

Scientific paper

## Ecological role of fungal infections of moss carpet in Svalbard

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**Abstract:** Moss vegetation plays an important role as a producer in the early stages of primary succession in the Arctic. Some fungi actively attack mosses growing in polar regions. We observed the ecological impact of phytopathogenic fungi in Barentsburg, Longyearbyen and Ny-Ålesund in Svalbard. Many fungal infections were seen in some kinds of moss colonies (*Aulacomnium palustre*, *Sanionia uncinata*, *Straminergon stramineum* and *Tomenthypnum nitens*), and pathogenic fungi formed moribund patches in the moss carpet. Higher plants and other mosses had invaded in those moribund moss patches. These findings suggest that phytopathogenic fungi play an important role in the pattern of succession in Arctic terrestrial ecosystems.

### 1. Introduction

Moss vegetation plays an important role in primary succession in polar regions. Moss colonies also offer habitats for terrestrial invertebrates such as insects, ticks and nematodes. Therefore, moss communities are a key part of the terrestrial ecosystems in polar regions (Longton, 1997). Microorganisms, especially fungi in polar regions, are well known for their formation of mycorrhizae, basidiolichen and decomposers (Laursen and Chmielewski, 1982). In addition, some fungi have been reported to actively attack mosses growing in the Arctic, including Jan Mayen in the Greenland Sea (Wilson, 1951), Ellesmere Island in northern Canada (Longton, 1973), and Svalbard in the Barents Sea (Ridley *et al.*, 1979; Hoshino *et al.*, 1999); and in Antarctica, in the South Sandwich Islands, South Orkney Islands (Longton, 1973) and on Cape Bird, Victoria Land (Greenfield, 1983).

Wilson (1951) studied infections of *Rhacomitrium* carpet on Jan Mayen Island and reported that the moss disease was caused by an unidentified basidiomycete. *Pythium ultimum* var. *ultimum* (Hoshino *et al.*, 1999) and *Pythium* sp. (Tojo *et al.*, unpublished results) cause parasitic disease in *Sanionia uncinata* in Svalbard. On the other hand, *Thyronectria antarctica* var. *hyperantarctica*, an undetermined plectomycete (Hawksworth, 1973; Longton, 1973), *Coleroa turfosorum*, *Bryosphaeria megaspora*, *Epibryon chorisodontii* (Fenton, 1983) and *Rhizopus* sp. (Greenfield, 1983), which may cause parasitic disease in mosses, have been isolated from various regions of the Antarctic Zone.

Therefore, fungi also play another ecological role in polar regions, since some fungi may cause not only disintegration of dead moss shoots but also infection in moss colonies. However, there have been very few ecological studies on moss pathogenic fungi in the Arctic and Antarctic regions. In this study, we aim to elucidate the ecological characteristics of moss pathogenic fungi in the Arctic.

## 2. Materials and methods

### 2.1. Isolation of fungi from moss colonies

Moribund moss shoots were collected to isolate parasitic fungi in Barentsburg (78°N, 14°E), Longyearbyen (78°N, 15°E) and Ny-Ålesund (79°N, 12°E) on Svalbard in June and August, 1999.

Fungi were isolated at sampling sites. We collected *ca.* 2000 shoots respectively from 5 dead and 2 healthy moss colonies at each site. Collected dead and healthy moss shoots were untied and rinsed twice with sterilized water. Each shoot was cut up into 1 cm pieces. Fifty dead and 20 healthy moss shoots from each site were immediately placed on potato dextrose agar (PDA, Difco) plates. Fungi growing on moss shoots were cultivated at room temperature (*ca.* 15–20°C) for 2–5 days. Single fungal colonies were selected from each plate and subcultured on PDA slants.

### 2.2. Morphology

Isolates were pre-grown on corn meal agar (CMA, Difco) plates at 15°C, and agar discs 7 mm in diameter were taken from actively growing colony margins and inoculated onto CMA plates. Cultures were incubated for 7 to 30 days at 15°C for morphological observation. The morphological characteristics examined were: dimensions of hyphal swelling, and width of the main hyphae. The isolates were also grown on grass blades for 3 to 7 days at 5 and 15°C to determine zoospore production (Martin, 1992). At least 30 hyphal swellings were examined for each isolate for all characteristics.

