disjunctive distribution in Neotropics and Japan. *The Journal of Japanese Botany* 62: 7–15.

Drummond, A.J., Suchard, M.A., Xie, D. & Rambaut, A. (2012) Bayesian phylogenetics with BEAUti and the BEAST 1.7. *Molecular Biology and Evolution* 29: 1969–1973.
http://dx.doi.org/10.1093/molbev/mss075

Felsenstein, J. (1981) Evolutionary trees from DNA sequences: a maximum likelihood approach. *Journal of Molecular Evolution* 17: 368–376.
http://dx.doi.org/10.1007/bf01734359

Fitch, W.M. (1971) Toward defining the course of evolution: minimum change for a specific tree topology. *Systematic Zoology* 20: 406–416.
http://dx.doi.org/10.2307/2412116

Frey, W. & Stech, M. (2009) Marchantiophyta, Bryophyta, Anthocerotophyta. *In*: Frey, W. (Ed.) *Syllabus of plant families. A. Engler's syllabus der Pflanzenfamilien, 13th ed., Part 3 Bryophytes and seedless vascular Plants*. Gebr. Borntraeger, Stuttgart, pp. 1–257.

Greuter, W., Burdet, H.M., Chaloner, W.G., Demoulin, V., Grolle, R., Hawks-Worth, D.L., Nicolson, D.H., Silva, P.C., Stafleu, F.A., Voss, E.G. & McNeill, J. (1988) *International Code of Botanical Nomenclature: adopted by the Fourteenth International Botanical Congress, Berlin, July–August 1987*. Koeltz Scientific Books, Köenigstein, xiv + 328 pp.

Hampe, G.E.L. (1860) Musci Californici novi. *Lineaea* 30: 455–464.

Hampe, G.E.L. (1867) *Ditrichum* Timm. statt *Leptotrichum* Hpe. *Flora* 50: 181–182.

Hasegawa, M. & Kishino, H. (1989) Confidence limits on the maximum likelihood estimate of the hominoid tree from mitochondrial DNA sequences. *Evolution* 43: 672–677.
http://dx.doi.org/10.2307/2409071

Hedderson, T.A., Murray, D.J., Cox, C.J. & Nowell, T.L. (2004) Phylogenetic relationships of haplolepideous mosses (Dicranidae) inferred from *rps4* gene sequences. *Systematic Botany* 29: 29–41.
http://dx.doi.org/10.1600/036364404772973960

Hedwig, J. (1801) *Species Muscorum Frondosorum*. J.A. Barth, Lipsiae, vi + 357 pp + 77 pls.

Hilpert, F. (1933) Studien zur systematik der Trichostomaceen. *Beihefte zum Botanischen Centralblatt* 50: 585–706.

Inoue, Y., Tsubota, H., Kubo, H., Uchida, S., Mukai, S., Shimamura, M. & Deguchi, H. (2011) A note on *Pottia intermedia* (Turner) Fürnr.

(Pottiaceae, Bryopsida) with special reference to its phylogeny and new localities in SW Japan. *Hikobia* 16: 67–78.

Inoue, Y., Tsubota, H., Sato, H. & Yamaguchi, T. (2012) Phylogenetic note on *Pachyneuropsis miyagii* T.Yamag. (Pottiaceae, Bryophyta). *Hikobia* 16: 221–228.

Inoue, Y., Nagatani, S. & Tsubota, H. (2014) New localities of *Timmiella anomala* (Pottiaceae, Bryophyta) and its distribution in Japan. *The Journal of Japanese Botany* 89: 189–192. [In Japanese with English abstract]

Katoh, K. & Standley, D.M. (2013) MAFFT multiple sequence alignment software version 7: improvements in performance and usability. *Molecular Biology and Evolution* 30: 772–780.
http://dx.doi.org/10.1093/molbev/mst010

Koch, L.F. (1950) Mosses of California: an annotated list of species. *Leaflets of Western Botany* 6: 1–40.

La Farge, C., Mishler, B.D., Wheeler, J.A., Wall, D.P., Johannes, K., Schaffer, S. & Shaw, A.J. (2000) Phylogenetic relationships within the haplolepideous mosses. *The Bryologist* 103:257–276.
http://dx.doi.org/10.1639/0007-2745(2000)103[0257:prwthm]2.0.co;2

La Farge, C., Shaw, A.J. & Vitt, D.H. (2002) The circumscription of the Dicranaceae (Bryopsida) based on the chloroplast regions *trnL–trnF* and *rps4*. *Systematic Botany* 27: 435–452.

