



Frullania subarctica—a new species of the *Frullania tamarisci* complex (Frullaniaceae, Marchantiophyta)

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Abstract

This study tests the phylogenetic affinity and clarifies the taxonomy of *Frullania tamarisci* s. l. in Russia and adjacent areas based on critical morphological reinvestigation and DNA analyses. More than 100 accessions of *F. tamarisci* s. l. from the collections of KPABG, VBG and UBC were studied morphologically, and the nrITS1-5.8S-ITS2 and *trnL-trnF* cpDNA loci of sixteen accessions were sequenced. Molecular data were combined with accessions from GenBank and phylogenetic estimations by maximum parsimony, maximum likelihood and Bayesian approaches were performed. The tree topologies obtained were congruent and resolved the specimens previously referred to *F. nisquallensis* from Russian North in a clade together with an accession from Alaska. This clade is only distantly related to European *F. tamarisci* s. str. and temperate western North American *F. nisquallensis*. Taking into account the morphological differences, we describe a new species *Frullania subarctica* Vilnet, Borovich. & Bakalin *sp. nov.* The species status for *F. appendiculata* occurring mainly in temperate East Asia was supported by molecular evidence, based on specimens from the Primorsky Territory of Russia. Populations of *F. tamarisci* s. str. from the Russian North West and the Caucasus Mountains are quite similar to those from European countries both morphologically and molecularly.

Key words: DNA taxonomy, Jubulineae, liverworts, morphology, systematics

Introduction

Contemporary studies of previously poorly known local liverwort (Marchantiophyta) floras allow to redefine distributional range of some species, clarify their variability and reveal that sometimes commonly accepted binomials in fact represent genetically different entities that should be described as new species. The critical investigation of the genera *Jungermannia* L. and *Solenostoma* Mitt. in the Russian Far East liverwort flora resulted in the description of four new species (Bakalin & Vilnet 2009, 2012) that were before identified as Japanese vicariants of European taxa. Similar evidence were found in the Russian part of Caucasus with specimens of *Jubula hutchinsiae* (Hooker 1816: tab. 1) Dumort. (1822: 122) that had been ambiguously determined based on morphological evidence while DNA data suggested its separation from all known taxa and supported the description of the new subspecies, *Jubula hutchinsiae* subsp. *caucasica* Konstantinova & Vilnet (2011: 234) An integrative taxonomy approach applied to the genus *Frullania* Raddi (1918: 9) in New Zealand revealed the new species *Frullania knightbridgei* von Konrat & de Lange (2012: 28) as a segregate of *F. rostrata* (Hooker & Taylor 1845: 87) Gottsche *et al.* (1845: 445) which due to its taxonomical ambiguity “might well be regarded as a Southern Hemisphere equivalent of the Holarctic *Frullania tamarisci*” (von Konrat *et al.* 2012).

For over half a century *Frullania tamarisci* (Linnaeus 1753: 1134) Dumortier (1835: 13) s. l. has been the focus of morphological, biochemical and more recently, molecular studies, aimed at determining the number of taxa and their taxonomical status. Hattori (1972) accepted four subspecies, *F. tamarisci* subsp. *tamarisci*, *F. tamarisci* subsp. *obscura* (Verdoorn 1930: 80) Hattori (1972: 216) [= *F. appendiculata* Stephani (1897: 88)], *F. tamarisci* subsp. *asagrayana* (Montagne 1842: 14) Hattori (1966: 528), *F. tamarisci* subsp. *nisquallensis* (Sullivant 1849: 175) Hattori (1966: 528) based on morphological evidence. Hattori also showed that *F. tamarisci* subsp. *moniliata* sensu Kamimura p.p. (1961: 65) p.p., auct. non *Jungermannia moniliata* Reinwardt *et al.* (1825: 224), really represents *F. tamarisci* subsp. *obscura*

