Phytotaxa 164 (4): 239–254
www.mapress.com/phytotaxa/

Article

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

http://dx.doi.org/10.11646/phytotaxa.164.4.3

Auxosporulation, morphology of vegetative cells and perizonium of *Fallacia tenera* (Hust.) D.G. Mann (Bacillariophyceae)

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Abstract

Specimens of *Fallacia tenera* were collected from the surface sediment at in a river estuary in Japan. Auxosporulation occurred in a rough culture. Morphological structures of vegetative cells and auxospores were observed in detail. The vegetative cells have one H-shaped chloroplast. The striae were interrupted by two depressed lateral sterna internally and partly covered by a finely porous conopeum on the external surface. The lateral sterna and porous conopea formed two more or less curved longitudinal canals connecting with the exterior via opening pores on both sides of a terminal fissure. This combination of characteristics is unique to the genus *Fallacia*. The cingulum was composed of three bands, such as an open valvocupula and two comparatively thin pleurae. The two pleurae could be distinguished by the shape of their ligulae. The second band had a triangular ligula, whereas the ligula of the third band is arc-shaped. The auxosporulation was type IA1a in Geitler's classification. Two paired gametangia formed two anisogametes in each of them. Two auxospores formed in the thecae of the gametangia after a trans physiological anisogamy. The perizonium of the auxospore consisted of a set of transverse bands and five longitudinal bands. The primary transverse band was about twice wider than the secondary ones. The circular incunabular scales were present on the two terminals of the auxospore and on the surface of the primary transverse band. The primary longitudinal band had an acute terminal and was flanked by secondary longitudinal bands. Each side had two secondary longitudinal bands. All longitudinal bands were immediately beneath the transverse bands. Morphological comparison between *Fallacia* and *Pseudofallaica*, and the taxonomic position of *F. tenera* is also discussed.

Key words: Auxospore, Auxosporulation, Conopeum, Depressed later sterna, Diatom, *Fallacia tenera*, Incunabula scales, Perizonium, *Pseudofallacia*, Sexual reproduction.

Introduction

The genus *Fallacia* A.J. Stickle & D.G. Mann in Round *et al.* (1990: 667) includes many small taxa formerly assigned to *Navicula* sect. *Lyratae* and sect. *Bacillares* (Hustedt 1961–1966). Most *Fallacia* species are epipelic and epipsammic, living among coastal and estuarine intertidal sediments (Sabbe *et al*. 1999, Round *et al*. 1990). The genus *Fallacia* is characterized by a single H-shaped plastid, lyre-shaped hyaline lateral areas and finely porous conopeum partly or completely covering the striae (Round *et al.* 1990). The taxonomy of this genus has been studied by Sabbe *et al.* (1999) and Garcia (2003). There also have other reports of the genus *Fallacia* (Witkowski 1991, 1993, Witkowski *et al.* 2000, Procopiak & Fernandes 2003, Mann & Stickle 2009, Rakowska 2010). Diatoms in the genus *Fallacia* have a well-developed finely porous conopeum, elevated silica structure on the mantle and intricate structure of the valve. We still know little about those structures and their variation in many *Fallacia* species. In addition, the morphology of many *Fallacia* species has never been studied in detail.

Recently, a new genus *Pseudofallacia* Y. Liu, Kociolek & Q. X. Wang (2012: 624) was proposed based on the morphological study of *Pseudofallacia occulta* (Krasske) Y. Liu, Kociolek & Q. X. Wang (2012: 625). Four species of *Fallacia* were transferred to this new genus, including *Fallacia tenera* (Hust.) D.G. Mann in Round *et al.* (1990: 669) (Liu *et al.* 2012). *Pseudofallacia* differs from *Fallacia* mainly in the structure of lateral canals on both sides of the raphe. The canals in *Pseudofallacia* are formed by the depressed part of valve plane, which continue to

Accepted by Patrick Kociolek: 11 March 2014; published: 11 Apr. 2014

References

Anonymous (1975) Proposals for a standardization of diatom terminology and diagnoses. *Nova Hedwigia, Beiheft* 53: 323–354.

Boyer, C.S. (1927) Synopsis of North American diatomaceae, supplement, part 2.-Naviculatae, Surirellatae. *Proceedings of the Academy of Natural Sciences of Philadelphia* 79: 229–583.

Cleve, P.T.(1894) Synopsis of the Naviculoid Diatoms, Part I. *Kongliga Svenska-Vetenskaps Akademiens Handlingar*, 26: 1–194.