Limpricht, K.G. (1885–1889) *Die Laubmoose Deutschlands, Österreichs und der Schweiz 1*. Eduard Kummer, Leipzig, 836 pp.

Longton, R.E. (1988) *Biology of Polar Bryophytes and Lichens*. Cambridge University Press, Cambridge, viii + 391 pp.

Magill, R.E. (1977) Towards the conservation of four family names in Musci. *Taxon* 26: 597–598.

Masuzaki, H., Shimamura, M., Furuki, T., Tsubota, H., Yamaguchi, T., Haji Mohamed, A.M. & Deguchi, H. (2010) Systematic position of the enigmatic liverwort *Mizutania* (Mizutaniaceae, Marchantiophyta) inferred from molecular phylogenetic analyses. *Taxon* 59: 448–458.

McNeill, J., Barrie, F.R., Buck, W.R., Demoulin, V., Greuter, W., Hawksworth, D.L., Herendeen, P.S., Knapp, S., Marhold, K., Prado, J., Prud'Homme van Reine, W.F., Smith, G.F., Wiersema, J.H. & Turland, N.J. (2012) *International Code of Nomenclature for algae, fungi and plants (Melbourne Code): adopted by the Eighteenth International Botanical Congress Melbourne, Australia, July 2011*. Koeltz Scientific Books, Köenigstein, xxx + 208 pp.

Mitten, W. (1869) Musci Austro-Americani. *Journal of the Linnean Society, Botany* 12: 1–659.

Mitten, W. (1891) An enumeration of the species of Musci and Hepaticae recorded from Japan. *Transactions of the Linnean Society of London, Botany* 3: 153–206.
http://dx.doi.org/10.1111/j.1095-8339.1891.tb00626.x

Mönkemeyer, W. (1927) *Die Laubmoose Europas*. Akademische Verlagsgesellschaft, Leipzig, x + 960 pp.

Müller, C. (1878–1879) Prodromus bryologiae Argentinicae I. *Linnaea* 42: 217–460.

Müller, C. (1890) Bryologia Austro-Georgiae 2. *In*: Neumayer, G.B. (ed.) *Die internationale Polarforschung 1882–1883*. A. Asher & Co., Berlin, pp. 279–322.

Müller, C. (1898) Bryologia provinciae Schen-si Sinensis ex collectione Giraldiana III. *Nuovo Giornale Botanico Italiano, new series* 5: 158–209.

Müller, F.A. (1829) Erstes Verzeichnis sardinischer Laubmoose, wie auch derjenigen welche von meinem Freunde Herrn Fleischer bei Smyrna aufgefunden worden sind, nebst Beschreibungen und Abbildungen einiger neuer Arten. *Flora* 12: 385–396.

Nadot, S., Bajon, R. & Lejeune, B. (1994) The chloroplast gene *rps4* as a tool for the study of Poaceae phyloneny. *Plant Systematics and Evolution* 191: 27–38.

Nixon, K.C. (1999) The parsimony ratchet, a new method for rapid parsimony analysis. *Cladistics* 15: 407–414.
http://dx.doi.org/10.1006/clad.1999.0121

Ochyra, R., Zarnowiec, J. & Bednarek-Ochyra, H. (2003) Census catalogue of Polish mosses. *Biodiversity of Poland* 3: 1–372.

Ozeki, M., Isagi, Y., Tsubota, H., Jacklyn, P. & Bowman, D.M.J.S. (2007) Phylogeography of an Australian termite, *Amitermes laurensis* (Isoptera, Termitidae), with special reference to the variety of mound shapes. *Molecular Phylogenetics and Evolution* 42: 236–247.
http://dx.doi.org/10.1016/j.ympev.2006.06.024

Potier de la Varde, R. (1936) *Luisierella*, genus novum familliae Pottiacearum, s.f. Pottioideaearum. *Bulletin de la Société Botanique de France* 83: 73–76.
http://dx.doi.org/10.1080/00378941.1936.10837293

Podpěra, J (1954) *Conspectus Muscorum Europaeorum*. Československé akademie věd, Praha, 697 pp.

Reese, W.D. (1984) *Mosses of the Gulf South from the Rio Grande to the Apalachicola*. Louisiana State University Press, Baton Rouge, 252 pp.

