DIDERMA MEYERAE

A. Sporocarps (bar = 1 mm). **B**. Capillitium and spores (bar = 20 µm). [Photographs: A. Michaud]

Diderma meyerae H. Singer, G. Moreno, Illana & A. Sánchez, *Cryptogamie* Mycologie **24**(1): 53 (2003). [*IndexFungorum* 461888; *Didymiaceae*, *Stemonitiida*]

Diagnostic features. Sporangia pale and usually sessile; distinguished from other nivicolous *Diderma* species by the non-reticulate capillitium, the double-layered peridium with an iridescent inner layer, and warted spores.

On natural substratum. *Amoebal state* no information. *Plasmodium* white. *Hypothallus* white to ochraceous yellow, sparse to extensive. *Sporocarps* sessile sporangia. *Stalks* absent. *Sporothecae* subglobose, strongly aggregated, 0·7–2·5 mm diam., white or pale pinkish ochraceous. *Peridium* double-layered, the outer thick, eggshell, snow white, the inner membranous, iridescent, mottled with white spots; dehiscence irregular. *Columella* well developed, subglobose, ochraceous cream to pale ferruginous, 0·4–0·6 mm diam. *Capillitium* partly rugose, radiating, abundant, dark brown, hoary to violaceous, the filaments often rather thick, 1–5 µm diam., marked with frequent swellings, with dark nodes and paler ramifications at the extremities. *Spores* black *en masse*, individually violaceous, globose, warted, 10–13(–15) µm diam.

ASSOCIATED ORGANISMS & SUBSTRATA: **Plantae**. *Alnus alnobetula* (Ehrh.) K. Koch [as *A. viridis* (Chaix) DC.], *Alnus* sp. (stem); *Apiaceae* indet (stem); *Calluna vulgaris* L.; *Epilobium* sp.; *Fagus sylvatica* L. (branch, leaf, twig); *Galeopsis tetrahit* L. (flower, twig); *Gramineae* indet.; *Juniperus communis* L. [also as *J. communis* subsp. *hemisphaerica* (J. Presl & C. Presl) Nyman] (leaf), *Juniperus* sp.; *Plantae* indet. (twig); *Poaceae* indet.; *Rhododendron ferrugineum* L., *Rhododendron* sp. (twig); *Rubus* sp. (stem); *Vaccinium myrtillus* L. (twig), *Vaccinium* sp. **Protista**. *Diderma niveum* (Rostaf.) E. Sheld. [as *D. niveum* var. *alpinum* not traced]. **Associated organism of type specimen**. *Magnoliophyta* [as 'on herbs']. **Comment**. This species occurs on living branches, living flowers, living and dead stems, living and dead dry fallen twigs, and dry fallen leaves.

INTERACTIONS & HABITATS: For a thorough introduction to myxomycete ecology, see MADELIN (1984). The dead plant material with which myxomycetes are very widely associated, while undoubtedly a platform for their sporocarps, is not necessarily a source of nutrition. Sporocarps are the only stage in myxomycete life cycles where species can be identified by morphology. The other states, as amoebae and plasmodia, have received little attention. SHCHEPIN *et al.* (2019) suggested that populations of myxomycete amoebae may inhabit much wider ecological niches than indicated by records of their sporocarps. With the advent of molecular techniques (KAMONO *et al.*, 2013), specific information about the ecology and nutrition of the amoebal state of *D. meyerae* is now starting to emerge (BORG DAHL, 2018; BORG DAHL *et al.*, 2018). In their amoebal state, myxomycetes are known to feed on small organic particles and micro-organisms (including some fungi), but the identity of those micro-organisms is rarely, if ever, recorded. This is a nivicolous species, found in spring near melting snow, mainly in mountainous or upland areas. Other than a single observation on moorland, virtually nothing is known about the habitats occupied by *D. meyerae*, though they presumably include alpine, subalpine and tundra vegetation, and perhaps woodland. Other myxomycetes have been observed growing on the same substratum. Although associations with animals and fungi are known or suspected, no observations were found where the associated organism was identified to genus or species level.