### 2.3. Growth temperature

Mycelial discs 5 mm in diameter were cut from the margin of an actively growing fungal colony in subcultured PDA plates, transferred to the centers of PDA plates (9 cm in diameter), and inoculated at 9 different temperatures from 0 to 40°C, in duplicate. After 1, 2 and 3 days following inoculation, the colony diameters were determined. The linear mycelial growth rate per day was calculated after the initial lag period.

## 3. Results and discussion

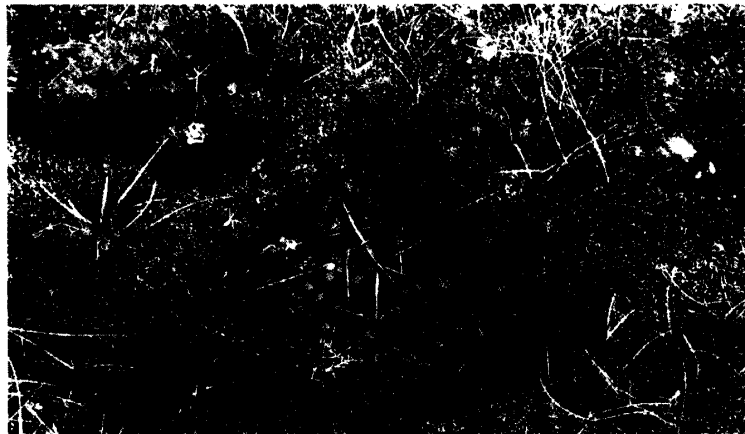
### 3.1. Fungal infection pattern

Moss carpets of *Sanionia uncinata* (Hedw.) Loeske [= *Drepanocladus uncinatus* (Hedw.) Warnst.] predominated in Barentsburg, Longyearbyen and Ny-Ålesund. Moribund moss colonies were sometimes found in the moss carpets after the snow bed had melted in wet or submerged areas (Fig. 1A). Especially, many fungal infections were distributed at bases of cliff where there were snowdrifts during spring. Fungal infections were seen in irregular patches along a snow melt stream or forming a circular pattern

**A.**



**B.**



**C.**



*Fig. 1. Fungal infections in Sanionia uncinata in Svalbard. A: Fungal infections in Ny-Ålesund. B and C: Fungal infections in Barentsburg.*

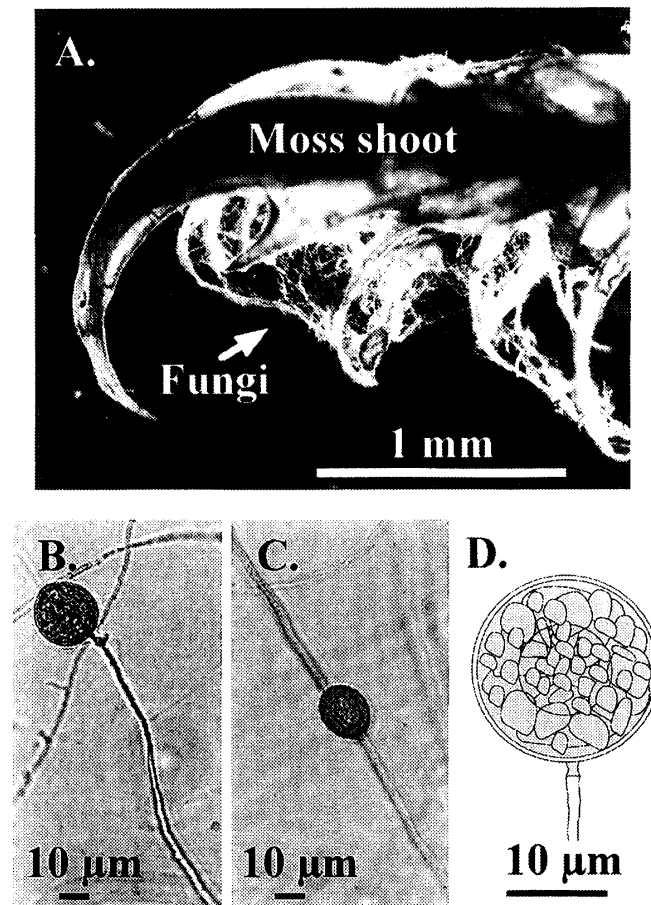


Fig. 2. Mycological characteristics of moss pathogenic fungi from Svalbard. A: Microscopically observation of fungal infected moss shoot. Terminal (B) and intercalary (C) hyphal swellings in CMA plates. D: Illustrated terminal hyphal swelling.

