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SHORT NOTE

C.H. Robinson · O.B. Borisova · T.V. Callaghan
J.A. Lee

Fungal hyphal length in litter of *Dryas octopetala* in a high-Arctic polar semi-desert, Svalbard

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Abstract Mean fungal hyphal length was estimated in the surface horizons of a lithosol under *Dryas octopetala* in a polar semi-desert ecosystem at Ny-Ålesund, Svalbard (78°56′N, 11°50′E). This site is the most northerly from which such values have been collected and provides the only record from polar semi-desert sites in the Eurasian high Arctic. Although mean ($\pm$ SE) fungal hyphal length was the lowest recorded in surface horizons of northern tundra (23 ± 1 m g^{-1}), it was of the same order as results from a Canadian high-Arctic soil and Antarctic soils of high pH and low moisture and organic matter content, with little vegetation cover.

Introduction

Tundra ecosystems contain 11% of the world's soil carbon pool (Mellilo et al. 1990), and in these, soils hold 95% of the organically bound plant nutrients (Jonasson 1983). Even so, because of slow decomposition rates in cold, wet or dry soil environments, plant growth is often limited by nutrient availability (e.g. Wookey et al. 1994). Since saprotrophic fungi are primary decomposers of organic matter, and mycorrhizas of polar dwarf shrubs may facilitate plant nutrient uptake, fungal biomass[1], which can be estimated from fungal hyphal length, is a measure of a potentially major influence on the nutrition of (Arctic) plants through uptake, immobilisation and mineralisation of nutrients (Frankland et al. 1990). Total fungal hyphal length is a measure of absolute fungal presence, and has been widely used in soil perturbation studies (e.g. Bardgett 1991) and site comparisons (review by Kjøller and Struwe 1982).

Despite the excellent synthesis of hyphal length values from various tundra ecosystems during the International Biological Programme (Dowding and Widden 1974; Holding 1981), such measurements were obtained from only one polar semi-desert site in the northern hemisphere, Truelove Lowland in Canada's Devon Island (Widden 1977), although polar desert and semi-desert tundra are characteristic of 93% of the high-Arctic land area (Bliss and Matveyeva 1992). In this study, we aimed to quantify fungal hyphal length in the surface soil horizons of one of the most northerly Eurasian polar semi-desert ecosystems, in order to compare these values with those from surface horizons of other tundra soils.

Materials and methods

The polar semi-desert site in situated within the *Dryas octopetala* L. zone of Svalbard (Brattbakk 1986), 3 km to the west of Ny-Ålesund in northwestern Spitsbergen at an elevation of 22 m a.s.l.. Approximately 70% of the ground surface is bare of vegetation; the soil is a lithosol developed over limestone, and organic matter is mostly present under mats of *Dryas octopetala*, a winter-green prostrate dwarf shrub. The area is a well-drained interfluve with little sign of frost heave or sorting. Full details of the research site are provided in Wookey et al. (1993) and Robinson et al. (1995). Replicate plots, each measuring 1.5 m × 1.5 m, were allocated randomly in 1991. Three cores (51-mm diameter, *ca.* 10-g fresh weight) were taken randomly from the surface to 30 mm depth (= standing dead plus fallen litter) of 15 plots from under *D. octopetala* on 14 July 1994. At this site, in common with many previous tundra studies (Dowding and Widden 1974), only a 'summer' sampling was made due to practical difficulties in winter sampling and minimal microbiological facilities. No more than three soil samples were available per plot due to the lack of vegetation cover and organic soil on the plots. The soil samples were placed in plastic bags and stored at 2°C for up to 3 days. The gravimetric moisture content of each core was determined by oven-

[1] On etymological grounds, 'biomass' should be restricted to living matter, but here, as in many mycological studies, total mass is the intended meaning (Frankland et al. 1990)

C.H. Robinson (✉) · O.B. Borisova · T.V. Callaghan · J.A. Lee
Sheffield Centre for Arctic Ecology,
Department of Animal and Plant Science,
University of Sheffield, Sheffield,
S10 2UQ, UK