GEOGRAPHICAL DISTRIBUTION: ASIA: Japan, Kazakhstan (Almaty Oblast). EUROPE: Austria, France, Germany, Italy, Norway, Russia (Karachay-Cherkess Republic, Murmansk Oblast), Spain, Switzerland, Ukraine.

Elevation (m above sea level). Records up to 2900 (Russia: Karachay-Cherkess Republic), and 2000 (Japan).

Comment. More than 80% of all records are from France. Native to mountainous areas of Europe and northern Asia. There is a doubtful record of this species on bark of *Pinus sylvestris* from Turkey (ONER *et al.*, 2009).

ECONOMIC IMPACTS: There is experimental evidence that this species can accumulate heavy metals (KRYVOMAZ, 2015*a*; KRYVOMAZ & ANDRUSISHINA, 2015; KRYVOMAZ *et al.*, 2016*a*, *b*, 2017). KRYVOMAZ (2017*a*) measured metal levels in sporocarps of *D. meyerae*. The levels of different elements were, in descending order, as follows [µg of metal per g of myxomycete tissue]: Ca (11185), Mn (9705), Mg (595), Si (135), Al (85), Fe (75), Zn (65), Pb (10·5), Cd (1·05), Ni (0·9), Cu (0·15), Cr (0·05). Analysis of those results showed that Mn and the highly toxic heavy metal Cd were accumulated much more strongly by this species than by the others included in the study. Heavy metal accumulating properties are likely to have significant positive economic potential (STEPHENSON & MCQUATTIE, 2000). Although nothing has yet been developed for the present species, there is considerable interest in use of fungi with similar abilities for bioremediation and other applications (GADD, 2007). No evaluations have been made of any other possible positive economic impact of this organism (e.g. as a recycler, as a source of useful products, as a provider of checks and balances within its ecosystem, etc.). No reports of negative economic impacts have been found.

INFRASPECIFIC VARIATION: No subspecific taxa have been described. SINGER *et al.* (2005) synonymized *D. niveum* f. *pulverulentum* Meyl. with the present species, but this has not been accepted by *Nomen.mycetozoa.com* [accessed 17 November 2019], which treats it as a synonym of *D. niveum* (Rostaf.) E. Sheld. [*Descriptions* sheet **2214**].

DISPERSAL & TRANSMISSION: For a general discussion about myxomycete dispersal, see KRYVOMAZ & STEPHENSON (2017). Myxomycete spores are dispersed considerable distances by wind. Field experiments and mathematical modeling have shown that, with winds of 0·1 m/s, spores can travel up to *c.* 1·8 km, and when wind speed reaches 28 m/s, this rises to over 500 km (TESMER & SCHNITTLER, 2007). Spores and myxamoebae may be dispersed by rainwater, meltwater and water in soil. Some local dispersal may also occur by movement of myxamoebae and plasmodia. Insects and other invertebrates feed on sporophores, as probably do terrestrial vertebrates including birds, and myxomycete spores have been found in insect faeces, suggesting that animals may play a part in their dispersal. For some species (but probably very rarely or never nivicolous myxomycetes), plant debris floating in seawater may also contribute to dispersal between land masses.