Saito, K. (1975) A monograph of Japanese Pottiaceae (Musci). *Journal of the Hattori Botanical Laboratory* 39: 373–537.

Schimper, W.P. (1856) *Corollarium Bryologiae Europaeae.* E. Schweizerbart, Stuttgart, 141 pp.

Schimper, W.P. (1860) *Synopsis Muscorum Europaeorum*. E. Schweizerbart, Stuttgart, clix + v + 733 pp.

Schwägrichen, C.F. (1811) *Species Muscorum Frondosorum, Supplementum Primum 1 sect. 1.* Barth, Leipzig, xvi + 196 pp. + 49 pls.

Schwägrichen, C.F. (1826) *Species Muscorum Frondosorum, Supplementum Primum 2 sect. 1.* Barth, Leipzig, iii + 79 pp. + pl. 151–175.

Schwarz, G. (1978) Estimating the dimension of a model. *The Annals of Statistics* 6: 461–464. http://dx.doi.org/10.1214/aos/1176344136

Shimodaira, H. (2002) An approximately unbiased test of phylogenetic tree selection. *Systematic Biology* 51: 492–508. http://dx.doi.org/10.1080/10635150290069913

Shimodaira, H. (2004) Approximately unbiased tests of regions using multistep-multiscale bootstrap resampling. *The Annals of Statistics* 32: 2616–2641. http://dx.doi.org/10.1214/009053604000000823

Shimodaira, H. & Hasegawa, M. (2001) CONSEL: for assessing the confidence of phylogenetic tree selection. *Bioinformatics* 17: 1246–1247. http://dx.doi.org/10.1093/bioinformatics/17.12.1246

Sikes, D.S. & Lewis, P.O. (2001) *Software manual for PAUPRat: a tool to implement Parsimony Ratchet searches using PAUP*.* University of Connecticut, Storrs, 12 pp.

Stamatakis, A. (2014) RAxML Version 8: a tool for phylogenetic analysis and post-analysis of large phylogenies. *Bioinformatics* 30: 1312–1313. http://dx.doi.org/10.1093/bioinformatics/btu033

Stech, M. (2008) A morpho-molecular classification of the mosses (Bryophyta). *Nova Hedwigia* 86: 1–21.

Stech, M., McDaniel, S.F., Hernández-Maqueda, R., Ros, R.M., Werner, O., Muñoz, J. & Quandt, D. (2012) Phylogeny of haplolepideous mosses — challenges and perspectives. *Journal of Bryology* 34: 173–186. http://dx.doi.org/10.1179/1743282012y.0000000014

Steere, W.C. (1945) *Luisierella*, a genus of mosses new to North America. *The Bryologist* 48: 83–85. http://dx.doi.org/10.2307/3239127

Sugiura, N. (1978) Further analysis of the data by Akaike's information criterion and the finite corrections. *Communications in Statistics: Theory and Methods* 7: 13–26.

Suzuki, T., Inoue, Y., Tsubota, H. & Iwatsuki, Z. (2013) Notes on *Aptychella* (Sematophyllaceae, Bryopsida): *Yakushimabryum longissimum*, syn. nov. *Hattoria* 4: 107–118.

Swofford, D.L. (2002) *PAUP*. Phylogenetic Analysis Using Parsimony (*and Other Methods), Version 4.0 beta version*. Sinauer Associates, Massachusetts, 142 + ii pp.

Tamura, K., Peterson, D., Peterson, N., Stecher, G., Nei, M. & Kumar, S. (2011) MEGA5: molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. *Molecular Biology and Evolution* 28: 2731–2739. http://dx.doi.org/10.1093/molbev/msr121

Tanabe, A.S. (2011) Kakusan4 and Aminosan: two programs for comparing nonpartitioned, proportional and separate models for combined molecular phylogenetic analyses of multilocus sequence data. *Molecular Ecology Resources* 11: 914–921. http://dx.doi.org/10.1111/j.1755-0998.2011.03021.x

Tanaka, A. (2012) Calcareous mosses in Japan. *Naturalistae* 16: 47–82. [In Japanese with English abstract]

Tsubota, H., Nakao, N., Arikawa, T., Yamaguchi, T., Higuchi, M., Deguchi, H. & Seki, T. (1999) A preliminary phylogeny of Hypnales (Musci) as inferred from chloroplast *rbcL* sequence data. *Hikobia* 7: 233–248.