Table 1 Mean total fungal length (m g^{-1} oven-dry soil) and associated parameters in tundra soils (only the results from the Ny-Ålesund site were obtained in the present study). (Key: *J & M* Jones & Mollison (1948), *f* shows the source of the fungal data, *s* the source of the soil data and + indicates values from Heal et al. (1981))

Location	Latitude	Description	Horizon (cm)	Mean hyphal length (m g^{-1})	Method	Sampling time	Surface horizon soil pH	Surface horizon moisture (% odw)	Organic matter (kg m^{-2})$^{+}$	July mean temp at 5 cm (°C)	References
Svalbard, Ny-Ålesund	78°56′N	Litter and standing dead under *Dryas* in polar semi-desert	0.0–3.0	23	Membrane filter	July	6.87–6.93	83–113	*Dryas* patches only	4.5^{a}–6.1^{a}	This study
							(6.9–8.0* for bulk soil)	47^{a} for bulk soil			a Robinson et al. (1995) * Wookey et al. (1993)
Canada, Devon I.	75°33′N	Beach ridge under *Dryas*	0.0–5.0	39–112	Modified J&M	July–August	7.8	30	9	≈ 10	f Widden and Parkinson (1979) s Brown and Veum (1974)
		Mesic meadow	0.0–3.0	2228	Modified J&M	July	6.5	617	51		f Widden et al. (1972) s Brown and Veum (1974)
USA, Barrow	71°18′N	High, dry, polygon	1.0–2.0	200	Modified J&M	July–August	5.3?	≈ 33^{f}	?	≈ 5.5	f Miller and Laursen (1974) s Brown and Veum (1974)
Sweden, Stordalen	68°22′N	Mire	0.0–5.0	3033	J&M		4.0	84 (fw)	100	8.0 (0–10 cm)	f Hayes (1973); Rheinberg (1974) s Brown and Veum (1974)
Norway, Hardanger	60°17′N	Lichen heath, Iron podsol	0.0–2.0	730	Membrane filter		4.0	5–19 (fw)	8	7.8 (at 10 cm)	f Hanssen and Goksøyr (1975) s Brown and Veum (1974)
UK, Moorhouse	54°65′N	L_1	0.0–1.0	6050	J&M	Throughout year	3.6	1800/400 max/min	100		f Kjøller and Struwe (1982)
		L_2	1.0–6.6	9600	" "	Throughout year					s Brown and Veum 1974)
Canada, Mt. Allen		1900 m asl	0.0–2.0	580	J&M						f Kjøller and Struwe (1982)
			5.0–8.0	224	" "						s Dowding and Widden (1974)
		2800 m asl		50	" "						
Antarctica, Signy Island	60°S	Hut bank	0.0–1.3	6328	J&M	Summer	4.5	86 (fw)	≈ 40		f,s Bailey and Wynn-Williams (1982)
		Mountain moss	" "	2783	" "	"	5.2	83		4.1^{ss}	ss Brown and Veum (1974)
		Grassland	" "	288	" "	"	5.6	51	42		
		Old moraine	" "	84	" "	"	6.0	19.3	v. low?	3.1 at 2.5 cm	
		New moraine	" "	4	" "	"	9.2	12.3	" "	" "	
		Marble knolls	" "	144	" "	"	8.5	7.3	" "	" "	
		Marble schist	" "	44	" "	"	8.4	12.5	" "	" "	

drying a subsample at 105°C for 48 h. Fungal hyphal lengths were determined in a field laboratory, using the membrane filtration method (after Hanssen et al. 1974, modified by Sundman and Sivelä 1978). A sample of known weight (*ca.* 5-g wet weight) was homogenised in 100 ml of 60 mM phosphate buffer for 30 s. Ten millilitres of the homogenate was taken, diluted to 50 ml and a 5-ml sample to which one drop of 0.1% phenolic aniline blue had been added was filtered through a membrane filter (1.2-μm pore size). Each filter was blotted dry and mounted in immersion oil. Five filters were prepared per core, and total hyphal lengths were estimated in five microscope fields of view on each filter by a grid intersection method (Olson 1950) using × 500 magnification. Fungal diameter was estimated for each hyphal fragment in one randomly selected field of view from each filter to give a mean diameter for 100 hyphae per plot. Mycelial biomass was estimated from hyphal length as in Frankland et al. (1978). The pH of a soil subsample from each core was estimated after Allen (1989).