CONSERVATION STATUS: The IUCN's Red Listing Criteria were originally designed for evaluation of vertebrate animals and flowering plants, and present challenges to those trying to apply them to organisms like myxomycetes which are unicellular for a significant part of their life cycle. A discussion of those challenges, particularly in respect of myxomycetes and climate change, is provided by KRYVOMAZ & STEPHENSON (2017). **Previous evaluations**. Red listed for Thuringia, Germany (MÜLLER & RIEMAY, 2011). **Information base**. Over 570 records (specimens, databases and bibliographic sources combined, excluding duplicates) from at least 1953 to May 2018, with observations in March, April, May, June, July, August and October. **Estimated extent of occurrence** [calculated using *http://geocat.kew.org*]. Well over 5·9 million km^2 (Asia: insufficient data; Europe: 5·9 million km^2). **Estimated area of occupancy** [calculated using *http://geocat.kew.org*]. Well over 642 km^2. The method for estimating area of occupancy has produced an artificially low figure. The species is likely to be under-recorded because of the small number of people with the skills to search for and identify it. Some of the plants with which it is associated are common and widespread species. **Threats**. Insufficient information to enable threats to be identified. In particular, possible vulnerabilities of the amoebal and plasmodial states of this species are currently completely overlooked. **Population trend**. Not known. Of datable records, *c.* 5% are pre-1961, 55% post-1960 but pre-2001, and 40% post-2000. Common in the Caucasus (SCHNITTLER *et al.*, 2015). **Evaluation**. Using IUCN criteria (IUCN SPECIES SURVIVAL COMMISSION. *2006 IUCN Red List of Threatened Species* [*www.iucnredlist.org*]. Downloaded on 15 May 2006), the species is assessed globally as Data Deficient. ***In situ* conservation actions**. None noted. ***Ex situ* conservation actions**. 201 nucleotide sequences and 6 PopSet sequences were found in a search of the NCBI GenBank database [*www.ncbi.nlm.nih.gov*, accessed 11 November 2019]. No living strains of this species are listed by the ATCC, CABI and Westerdijk Institute [formerly CBS] culture collections.

NOTES: SINGER *et al.* (2003) made a scanning electron microscope study of this species. Molecular techniques are now being developed to detect myxomycetes in soil, and this may make it possible to identify species in their amoebal state. *Diderma meyerae* was included in one such pioneering study (HOPPE & SCHNITTLER, 2015). Radiation levels in this and several other nivicolous myxomycetes were monitored by KRYVOMAZ (2015*b*), and found not to exceed acceptable levels.