Cleve, P.T. & Grunow, A. (1880) Beiträge zur Kenntniss der Arctischen Diatomeen. *Kongliga Svenska-Vetenskaps Akademiens Handlingar*, Vol: 17, Issue: 2, 121 pp.

Garcia, M. (2003) Observations on the diatom genus *Fallacia* (Bacillariophyta) from southern Brazilian sandy beaches. *Nova Hedwigia* 77: 3–4.
http://dx.doi.org/10.1127/0029-5035/2003/0077-0309

Geitler, L. (1973) Auxosporenbildung und Systematik bei pennaten Diatomeen und die Cytologie von Cocconeis–Sippen. *Österreichische botanische Zeitschrift* 122: 299–321.
http://dx.doi.org/10.1007/bf01376232

Grunow, A. (1860) Über neue oder ungenügend gekannte Algen. Erste Folge, Diatomeen, Familie Naviculaceen. *Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft in Wein* 10: 503–582.

Grunow, A. (1862) Die österreichischen Diatomaceen nebst Anschluss einiger neuen Arten von andern Lokalitäten und einer kritischen Uebersicht der bisher bekannten Gattungen und Arten. Erste Folge. Epithemieae, Meridioneae, Diatomeae, Entopyleae, Surirelleae, Amphipleureae. Zweite Folge. Familie Nitzschieae. *Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft in Wien*, 12: 315–472, 545–588.
http://dx.doi.org/10.5962/bhl.title.64361

Guiry, M.D. & Guiry, G.M. (2013) *AlgaeBase*. World-wide electronic publication, National University of Ireland, Galway. Available from: http://www.algaebase.org/ (accessed:12 March 2013).

Hustedt, F. (1937) Systematische und ökologische Untersuchungen über die Diatomeenflora von Java, Bali und Sumatra nach dem Material der Deutschen Limnologischen Sunda-Expedition. Teil I. Systematischer Teil, Fortsetzung. . *Archiv für Hydrobiologie, Supplement* 15: 187–295.

Hustedt, F. (1961–1966) Die Kieselalgen Deutschlands, Österreichs und der Schweiz. In Dr. L. Rabenhorsts (ed.) *Kryptogamenflora von Deutschland, Österreich und der Schweiz*, Band 7, Teil 3, Akademische Verlagsgesellschaft, Leipzig: 816 pp.

Idei, M., Sato, S., Watanabe T., Nagumo, T. & Mann, D.G. (2013) Sexual reproduction and auxospore structure in *Diploneis papula* (Bacillariophyta). *Phycologia* 52: 295–308.
http://dx.doi.org/10.2216/12-021.1

Ishii, O., Idei, M., Suzuki, H., Nagumo, T. & Tanaka, J. (2012) Sexual reproduction and fine structure of auxospore in *Caloneis linearis* (Bacillariophyceae). *Journal of Japanese Botany* 87: 96–107.

Johnston, C. (1860) Descriptions of Diatomaceae, chiefly of those found in "Elide" (Lower California) Guano. *Quarterly Journal of Microscopical Science* 8:18–21.

Jurasinski G (2007) simba: A Collection of Functions for Similarity Calculation of Binary Data. R package version 0.2–5, URL http://CRAN.R-project.org/package=simba.

Karsten G. (1899) Die diatomeen der kieler bucht. *Wissenschaftliche meeresuntersuchungen*, N.F. (Kiel) 4:1–205.

Kaczmarska, I., Davidovich, N. A. & Ehrman, J. M. (2007) Sex cells and reproduction in the diatom *Nitzschia longissima* (Bacillariophyta): discovery of siliceous scales in gamete cell walls and novel elements of the perizonium. *Phycologia* 46: 726–737.
http://dx.doi.org/10.2216/07-04.1

Kaczmarska, I., Poulíčková, A., Sato, S., Edlund, M.B., Idei, M., Watanabe, T., & Mann, D.G. (2013) Proposals for a terminology for diatom sexual reproduction, auxospores and resting stages. *Diatom Research* 28: 263–294.
http://dx.doi.org/10.1080/0269249x.2013.791344

Kützing, F.T. (1844) *Die Kieselschaligen. Bacillarien oder Diatomeen*. Zu finden bei W. Köhne, Nordhausen, 152 pp., 30 pls.
http://dx.doi.org/10.1080/037454809495289

Liu, Y., Kociolek, J. P., Fan, Y. & Wang, Q. (2012) *Pseudofallacia gen. nov.*, a new freshwater diatom (Bacillariophyceae) genus based on *Navicula occulta* Krasske. *Phycologia* 51: 620–626.
http://dx.doi.org/10.2216/11-098.1

