DIDERMA FALLAX

A, **B**. Sporocarps, showing variability of colour (bars = 1 mm). **C**. Spores (bar = 10 µm). [Photographs: A. Michaud]

Diderma fallax (Rostaf.) E. Sheld., *Minnesota Botanical Studies* **1**: 477 (1895). [*IndexFungorum* 372424; *Didymiaceae*, *Stemonitiida*]

Chondrioderma fallax Rostaf., *Śluzowce (Mycetozoa) Monografia*: 171 (1874) [publ. 1875]. [*IndexFungorum* 245319]

Chondrioderma lyallii Massee, *A Monograph of the Myxogastres*: 201 (1892). [*IndexFungorum* 145650]

Leangium lyallii (Massee) E. Sheld., *Minnesota Botanical Studies* **1**: 479 (1895). [*IndexFungorum* 634760]

Diderma lyallii (Massee) Kuntze, *Revisio Generum Plantarum* 3(3): 466 (1898). [*IndexFungorum* 434156]

Chondrioderma niveum var. *lyallii* (Massee) Meyl., *Bulletin de la Société Vaudoise de Sciences Naturelles* **44**: 290 (1908). [*IndexFungorum* 418361]

Diderma niveum subsp. *lyallii* (Massee) G. Lister, in A. Lister, *A Monograph of the Mycetozoa* A Descriptive Catalogue of the Species in the Herbarium of the British Museum, Edn 2: 105 (1911). [*IndexFungorum* 410281]

Diagnostic features. Sporangia pale and usually sessile; easy to distinguish in field from other nivicolous species of *Diderma*, because polygonal scales on the peridium (which can be very dark brown when calcium is lacking) make sporocarps resemble golf balls; microscopically, *D. fallax* has unusually large, dark and markedly spiny spores.

On natural substratum. *Amoebal state* no information. *Plasmodium* white. *Hypothallus* white, distinct, common for all sporocarps within a group. *Sporocarps* short-stalked or sessile sporangia. *Stalks* often absent; when present, stout, furrowed, an extension of the hypothallus. *Sporothecae* crowded, subglobose, 1–1·5 mm diam., white, cream, or pale flesh-coloured, mottled. *Peridium* white, but often mottled with polygonal crystalline orange-pink scales, wrinkled and dark brown when lime is absent, double-layered, the outer thick and calcareous, the inner membranous, opaque, pink or buff. *Columella* large, clavate, calcareous, reaching to the centre of the sporotheca, cream-white, flesh-pink or very pale brown. *Capillitium* brown, rigid, dark, the thread thick, 2–4 µm wide, branched and anastomosed, often with fusiform or globose swellings, expanded at the junctions. *Spores* black *en masse*, dark purple-brown by transmitted light, 13–17 µm diam., coarsely spinose, the spines blunt, up to 1·5 µm long.

ASSOCIATED ORGANISMS & SUBSTRATA: **Plantae**. *Apiaceae* gen. indet. (twig); *Cytisus* sp.; *Gramineae* indet.; *Plantae* indet. (litter, twig); *Prunus spinosa* L. (branch); *Vaccinium myrtillus* L. (twig). **Associated organism of type specimen**. Not noted. **Comment**. Observed on dead branches and twigs in the litter.

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. fallax* is now starting to emerge (BORG DAHL, 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. There is very little information about habitats in which *D. fallax* is found, but it is known to be nivicolous, particularly in mountain regions, with sporocarps found near melting snow in spring. Although associations with animals, fungi and micro-organisms are known or suspected, no observations were found where the associated organism was identified to genus or species level.

GEOGRAPHICAL DISTRIBUTION: AFRICA: Morocco. NORTH AMERICA: Canada (British Columbia), USA (California, Colorado, Kansas, Montana, New Mexico, Oregon, Utah, Washington, Wyoming). SOUTH AMERICA: Chile. ASIA: Philippines, Russia (Khanty-Mansi Autonomous Okrug). EUROPE: Austria, France, Germany, Italy, Romania, Russia (Karachay-Cherkess Republic, Tver Oblast), Spain, Sweden, Switzerland, UK.
Elevation (m above sea level). Records up to 2800 (USA: Colorado); up to 2600 (France).
Comment. Native to mountainous areas of Europe, North America and northern Asia, and, possibly, elsewhere; the Philippine record may represent a lookalike taxon.

ECONOMIC IMPACTS: There is experimental evidence that this species can accumulate heavy metals (KRYVOMAZ, 2015; KRYVOMAZ *et al.*, 2015, 2016, 2017). KRYVOMAZ (2017*a*) measured metal levels in sporocarps of *D. fallax*. The levels of different elements were, in descending order, as follows [µg of metal per g of myxomycete tissue]: Ca (2496), Mg (1157·2), Fe (722·28), Al (177·25), Mn (150), Si (149·28), Zn (95·42), Pb (26·7), Cu (16·8), Ni (7·8), Cd (4·2). Analysis of those results showed that Pb, Cd and Ni were accumulated much more strongly by this species than by the others included in the study. An accumulation coefficient was used to calculate the concentration ratios between myxomycete and substratum. In comparison with the substratum (a living branch of *Prunus spinosa* from France), *D. fallax* had very high accumulation coefficients for Cu (280) and Pb (190), and high levels for Ni (46), Zn

(40), Cd (22), Fe (21). Of the above metals Cd, Pb, Zn are highly, and Ni, Cu moderately, toxic. 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 other than those listed in the synonymy above. POULAIN *et al.* (2011) state that 'a lepidodermoid form has been recorded by Meylan' but do not cite a source. *Nomen.mycetozoa.com* [accessed 21 November 2019] does not list a 'forma lepidodermoides' for this species; nor does *IndexFungorum* [accessed 21 November 2019]. The only 'forma lepidodermoides' listed by *IndexFungorum* is not attributed to Meylan and is clearly different. The epithet does not appear in the thorough treatment of Meylan's nivicolous myxomycetes by KOWALSKI (1975). It is therefore likely to be an unpublished name. Specimens where the peridium has crystalline scales have been attributed to this form (KRYVOMAZ & MICHAUD, unpublished).

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**. None. **Information base**. About 800 records (specimens, databases and bibliographic sources combined, excluding duplicates) from at least 1875 to May 2013, with observations in every month of the year, peaking from April to July in the northern hemisphere. **Estimated extent of occurrence** [calculated using *http://geocat.kew.org*]. Well over 7·4 million km^2 (Africa: insufficient data; Asia: insufficient data; Europe: 5·1 million km^2; North America: 2·3 million km^2; South America: insufficient data). **Estimated area of occupancy** [calculated using *http://geocat.kew.org*]. Well over 508 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. At least some of the plants with which it is associated are common and widespread species. **Threats**. As a nivicolous species, *D. fallax* is likely to be seriously threatened by climate change. Insufficient information to enable other 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, 75% post-1960 but pre-2001, and 20% post-2000. **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**. 44 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: 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 fallax* was included in one such pioneering study (Hoppe & Schnittler, 2015).

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