LITERATURE & OTHER SOURCE MATERIAL: BORG DAHL, M. *Exploring the Diversity of Nivicolous Myxomycetes* An Analysis of the Genetic Diversity, Species Distribution and Community Composition. Thesis (Dr Rerum Naturalium), University of Greifswald, Germany: 114 pp. (2018). BORG DAHL, M., SHCHEPIN, O., SCHUNK, C., MENZEL, A., NOVOZHILOV, Y.K. & SCHNITTLER, M. A four year survey reveals a coherent pattern between occurrence of fruit bodies and soil amoebae populations for nivicolous myxomycetes. *Scientific Reports* **8** [11662]: 12 pp. (2018) [DOI: 10.1038/s41598-018-30131-3]. DUSSAUSSOIS, G., MICHAUD, A. & KRYVOMAZ, T.I. Myxomycètes nivicoles Pyrénéens et végétation. *Pyrénées* France **277**: 62-75 (2019). ERASTOVA, D.A., NOVOZHILOV, Y.K. & SCHNITTLER, M. Nivicolous myxomycetes of the Khibiny Mountains, Kola Peninsula, Russia. *Nova Hedwigia* **104**(1-3): 85-110 (2017). GADD, G.M. Geomycology: biogeochemical transformations of rocks, minerals, metals and radionuclides by fungi, bioweathering and bioremediation. *Mycological Research* **111**(1): 3-49 (2007). GALLINARI, A. & FERRARI, P. Contributo alla conoscenza dei myxomiceti nivicoli della provincia di Brescia. *Natura Bresciana* **38**: 57-69 (2013). GMOSCHINSKIY, V.I. [as ГМОШИНСКИЙ, В.И.]. Ресултатыи зучения видового разнообразия миксомицетов Порьей губы и окрестностей пос. Лувеньга в 2014 году [The results of the study of diversity myxomycetes of the Poriya Guba bay and Luvenga area in 2014]. *In*: Е.Л. Толмачева [E.L. Tolmacheva] (ed.) Летопись Природы Кандалакшского Заповедника за 2014 год (ежегодный отчет, Т. **1**, Ч. 2) Кандалакша [The Chronicle of Nature of the Kandalaksha Reserve for 2014 (Annual report, volume **1**, part 2). Kandalaksha]. *Летопись Природы Кандалакшского Заповедника* [*The Chronicle of Nature of the Kandalaksha Reserve*] **60**: 19-30 (2015) [text in Russian]. Hoppe, T. & Schnittler, M. Characterization of myxomycetes in two different soils by TRFLP analysis of partial 18S rRNA gene sequences. *Mycosphere* **6**(2): 216-227 (2015). Ing, B. *The Myxomycetes of Britain and Ireland* (Slough, UK: Richmond Publishing): iv + 374 pp. (1999). Ing, B. Snowline myxomycetes in Britain. *Field Mycology* **4**(1): 7-14 (2003). Kamono, A., Meyer, M., Cavalier-Smith, T., Fukui, M. & Fiore-Donno, A.M. Exploring slime mould diversity in high-altitude forests and grasslands by environmental RNA analysis. *FEMS Microbiology Ecology* **84**(1): 98-109 (2013). Keller, H.W. & Everhart, S.E. Importance of myxomycetes in biological research and teaching. *Fungi* **3**(1): 13-27 (2010). Kryvomaz, T.I. [as Кривомаз, Т.І.]. Ювілейна сесія по вивченню нівальних міксоміцетів в Альпах [Jubilee study session on nivicolous myxomycetes in the Alps]. *Український Ботанічний Журнал* [*Ukrainian Botanical Journal*]. **70**(3): 423 (2013). Kryvomaz, T.I. The assessment of heavy metal accumulation by myxomycetes. *Motrol* Lublin **17**(8): 157-164 (2015*a*). Kryvomaz, T.I. [as Кривомаз, Т.І.] Радіаційний контроль нівальних міксоміцетів Карпат [Radiation monitoring of Carpathian nivicolous myxomycetes]. *Екологічна Безпека та Природокористування* [*Environmental Safety and Natural Resources*] **2**(12): 72-79 (2015*b*) [text in Ukrainian]. Kryvomaz, T.I. [as Кривомаз, Т.І.]. *Наукові Основи Моніторингу Забруднення Навколишнього Середовища Токсичними Елементами з Використанням Міксоміцетів* [*Scientific Basis for Monitoring Environmental Pollution by Toxic Elements using Myxomycetes*]. Дис. д-ра техн. наук [Thesis (DSc), Technical Science], 21.06.01 (Київ: Київ Національний Університет Будівництва і Архітектури [Kyiv: Kyiv National Construction and Architecture University]): 349 pp. (2017*a*) [text in Ukrainian]. Kryvomaz, T.I. Accumulation of toxic metals and other elements by myxomycetes. In: *Abstracts of 9th International Congress on the Systematics and Ecology of Myxomycetes* Tanabe, Japan, 18-23 August 2017: 38 (2017*b*). Kryvomaz, T.I. & Andrusishina, I.M. [as Кривомаз, Т.І. & Андрусишина, І.М.]. Перший аналіз вмісту важких металів та інших елементів в плодових тілах нівальних міксоміцетів Карпат [The first analysis of heavy metals and other elements in the fruit bodies of nivicolous myxomycetes in Carpathians]. *Екологічна Безпека та Природокористування* [*Environmental Safety and Natural Resources*] **4**(20): 20-31 (2015) [text in Ukrainian]. Kryvomaz, T.I., Demecka, O.V. & Movchan, V.O. [as Кривомаз, Т.І., Демецька, О.В. & Мовчан, В.О.]. Аналіз цитотоксичності міксоміцетів для оцінки екологічних ризиків [Analysis of myxomycetes cytotoxicity for environmental risks assessment]. *Екологічна Безпека та Збалансоване Ресурсокористування* [*Environmental Safety and Sustainable Resources Management*] **1-2**(21): 57-62 (2016) [text in Ukrainian]. Kryvomaz, T.I. & Stephenson, S.L. Preliminary evaluation of the possible impact of climate change on myxomycetes. *Nova Hedwigia* **104**(1-3): 5-30 (2017). Kryvomaz, T.I., Voloshkina, O., Maximenko, D.V. & Zhukova, O.G. [as Кривомаз, Т.І., Волошкіна, О.С., Максименко, Д.В. & Жукова, О.Г.]. Регресійні моделі переходу елементів в міксоміцетах в залежності від параметрів навколишнього середовища [Regression models for the transition of elements in myxomycetes depending on the environmental parameters]. *Екологічна Безпека та Збалансоване Ресурсокористування* [*Environmental Safety and Sustainable Resources Management*] **1**(15): 97-104 (2017) [text in Ukrainian]. Kryvomaz, T.I., Voloshkina, O.S., Michaud, A. & Andrusishina, I.M. The analysis of metals biotransformation by alpine nivicolous myxomycetes from substrates. *Eastern-European Journal of Enterprise Technologies* **5/10**(83): 50-57 (2016). Lado, C. & Ronikier, A. Nivicolous myxomycetes from the Pyrenees: notes on taxonomy and species diversity. Part 1. *Physarales* and *Trichiales*. *Nova Hedwigia* **87**(3-4) 337-360 (2008). Lado, C., Ronikier, A., Ronikier, M. & Drozdowicz, A. Nivicolous myxomycetes from the Sierra de Gredos (central Spain). *Nova Hedwigia* **81**(3-4): 371-394 (2005). Lavoise, C., Bellido-Bermejo, F., Mateos-Moreno, M. & Paz, A. Myxomycetes nivícolas de la Comunidad de Cantabria. *YESCA* Revista de Micología **27**: 99-126 (2015). Madelin, M.F. Myxomycete data of ecological significance. *Transactions of the British*