(Hoshino *et al.*, 1999). Mycelia on moss shoots were visible to the naked eye immediately after thawing (Fig. 2A). In Antarctica, many fungal infections in *S. uncinata* and *Polytrichum juniperinum* have been observed in moss vegetation near the seashore (Hoshino *et al.*, unpublished results). However, we could not find any obvious disease in moss along the coasts of Barentsburg, Longyearbyen and Ny-Ålesund.

Ridley *et al.* (1979) reported a large number of concentric bands in dead moss in Reindalen, Svalbard, although the host moss was not described in their brief report. They reported that there were many concentric fungal rings in the Arctic moss, one of the rings reaching 1 m in diameter. However, we observed only irregular patches and small circular patterns of fungal infections. A similar infection pattern was reported on Ellesmere Island and in Antarctica (Longton, 1973). We also found a regrowth of moss shoots in center of fungal infections in Ny-Ålesund (Fig. 1A). On the other hand, in relatively warmer areas, Barentsburg and Longyearbyen, we did not observe such regrowth. Many saprophytic microorganisms invaded and to grow in fungal infections in Barentsburg and Longyearbyen. Therefore, moss shoots in fungal infections were destroyed by the fungal decomposition process.

### 3.2. Mycological characteristics of pathogenic fungi

All isolates from dead moss shoots from Barentsburg, Longyearbyen and Ny-Ålesund produced only non-sexual organs, hyphal swellings in CMA plates and grass blades (Fig. 2B–D: all of them were lacking in oogonia production). In addition, isolates did not produce zoospores in artificial condition. However, all isolates from dead moss shoots in Svalbard could not grow in CMA plates containing 5  $\mu$ M metalaxyl (specific growth inhibitor of *Pythium*, data not shown). Hyphal swellings of isolates from Svalbard were terminal globose and sometimes formed intercalary (Fig. 2B and C). Diameters of hyphal swellings were 20–25  $\mu$ m. Hyphal swellings had outer wall like chlamydozoospores (Fig. 2B and D). Similar morphological characteristics were reported from the *Pythium* sp. from Alaska (Hamm *et al.*, 1988). Morphological comparisons between these characteristics and reference data from Van der Plaats-Niterink (1981) indicate that the isolate was the *Pythium* sp. HS group. Previously, *Pythium* spp. were isolated in Alaska (Hamm *et al.*, 1988), Devon Island (Booth and Barrett, 1971), Kola peninsula in Russian Arctic (Petrov, 1983), Finnmark in northern Norway (Hoshino *et al.*, 2000) and Svalbard (Gaertner, 1954).

### 3.3. Ecological characteristics of moss pathogenic fungi

Our previous report (Hoshino *et al.*, 1999) showed that the host plant of *Pythium* spp. was *S. uncinata* in Longyearbyen and Ny-Ålesund. In this report, we found fungal infection patches in other moss species such as *Aulacomnium palustre* (Hedw.) Schwaegr., *Straminergon stramineum* (Brid.) Hedenaes and *Tomenthypnum nitens* (Hedw.) Loeske in Barentsburg. Parasitic fungus, *Pythium* sp. HS group was isolated from all species of moribund mosses. However, we could not obtain *Pythium* sp. from healthy moss shoots. Therefore, it is thought that this parasitic fungus has low host specificity.

The *Pythium* HS group isolated from plants collected in temperate zone countries, has been shown to be parasitic with strong pathogenic activity in many cultured plants (Van der Plaats-Niterink, 1981), but there have been no reports of this fungus having pathogenic activity in mosses. However, Arctic isolates killed artificially inoculated shoots of *S. uncinata* (Hoshino *et al.*, unpublished results). Agricultural activity in Svalbard is very low (a few greenhouse and farm lands are in two Russian settlements), and moss is one of