Results and Discussion

The range of values obtained was between 13 and 32 m g^{-1}, with a median of 23 m g^{-1}, and a mean ($\pm$ SE) per plot of 23 $\pm$ 1 m g^{-1} ($n = 15$). These values have been estimated, we believe, from the most northerly latitude to date (see Table 1) and are extremely low compared to those from other biomes. For example, estimates of 1900–4432 m g^{-1} have been recorded for the litter layer of temperate woodland soils (review by Kjøller and Struwe 1982). The mean value is also considered to be the lowest reported from the surface horizons of tundra in the northern hemisphere, but is, however, of the same order as those at 30-cm horizontal distance from a mat of *Dryas integrifolia* M. Vahl. in a raised beach soil on Devon Island (39 m g^{-1}), from a new moraine and a marble schist soil on Signy Island, Antarctica and from Mt. Allen in Canada at 2800 m (Table 1). Data available for Signy and Devon Islands showed that the above soils were dry, of high pH and contained low amounts of organic matter, similar to the polar semi-desert soils in the present study (Table 1). Fungal hyphal length in tundra soils has been shown to increase with soil temperature and moisture, together with decreasing soil pH (Dowding and Widden 1974). The summer soil temperature was relatively high at the Ny-Ålesund site (Table 1), and thus, the low hyphal length could have been due to the relatively low moisture content and high pH of the soils present. Additionally, in polar semi-desert communities the major factor inhibiting saprotrophic fungal development could be a lack of organic matter rather than physical conditions (Widden and Parkinson 1979), or simply the lack of plant cover itself, which would reduce the possibility of including the ectomycorrhizal hyphae often associated with polar dwarf shrubs (Miller and Laursen 1974). The extremely small value in the present study may also represent an atypical seasonally low length, however, the maximum value (136 m g^{-1}) in Truelove Lowland was approximately only twofold higher than the minimum (Widden et al. 1972), and is still very low compared to non-lithosol estimates (Table 1). Using a mean ($\pm$ SE) hyphal diameter of 2.99 ($\pm$ 0.07) μm, the mean ($\pm$ SE) fungal biomass value for the Ny-Ålesund site was 4.89×10^{-5} ($\pm 0.323 \times 10^{-5}$) g oven-dry weight mycelium per g oven-dry litter. With an estimated soil bulk density of 0.13 g cm^{-3} [calculated by the method of Harrison and Bocock (1981), using 79% loss-on-ignition determined from these soils] the fungal biomass was equivalent to 0.1 g m^{-2} which, although very low in comparison with other Arctic sites and other biomes (Kjøller and Struwe 1982; Syzova and Panikov 1995), is similar to the values obtained from standing dead material on a polygon rim (0.3 g m^{-2}) and from the litter (0–20 mm) of a dry grass-covered polygon (0.5 g m^{-2}) in tundra at Barrow, Alaska (in Kjøller and Struwe 1982).

Measurements of fungal hyphal length recorded in Table 1, including ours, were not all carried out using the membrane filter technique, but all refer to total (living and dead) length. Bååth and Söderström (1980) showed that hyphal length values were 1.1–3.9 times higher using the Jones and Mollison (1948) agar film technique than the membrane filter method. Even if the higher correction factor was used, the value obtained in our study (90 m g^{-1}) would be of the same order as those from the Devon Island beach ridge and the Signy Island old and new moraine soils, together with the marble schist soils, and many orders different to values from other tundra biome sites (Table 1).

This study has shown that, although the mean fungal hyphal length at this polar semi-desert site is very low compared to temperate and most other tundra values, it is similar to those from analogous lithosols in both Arctic and Antarctic regions.

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