Mycological Society **83**(1): 1-19 (1984). MORENO, G., CASTILLO, A. & DESCHAMPS, J.R. Critical revision of myxomycetes in the Buenos Aires BAFC herbarium - 1. *Mycotaxon* **123**: 63-79 (2013). MÜLLER, H. Beitrag zur Kenntnis und Verbreitung nivicoler Myxomyceten im Thüringer Wald. *Zeitschrift für Mykologie* **68**(2): 199-208 (2002). MÜLLER, H. & RIEMAY, K.-H. Rote Liste der Schleimpilze (*Myxomycetes*) Thüringens. *In*: F. FRITZLAR *et al.* (eds) *Rote Listen der gefährdeten Tier- und Pflanzenarten, Pflanzengesellschaften und Biotope Thüringens* (Jena: Thüringer Landesanstalt für Umwelt und Geologie). *Naturschutzreport* **26**: 485-490 (2011) [*https://umwelt.thueringen.de/fileadmin/001_TMUEN/Unsere_Themen/Natur_Artenschutz/Biologische_Vielfalt/Rote_Liste/52_schleimpilze_muller_nsr26_485_490.pdf*, accessed 17 November 2019]. NEUBERT, H., NOWOTNY, W. & BAUMANN, K. *Die Myxomyceten Deutschlands und des angrenzenden Alpenraumes unter besonderer Berücksichtigung Österreichs* **2**: *Physarales* (Gomaringen, Germany: Karlheinz Baumann Verlag): 368 pp. (1995). NOVOZHILOV, Y.K., SCHNITTLER, M., ERASTOVA, D.A., OKUN, M.V., SCHEPIN, O.N. & HEINRICH, E. Diversity of nivicolous myxomycetes of the Teberda State Biosphere Reserve (northwestern Caucasus, Russia). *Fungal Diversity* **59**(1): 109-130 (2013). ONER, N., DOGAN, H.H., OZTURK, C. & GURER, M. Determination of fungal diseases, site and stand characteristics in mixed stands in Ilgaz-Yenice forest district, Cankiri, Turkey. *Journal of Environmental Biology* **30**(4): 567-575 (2009). POULAIN, M., MEYER, M. & BOZONNET, J. *Les Myxomycètes* (Sevrier, France: Fédération Mycologique et Botanique Dauphiné-Savoie): **2** vols, 568 pp. + 544 plates (2011). RONIKIER, A. & RONIKIER, M. How ‘alpine’ are nivicolous myxomycetes? A worldwide assessment of altitudinal distribution. *Mycologia* **101**(1): 1-16 (2009). SHCHEPIN, O.N., SCHNITTLER, M., ERASTOVA, D.A., PRIKHODKO, I.S., DAHL, M.B., AZAROV, D.V., CHERNYAEVA, E.N. & NOVOZHILOV, Y.K. Community of dark-spored myxomycetes in ground litter and soil of taiga forest (Nizhne-Svirskiy Reserve, Russia) revealed by DNA metabarcoding. *Fungal Ecology* **39**(1): 80-93 (2019). SCHNITTLER, M., ERASTOVA, D.A., SHCHEPIN, O.N., HEINRICH, E. & NOVOZHILOV, Y.K. Four years in the Caucasus – observations on the ecology of nivicolous myxomycetes. *Fungal Ecology* **14**: 105-115 (2015) [DOI: 10.1016/j.funeco.2015.01.003]. SINGER, H., MORENO, G. & ILLANA, C. Mountainous and nivicolous myxomycetes described by Charles Meylan. A SEM-study. *Österreichisches Zeitschrift für Pilzkunde* **14**: 11-29 (2005). SINGER, H., MORENO, G., ILLANA, C. & SÁNCHEZ, A. SEM-studies on nivicolous myxomycetes. *Cryptogamie* Mycologie **24**(1): 39-58 (2003). STEPHENSON, S.L. & MCQUATTIE, C.J. Assessing the potential use of myxomycetes as biomonitors of heavy metals in the environment. *Proceedings of the West Virginia Academy of Science* **72**: 32-33 (2000). TESMER, J. & SCHNITTLER, M. Sedimentation velocity of myxomycete spores. *Mycological Progress* **6**(4): 229-234 (2007). YAJIMA, Y., KONDO, N. & YAMAMOTO, Y. [*Diderma meyerae*, new to Japan]. *Transactions of the Mycological Society of Japan* **50**(2): 129-131 (2009) [text in Japanese].