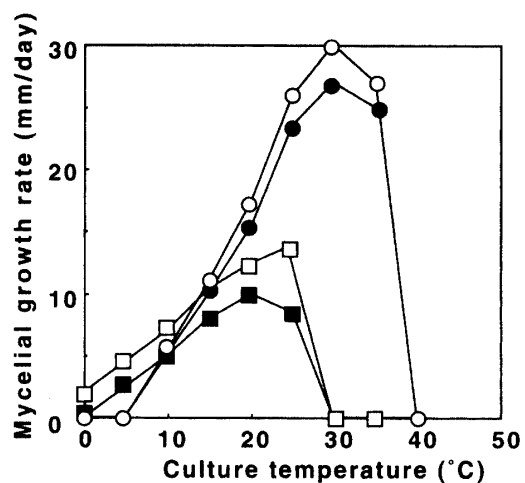


Fig. 3. Effects of culture temperature on mycelial growth of Arctic and temperate zone isolates, *Pythium* HS group. Temperate isolates (94Py1-4: ○, 94Rh-1: ●) were isolated from Yamanashi Prefecture in Japan. Arctic isolates were isolated from Barentsburg (□) and Longyearbyen (■).

the dominant vegetation plants. Therefore, these Arctic isolates probably gained a wide range of parasitic activity to adapt to the environmental conditions of the high Arctic.

The morphological characteristics of Arctic isolates corresponded to those of temperate isolates. However, Arctic isolate showed a different response to temperature (Fig. 3). They grew at 0°C but the temperate isolates did not grow at 0°C (same conditions as those under snow cover). The optimal growth temperature of Arctic isolates is 20–25°C and that of temperate isolates is 30°C. On the other hand, the mycelial growth rate of isolates from Svalbard, compared with that of isolates from the temperate zone, was very low at temperatures above 10°C. These results suggest that the Arctic isolates have evolved as “specialists” with a narrow temperature range and high adaptation to the cold climate in Svalbard.

### 3.4. Ecological role of pathogenic fungi

Pathogenic fungi have invaded in a moss carpet and formed patches after several years. Host moss shoots were destroyed in the center parts of fungal infections. We often found some higher plants (*Deschampsia* spp., *Poa* spp. and etc.) or other mosses (*Bryum* spp., *Polytrichum* spp. and etc.) in those moribund moss patches (Fig. 1B and C). Thus, the invasion of phytopathogenic fungi in a moss carpet is thought to lead the formation of pathogenic patches as “open spaces” where other plants easily colonize. Figure 4 shows our hypothesis concerning the development of moribund moss colonies and the ecological role of phytopathogenic fungi in the Arctic. The formation of pathogenic patches might be the