Mann, D.G. (1982) Structure, life history and systematics of *Rhoicosphenia* (Bacillariophyta) II. Auxospore formation and perizonium structure of *Rh. curvata. Journal of Phycology* 18: 264–274.
http://dx.doi.org/10.1111/j.1529-8817.1982.tb03183.x

Mann, D.G. (1989) On auxospore formation in *Caloneis* and the nature of *Amphiraphia* (Bacillariophyta). *Plant Systematics and Evolution* 163: 43–52.
http://dx.doi.org/10.1007/bf00936152

Mann, D.G. & Poulíčková, A. (2009) Incunabula and perizonium of *Neidium* (Bacillariophyta). *Fottea* 9: 211–222.

Mann, D.G., Poulíčková, A., Sato, S. & Evans, K.M. (2011) Scaly incunabula, auxospore development, and girdle

polymorphism in *Sellaphora marvanii sp. nov.* (Bacillariophyceae). *Journal of Phycology* 47: 1368–1378.
http://dx.doi.org/10.1111/j.1529-8817.2011.01058.x

Mann, D.G., Sato, S., Rovira, R. & Trobajo, S. (2013) Paedogamy and auxosporulation in *Nitzschia* sect. *Lanceolatae* (Bacillariophyta). *Phycologia* 52: 204–220.
http://dx.doi.org/10.2216/12-077.1

Mann, D.G. & Stickle, A.J. (2009) Cytological characteristics of the Sellaphoraceae. Acta botanica croatica 68: 239–250

McIntire, C.D. & Reimer, C.W. (1974) Some marine and brackish-water *Achnanthes* from Yaquina Estuary, Oregon (U.S.A.). *Botanica Marina* 17:164–175.
http://dx.doi.org/10.1515/botm.1974.17.3.164

Medlin, L.K. & Kaczmarska, I. (2004) Evolution of the diatoms: V. Morphological and cytological support for the major clades and a taxonomic revision. *Phycologia* 43: 245–270.
http://dx.doi.org/10.2216/i0031-8884-43-3-245.1

Nagumo, T. & Kobayasi, H. (1990) The bleaching method for gently loosening and cleaning a single duatom frustule. *Diatoms* 5: 45–50.

Østrup, E. (1913) Diatomaceae ex Insulis Danicis Indiae occidentalis. *Dansk Botanisk Arkiv* 1: 1–39.
http://dx.doi.org/10.5962/bhl.title.3831

Patrick, R.M. & Freese, L.R. (1961) Diatoms (Bacillariophyceae) from Northern Alaska. *Proceedings of the Academy of Natural Sciences of Philadelphia* 112: 129–293.

Poulíčková, A. & Mann, D.G. (2006) Sexual reproduction in *Navicula cryptocephala* (Bacillariophyceae). *Journal of Phycology* 42: 872–886.
http://dx.doi.org/10.1111/j.1529-8817.2006.00235.x

Poulíčková, A., Mayama, S., Chepurnov, V. A. & Mann, D.G. (2007) Heterothallic auxosporulation, incunabula and perizonium in *Pinnularia* (Bacillariophyceae). *European Journal of Phycology* 42: 367–390.
http://dx.doi.org/10.1080/09670260701476087

Procopiak, L. & Fernandes, L. (2003) Valve morphology of the benthic diatom *Fallacia marnieri* (Manguin) Witkowski (Sellaphoraceae-Bacillariophyta). *Brazilian Journal of Biology* 63: 113–119.
http://dx.doi.org/10.1590/s1519-69842003000100015

R Development Core Team (2008) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Rasband, W.S. (1997–2012) ImageJ, U. S. National Institutes of Health, Bethesda, Maryland, USA, http://imagej.nih.gov/ij/.

Rakowska, B. (2010) *Fallacia helensis* (schulz) D.G. Mann and associated diatoms in water drained from the "bełchat w brown coal mine". *Diatom Research* 25: 349–354.
http://dx.doi.org/10.1080/0269249x.2010.9705855

Ross, R., Cox, E.J., Karayeva, N.I., Mann, D.G., Paddock, T.B.B, Simonsen, R. & Sims, P.A. (1979) An amended terminology for the siliceous components of the diatom cell. *Nova Hedwigia Beiheft* 64: 513–533.

Round, F.E. (1953) An investigation of two benthic algal communities in Malham Tarn, Yorkshire. *The Journal of Ecology*, 174–197.
http://dx.doi.org/10.2307/2257108

Round, F.E., Crawford, R.M. & Mann D.G. (1990) *The diatoms: biology & morphology of the genera*. Cambridge University Press, Cambridge, 747 pp.