References

- Afonina, O.M. (2000) Bryophytes. In: Korneeva, T.M. (ed.) *Mosses and lichens of the Wrangel Island Nature Reserve*. Grif & Co, Moscow, pp. 6–46.
- Bakalin, V.A. (2012) A small collection of hepatics from Oregon and California. *Arctoa* 21: 201–205.
- Bakalin, V.A. & Vilnet, A.A. (2009) Two new species of Jungermanniaceae from Asian Russia. *Arctoa* 18: 151–162.
- Bakalin, V.A. & Vilnet, A.A. (2012) New combinations and new species of *Solenostoma* and *Plectocolea* (Solenostomataceae) from the Russian Far East. *Bryologist* 115: 566–584.
<http://dx.doi.org/10.1639/0007-2745-115.4.566>
- Crandall-Stotler, B., Stotler, R.E. & Geissler, P. (1987) A biosystematic study of the subspecies of *Frullania tamarisci* (L.). *Bryologist* 90: 287–308.
<http://dx.doi.org/10.2307/3243091>
- Dumortier, B.C. (1835) *Recueil d'Observations sur les Jungermanniacées. I. Révision des genres*. J.-A. Blanquart, Tournay, 27 pp.
- Evans, A.W. (1897) A revision of the North American species of *Frullania*, a new genus of Hepaticae. *Transactions of the Connecticut Academy of Arts and Sciences* 10: 1–39.
- Frahm, J.-P. (2006) *Frullania tamarisci* var. *azorica* (Jubulaceae, Marchantiopsida), a new taxon from the Azores. *Tropical Bryology* 27: 101–105.
- Goloboff, P., Farris, S. & Nixon, K. (2000) T.N.T.: Tree analysis using New Technology. Program and documentation, available from the authors, and at www.zmuc.dk/public/phylogeny.
- Gottsche, C.M., Lindenberg, J.B.G. & Nees von Esenbeck C.G. (1845) *Synopsis Hepaticarum, fasc. 3*. Meissner, Hamburg, pp. 305–464.
- Guindon, S., Dufayard, J.F., Lefort, V., Anisimova, M., Hordijk, W., & Gascuel, O. (2010) New Algorithms and Methods to Estimate Maximum-Likelihood Phylogenies: Assessing the Performance of PhyML 3.0. *Systematic Biology* 59: 307–321.
<http://dx.doi.org/10.1093/sysbio/syq010>
- 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.
- Hattori, S. (1972) *Frullania tamarisci*-complex and the species concept. *Journal of the Hattori Botanical Laboratory* 35: 202–251.
- Hattori, S. (1973) *Frullania tamarisci* from Lena, Siberia. *Miscellanea Bryologica et Lichenologica* 6: 72–73.
- Hattori, S. (1966) Anthocerotae and Hepaticae. In: Hara, H. (ed.) *Flora of Eastern Himalaya, I*. University of Tokyo Press, Tokyo, pp. 501–536.
- Heinrichs, J., Hentschel, J., Bombosch, A., Fiebig, A., Reise, J., Edelmann, M., Kreier, H.-P., Schäfer-Verwimp, A., Caspari, S., Schmidt, A., Zhu, R.-L., von Konrat, M., Shaw, B. & Shaw, A.J. (2010) One species or at least eight? Delimitation and distribution of *Frullania tamarisci* (L.) Dumort. s.l. (Jungermanniopsida, Porellales) inferred from nuclear and chloroplast DNA markers. *Molecular Phylogenetics and Evolution* 56: 1105–1114.
<http://dx.doi.org/10.1016/j.ympev.2010.05.004>
- Hentschel, J., von Konrat, M., Pócs T., Schäfer-Verwimp, A., Shaw, A.J., Schneider, H. & Heinrichs, J. (2009) Molecular insights into the phylogeny and subgeneric classification of *Frullania Raddii* (Frullaniaceae, Porellales). *Molecular Phylogenetics and Evolution* 52: 142–156.
<http://dx.doi.org/10.1016/j.ympev.2008.12.021>
- Hooker, J.D. & Taylor, T. (1845) Hepaticae Antarcticae, supplementum; or specific characters, with brief descriptions. of some additional species of the Hepaticae of the Antarctic regions, New Zealand, and Tasmania, together with a few from the Atlantic Islands and New Holland. *London Journal of Botany* 4: 79–97.
- Hooker, W.J. (1816) *British Jungermanniae being a history and description, with figures, of each species of the genus, and microscopical analysis of the parts*. London: Longmans.
- Howe, M.A. (1894) Notes on Californian bryophytes. 1. *Erythea* 2: 97–101.
- Kamimura, M. (1961) A monograph of Japanese Frullaniaceae. *Journal of the Hattori Botanical Laboratory* 24: 1–109.
- Katagiri, T. & Furuki, T. (2012) Checklist of Japanese liverworts and hornworts. *Bryological Research* 10: 193–210.
- Keane, T.M., Naughton, T.J. & McInerney, J.O. (2004) ModelGenerator: amino acid and nucleotide substitution model selection. Available from: <http://bioinf.may.ie/software/modelgenerator/>
- Konstantinova, N.A., Bakalin, V.A., Andreeva, E.N., Bezgodov, A.G., Borovichev, E.A., Dulin, M.A. & Mamontov, Y.S. (2010 [“2009”]) Checklist of liverworts (Marchantiophyta) of Russia. *Arctoa* 18: 1–64.
- Konstantinova, N.A. & Vilnet, A.A. (2011) *Jubula hutchinsiae* ssp. *caucasica* subsp. nov. (Jubulaceae, Marchantiophyta) — new taxon from western Caucasus. *Arctoa* 20: 227–238.