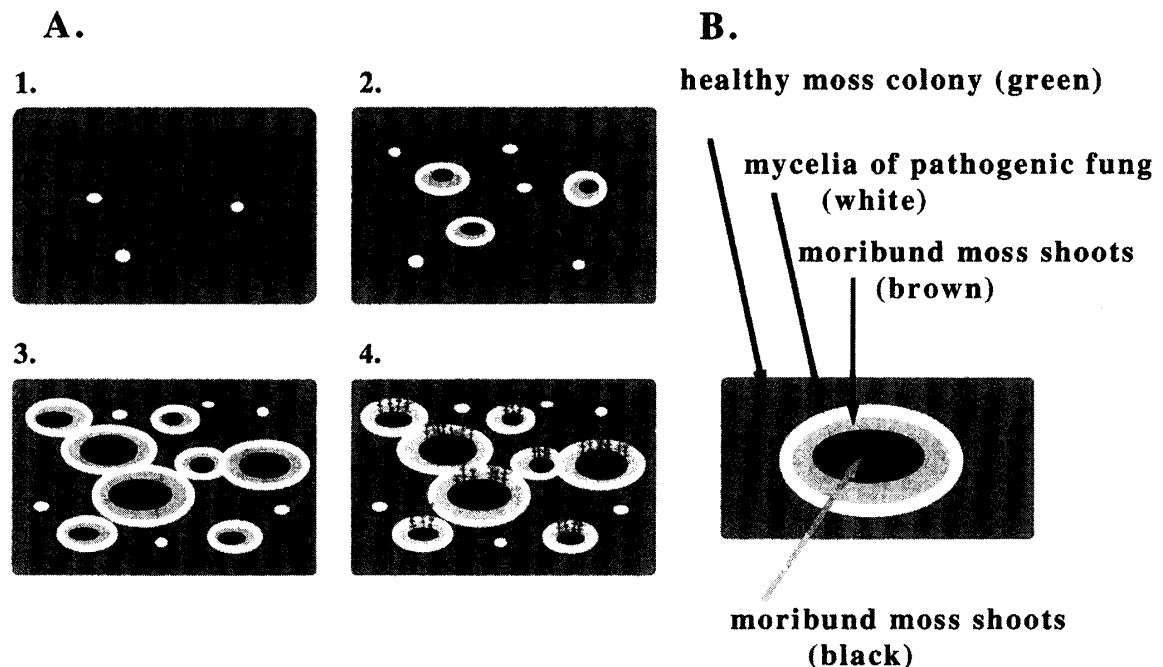


Fig. 4. The hypothesis of ecological impact of moss pathogenic fungi. A: Disease development of moss blight. 1: The invasion of pathogenic fungi in stable moss colony. 2: The spread of fungal infections. 3: The spread of moribund area. 4: the invasion of other plants. B: Morphology of fungal infection.

first step in changes in the patterns in plant communities in polar regions. Previous theories of the succession and colonization of polar plants have focused on plant-environmental or plant-plant interactions. Our observations offer a new concept of the colonization of polar plants.

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### References

- Booth, T. and Barrett, P. (1971): Occurrence and distribution of zoosporic fungi from Devon Island, Canadian Eastern Arctic. *Can. J. Bot.*, **49**, 359-369.
- Fenton, J.H.C. (1983): Concentric fungal rings in Antarctic moss communities. *Trans. Br. Mycol. Soc.*, **80**, 413-420.
- Gaertner, A. (1954): Über das vorkommen niederer Erdphycomyceten in Afrika, Schweden und an einigen mitteleuropäischen Standorten. *Arch. Mikrobiol.*, **21**, 4-56.
- Greenfield, L. (1983): Thermophilic fungi and actinomycetes from Mt. Erebus and a fungus pathogenic to *Bryum antarcticum* at Cape Bird. *N.Z. Antarct. Rec.*, **4**, 10-11.
- Hamm, P.B., Hansen, E.M., Hennon, P.E. and Shaw, C.G. (1988): *Pythium* species from forest and muskeg areas of southeast Alaska. *Trans. Br. Mycol. Soc.*, **91**, 385-388.
- Hawksworth, D.L. (1973): *Thyronectria antarctica* (Speg.) Seeler var. *hyperantarctica* D. Hawksw. var. nov. *Br. Antarct. Surv. Bull.*, **32**, 51-53.
- Hoshino, T., Tojo, M., Okada, G., Kanda, H., Ohgiya, S. and Ishizaki, K. (1999): A filamentous fungus, *Pythium ultimum* Trow var. *ultimum*, isolated from moribund moss colonies from Svalbard, Northern Islands of Norway. *Polar Biol.*, **12**, 68-75.
- Hoshino, T., Tojo, M. and Tronsmo, A.M. (2000): *Pythium* Blight of moss colonies (*Sanionia uncinata*) in Finnmark. *Polarflokken*, **24**, 161-164.
- Laursen, G. and Chmielewski, M. (1982): The ecological significance of soil fungi in Arctic tundra. *Arctic and Alpine Mycology*, ed by G.L. Laursen and J.F. Ammirati. Seattle, University of Washington Press, 432-492.
- Longton, R.E. (1973): The occurrence of radial infection patterns in colonies of polar bryophytes. *Br. Antarct. Surv. Bull.*, **32**, 41-49.
- Longton, R.E. (1997): The role of bryophytes and lichens in polar ecosystems. *Ecology of Arctic Environments*, ed. by S.J. Woodin and M. Marquiss. Oxford, Blackwell, 69-96.
- Martin, F.M. (1992): *Pythium*. *Methods for Research on Soilborne Phytopathogenic Fungi*, ed. by L.L. Sigleton *et al.* St. Paul, APS Press, 39-49.
- Petrov, V.F. (1983): Pathogenic microflora of root growth in perennial grasses in Khibiny. *Bull. Appl. Bot. Genet. Plant Breed.*, **82**, 45 (in Russian with English summary).
- Ridley, M., Gillow, C., Perkins, D. and Ogilvie, J. (1979): Oxford University expeditions to Svalbard 1978. *Bull. Oxf. Univ. Explor. Club. New Series, Commem. Vol.*, 29-79.
- Van der Plaats-Niterink, A.J. (1981): Monograph of the genus *Pythium*. *Stud. Mycol.*, **21**, 1-241.
- Wilson, J.W. (1951): Observations on concentric 'fairy rings' in Arctic moss mat. *J. Ecol.*, **39**, 407-416.

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