Sabbe, K., Vyverman, W. & Muylaert, K. (1999) New and little-known *Fallacia* species (Bacillariophyta) from brackish and marine intertidal sandy sediments in Northwest Europe and North America. *Phycologia* 38: 8–22.
http://dx.doi.org/10.2216/i0031-8884-38-1-8.1

Sato, S., Nagumo, T. & Tanaka, J. (2004) Auxospore formation and the morphology of the initial cell of the marine araphid diaotm *Gephyria media* (Bacillariophyceae). *Journal of Phycology* 40: 684–691.
http://dx.doi.org/10.1111/j.1529-8817.2004.03164.x

Sato, S., Kuriyama, K., Tadano, T. & Medlin, L.K. (2008a) Auxospore fine structure in a marine araphid diatom *Tabularia parva*. *Diatom Research* 23: 423–433.
http://dx.doi.org/10.1080/0269249x.2008.9705767

Sato, S., Mann, D.G., Matsumoto, S. & Medlin, L.K. (2008b) *Pseudostriatella* (Bacillariophyta): a description of a new araphid diatom genus based on observations of frustule and auxospore structure and 18S rDNA phylogeny. *Phycologia* 47: 371–391.
http://dx.doi.org/10.2216/ph08-02.1

Sato, S., Mann, D.G., Nagumo, T., Tanaka, J., Tadano, T. & Medlin, L.K. (2008c) Auxospore Fine Structure and variation in modes of cell size changes in *Grammatophora marina* (Bacillariophyta). *Phycologia* 47: 12–27.
http://dx.doi.org/10.2216/07-34.1

Schmidt, A., Fricke, F., Heiden, H., Müller, O. & Hustedt, F. (1874–1959) *Atlas der Diatomaceen-kunde*. R. Reisland, Ascherleben, Leipzig. 10 vol., 472 pl.

Schoeman, F.R. & Archibald, R.E.M. (1976–1980) *Diatom flora of Southern Africa*: CSIR, Special Report, Pretoria.

Sims, P.A. & Paddock, T.B.B. (1979) Observations and comments on some prominent morphological features of naviculoid genera. *Nova Hedwigia, Beiheft* 64: 169–191.

Simonsen, R. (1987) *Atlas and catalogue of the diatom types of Friedrich Hustedt*. J. Cramer, Berlin, 524 pp. 772 pl.
Stosch, H.A. (1982) On auxospore envelopes in diatoms. *Bacillaria* 5: 127–156.
Toyoda, K., Idei, M., Nagumo, T. & Tanaka, J. (2005) Fine-structure of the vegetative frustule, perizonium and initial valve of *Achnanthes yaquinensis* (Bacillariophyta). *European Journal of Phycology* 40: 269–279.
http://dx.doi.org/10.1080/09670260500150511
Toyoda, K., Williams, D.M., Tanaka, J. & Nagumo, T. (2006) Morphological investigations of the frustule, perizonium and initial valves of the freshwater diatom *Achnanthes crenulata* Grunow (Bacillariophyceae). *Phycological Research* 54: 173–182.
http://dx.doi.org/10.1111/j.1440-1835.2006.00420.x
Trobajo, R., Mann, D.G., Chepurnov, V.A., Clavero, E. & Cox, E.J. (2006) Taxonomy, life cycle, and auxosporulation of *Nitzschia fonticola* (Bacillariophyta). *Journal of Phycology* 42: 1353–1372.
http://dx.doi.org/10.1111/j.1529-8817.2006.00291.x
William, D.M. & Round, F.E. (1986) Revision of the genus *Synedra* Ehrenb. Diatom Research 1:313–339
http://dx.doi.org/10.1080/0269249x.1986.9704976
Witkowski, A. (1991) *Fallacia cassubiae sp. nov.*, a new brackish-water diatom from the puck bay (southern baltic sea), poland. *Diatom Research* 6: 401–409.
http://dx.doi.org/10.1080/0269249x.1991.9705184
Witkowski, A. (1993) *Fallacia florinae* (moeller) *comb. nov.* a marine, epipsammic diatom. *Diatom Research* 8: 215–219.
http://dx.doi.org/10.1080/0269249x.1993.9705254
Witkowski, A., Lange-Bertalot, H. & Metzeltin, D. (2000). Diatom flora of marine coasts I. Vol. 12. *In*: Lange-Bertalot, H. (ed.) *Iconographia Diatomologica*. A.R.G. Gantner Verlag K.G., Ruggell, 925 pp.