- Linnaeus, C. (1753) *Species Plantarum*, ed. 1. Holmiae [Stockholm], 1200 pp.
- Liu, K., Warnow, T.J., Holder, M.T., Nelesen, S.M., Yu, J., Stamatakis, A.P. & Linder, C.R. (2012) SATé-II: Very Fast and Accurate Simultaneous Estimation of Multiple Sequence Alignments and Phylogenetic Trees. *Systematic Biology* 61: 90–106.
<http://dx.doi.org/10.1093/sysbio/syr095>
- Montagne, J.P. (1842). Cryptogamae Nilgherienses seu plantarum cellularium in montibus peninsulae indicae Neel-Gherries dictis à cl. Perrottet collectarum enumeratio. *Annales des Sciences Naturelles, Botanique, Sér. 2*. 18: 12–23.
- Pattengale, N.D., Alipour, M., Bininda-Emonds, O.R.P., Moret, B.M.E. & Stamatakis, A. (2010) How many bootstrap replicates are necessary? – *Journal of Computational Biology* 17: 337–354.
<http://dx.doi.org/10.1089/cmb.2009.0179>
- Pearson, W.H. (1894). *Frullania microphylla*. *Journal of Botany, British and Foreign* 32: 328–330.
- Raddi, G. (1818) *Jungermannioграфия Etrusca*. La Società tipografica, Modena, 45 pp.
- Rambaut, A. & Drummond, A.J. (2007) Tracer v1.4. Available from <http://beast.bio.ed.ac.uk/Tracer>.
- Reinwardt, C.G.C., Blume, C. & Nees von Esenbeck, C.G. (1825) Hepaticae javanicae. *Nova Acta Physico-medica Academiae Caesareae Leopoldino-Carolinae Naturae Curiosorum Exhibentia Ephemerides sive Observationes Historias et Experimenta* 12: 181–238
- Ronquist, F., Teslenko, M., van der Mark, P., Ayres, D.L., Darling, A., Höhna, S., Larget, B., Liu, L., Suchard, M.A. & Hülsenbeck, J.P. (2012) MrBayes 3.2: Efficient Bayesian phylogenetic inference and model choice across a large model space. *Systematic Biology* 61: 539–542.
<http://dx.doi.org/10.1093/sysbio/sys029>
- Schljakov, R.N. (1982) *Pechenochnye Mchi Severa SSSR*. 5. Nauka, Leningrad, 196 pp.
- Sim-Sim, M., Fontinha, S., Mues, R. & Lion, U. (2000) A new *Frullania* species (subg. *Frullania*) from Deserta Grande, Madeira archipelago, *Frullania sergiae* sp. nov. *Nova Hedwigia* 71: 185–193.
- 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>
- Steere, W.C. & Inoue, H. (1978) The Hepaticae of Arctic Alaska. *Journal of the Hattori Botanical Laboratory* 44: 251–345.
- Stephani, F. (1897) Hepaticae Japonicarum. *Bulletin de l'Herbier Boissier, série 2* 5: 76–108.
- Stephani, F. (1887) Hepaticae d'Africa. In: Henriques, J.A. (ed.) *Especies distribuidas*. *Boletim da Sociedade Broteriana*. Coimbra, 5: pp. 1–258.
- Stephani, F. (1912) *Species Hepaticarum IV*. Georg & Cie, Genève & Bale, 824 pp.
- Sullivant, W.S. (1849) Contributions to the bryology and hepaticology of North America. II. *Memoirs of the American Academy of Arts and Science* 4: 169–176.
<http://dx.doi.org/10.2307/25058157>
- Taberlet, P., Gielly, L., Pautou, G. & Bouvet, J. (1991) Universal primers for amplification of three non-coding regions of chloroplast DNA. *Plant Molecular Biology* 17: 1105–1109.
<http://dx.doi.org/10.1007/bf00037152>
- Tamura, K., Peterson, D., Peterson, N., Stecher, G., Nei, M. & Kumar, S. (2011) MEGA 5: Molecular Evolutionary Genetics Analysis Using Maximum Likelihood, Evolutionary Distance, and Maximum Parsimony Method. *Molecular Biology and Evolution* 28: 2731–2739.
<http://dx.doi.org/10.1093/molbev/msr121>
- Verdoorn, F. (1930) Die Frullaniaceae der Indomalesischen Inseln (De Frullaniaceis VII). *Annales Bryologici, suppl.* 1: 1–187.
- White, T.J., Bruns, T., Lee, S. & Taylor, J. (1990) Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: Innis, M.A., Gelfand, D.H., Snisky, J.J. & White, T.J. (eds.) *PCR protocols: a guide to methods and applications*. San Diego, pp. 315–322.
- von Konrat, M., de Lange, P., Greif, M., Strozier, L., Hentschel, J., Heinrichs, J. (2012) *Frullania knightbridgei*, a new liverwort (Frullaniaceae, Marchantiophyta) species from the deep south of Aotearoa-New Zealand based on integrated evidence-based approach. *PhytoKeys* 8: 13–36.
<http://dx.doi.org/10.3897/phytokeys.8.2496>
- Yamada, K. & Iwatsuki, Z. (2006) Catalogue of the hepatics of Japan. *Journal of the Hattori Botanical Laboratory*, 99: 1–106.