Tsubota, H., Nakao, N., Yamaguchi, T., Seki, T. & Deguchi, H. (2000) Preliminary phylogenetic relationships of the genus *Brotherella* and its allied genera (Hypnales, Musci) based on chloroplast *rbcL* sequence data. *Journal of the Hattori Botanical Laboratory* 88: 77–99.

Tsubota, H., Akiyama, H., Yamaguchi, T. & Deguchi, H. (2001) Molecular phylogeny of the genus *Trismegistia* and related genera (Sematophyllaceae, Musci) based on chloroplast *rbcL* sequences. *Hikobia* 13: 529–549.

Tsubota, H., Ageno, Y., Estébanez, B., Yamaguchi, T. & Deguchi, H. (2003) Molecular phylogeny of the Grimmiales (Musci) based on chloroplast *rbcL* sequences. *Hikobia* 14: 55–70.

Tsubota, H., De Luna, E., González, D., Ignatov, M.S. & Deguchi, H. (2004) Molecular phylogenetics and ordinal relationships based on analyses of a large-scale data set of 600 *rbcL* sequences of mosses. *Hikobia* 14: 149–169.

Tsubota, H., Kubo, H. & Mukai, S. (2009) A new finding of seagrass *Halophila nipponica* J.Kuo (Hydrocharitaceae) from Miyajima Island in Hiroshima Prefecture, SW Japan. *Hikobia* 15: 339–347. [In Japanese with English abstract and protocol]

Tsubota, H., Kubo, H., Ohno, A., Inoue, Y., Nakahara-Tsubota, M., Takeuchi, K., Matsui, K., Uchida, S. & Mukai, S. (2013) Notes on naturalized plants in Hiroshima Prefecture: 4. New locality and phylogeny of *Sisymbrium orientale* L. (Brassicaceae) and its related species. *Hikobia* 16: 321–334. [In Japanese with English abstract and protocol]

Wahrmund, U., Rein, T., Müller, K.F., Groth-Malonek, M. & Knoop, V. (2009) Fifty mosses on five trees: comparing phylogenetic

information in three types of non-coding mitochondrial DNA and two chloroplast loci. *Plant Systematics and Evolution* 282: 241–255.
http://dx.doi.org/10.1007/s00606-008-0043-x

Wahrmund, U., Quandt, D. & Knoop, V. (2010) The phylogeny of mosses – Addressing open issues with a new mitochondrial locus: Group 1 intron *cobi420*. *Molecular Phylogenetics and Evolution* 54: 417–426.
http://dx.doi.org/10.1016/j.ympev.2009.09.031

Walther, K. (1983) Bryophytina. Laubmoose. *In*: Gerloff, J. & Poelt, A. (Eds.) *A. Engler's Syllabus der Pflanzenfamilien : mit besonderer Berücksichtigung der Nutzpflanzen nebst einer Übersicht über die Florenreiche und Florengebiete der Erde Kapitel V (2)*. Gebrüder Borntraeger, Berlin, 108 pp.

Werner, O., Ros, R.M., Cano, M.J. & Guerra, J. (2004) Molecular phylogeny of Pottiaceae (Musci) based on chloroplast *rps4* sequence data. *Plant Systematics and Evolution* 243: 147–164.
http://dx.doi.org/10.1007/s00606-003-0076-0

Werner, O., Rams, S., Kučera, J., Larraín, J., Afonina, O.M., Pisa, S. & Ros, R.M. (2013) New data on the moss genus *Hymenoloma* (Bryophyta), with special reference to *H. mulahaceni*. *Cryptogamie, Bryologie* 34: 1–18.
http://dx.doi.org/10.7872/cryb.v34.iss1.2013.13

Zander, R.H. (1993) Genera of the Pottiaceae: mosses of harsh environments. *Bulletin of the Buffalo Society of Natural Sciences* 32: 1–378.

Zander, R.H. (2006) The Pottiaceae s. str. as an evolutionary lazarus taxon. *Journal of the Hattori Botanical Laboratory* 100: 581–602.

Zander, R.H. (2007) Nine easy steps for constructing reliable trees from published phylogenetic analyses. *Annals of Missouri Botanical Garden* 94: 690–708.
http://dx.doi.org/10.3417/0026-6493(2007)94[690:nesfcr]2.0.co;2

Zwickl, D.J. (2006) *Genetic algorithm approaches for the phylogenetic analysis of large biological sequence datasets under the maximum likelihood criterion*. Ph.D. dissertation, The University of Texas at Austin, Austin, x + 115 pp.