Sources additional to those already cited from literature and the internet.

- *Biodiversity Heritage Library* [*www.biodiversitylibrary.org*].
- *Checklist of Fungi of the British Isles* [*https://basidiochecklist.science.kew.org/BritishFungi/FRDBI/FRDBI.asp*].
- *Cybertruffle* [*www.cybertruffle.org.uk*].
- *Discover Life (myxomycete pages)* [*www.discoverlife.org/mp/20q?guide=Myxomycetes*].
- *Fungal Records Database of Britain and Ireland* [*www.frdbi.info*]
- *Fungus Conservation Trust CATE2 Database* [*www.abfg.org*].
- *GBIF* [*www.gbif.org*].
- *Google* [*www.google.co.uk*].
- *Landcare Research New Zealand* [*http://nzfungi2.landcareresearch.co.nz*].
- *Mycoportal* [*www.mycoportal.org*].
- *Mycotaxon Regional Checklists in Downloadable Format* [*www.mycotaxon.com/mycobiota*].
- *National Center for Biotechnology Information* [*www.ncbi.nlm.nih.gov*].
- *Nomen.mycetozoa.com - an online nomenclatural information system of Eumycetozoa* [*http://eumycetozoa.com*].

- *USDA Fungal Databases* [*https://nt.ars-grin.gov/fungaldatabases*].

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