First records of protostelids from northern India

John D. Shadwick and Steven L. Stephenson*

Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701, USA

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Twelve species of protostelids were isolated from samples of aerial litter and ground litter collected from three study sites in the Himalayan Mountains of northern India. Samples of aerial litter yielded seven species, and nine species were recovered from samples of ground litter. Four species were recorded from both types of litter. *Schizoplasmodiopsis pseudoendospora* was the single most widely distributed species and was recorded from both types of litter and at all three study sites.

Key words: ecology, Eumycetozoa, forests, litter microhabitat, slime moulds.

Introduction

The protostelids are a group of unicellular mycetozoans (slime moulds) with amoeboid trophic cells and simple fruiting bodies in their life cycles. Together with two other groups of slime moulds, the myxomycetes and dictyostelids, they make up the taxonomic group Eumycetozoa (Olive, 1975; Spiegel *et al*., 1995). Slime moulds are eukaryotic, phagotrophic bacterivores that probably have an important role in the regulation of the populations of bacteria present in soils and other microhabitats (Feest, 1987). The amoeboid trophic cells of protostelids appear to be most common in litter microhabitats, both aerial litter (dead but still attached plant parts) and ground litter. Species diversity and richness of protostelids have been reported to vary among different types of terrestrial ecosystems. Temperate habitats in northwest Arkansas in the United States exhibit the greatest species diversity and richness reported to date (Moore and Spiegel, 2000a), followed by tropical montane forests in Puerto Rico (Moore and Spiegel, 2000b), with boreal forests and tundra of Alaska (Moore *et al*., 2000) having the lowest values for both parameters. However, the body of data available on the distribution and ecology of protostelids throughout most of the world is still very limited, and this is particularly true for Asia.

* Corresponding author: Steven Stephenson; e-mail: slsteph@mail.uark.edu

The purpose of the present study was to obtain some preliminary data on the species of protostelids associated with aerial litter and ground litter microhabitats in the forests of northern India. The general approach used was similar to that described in a number of other studies of mycetozoans (e.g. Schnittler *et al*., 2002; Lado *et al*., 2003), in which these organisms were cultured in the laboratory from samples collected in the field. In this study, samples were collected at three different study sites. Two of these (one located near the city of Shimla [31º 6' N, 77º 10' E] and the other near the village of Narkanda [31º 16' N, 77º 28' E]) are in Himachal Pradesh, whereas the third study site is in the Pauri region (30º 10' N, 78º 46' E) of Uttaranchal Pradesh. Sampling was carried out in early August 2000.

Study Area

All three study sites are within the Himalayan Mountains of northern India. Forests in the region range in elevation from about 1800 to more than 2600 m. Mean annual temperatures vary from about 10 to 14 C, with average monthly temperatures of 17 to 21 C in June and 3 to 6 C in January. Mean annual precipitation varies widely throughout northern India, but most areas receive more than 250 cm, the major portion of which occurs during the monsoon months of June to September. Forest types include those made up of chir (*Pinus roxburghii*) at the lowest elevations, oaks and other broad-leaved species at intermediate elevations, and spruce (*Picea smithiana*)–sliver fir (*Abies pindrow*) at elevations above about 2120 m. Among the more important trees in forests at intermediate elevations are banj oak (*Quercus leucotrichophora*), rhododendron (*Rhododendron arboreum*), kharsu oak (*Q. semecarpifolia*), and rianj oak (*Q. lanuginosa*) (Stephenson and Saxena, 1994).

Materials and methods

As used herein, the ground litter microhabitat was defined as the layer of twigs, leaves, and other plant debris extending over the soil surface on the ground, whereas the aerial litter microhabitat was defined as dead but still attached plant parts (mostly leaves and old inflorescences) located above the ground. At least one sample of each type of litter was collected at each study site, for a total of 10 samples (five aerial and five ground). All samples were placed in small paper bags, allowed to air-dry, and then sent to University of Arkansas, where protostelids were isolated using a modification of the technique described in Olive (1975). Each sample was broken into small pieces, soaked in sterile distilled water for *ca*. 20 minutes, and then removed.

At least two replicates of each sample were plated out onto a weak malt yeast medium (0.02 g malt extract, 0.02 g yeast extract, 0.75 g K_2HPO_4, 15 g agar/L of distilled water). Observations were made using the low power objective lens (100X total magnification) of a compound light microscope. Checking of culture plates began approximately five days after samples were plated out and continued for three weeks. Species were identified by fruiting body morphology and, if necessary, by characteristics of the amoebae. Nomenclature follows Olive (1975).

Results

Twelve different species of protostelids were recorded from litter samples collected in the three study sites (Table 1). Samples of aerial litter yielded seven species, and nine species were recovered from samples of ground litter. Three species were recorded only from aerial litter, and five species were recovered only from ground litter. Four species (*Protostelium mycophaga*, *Schizoplasmodiopsis pseudoendospora*, *Schizoplasmodiopsis amoeboidea*, and *Schizoplasmodium cavostelioides*) were associated with both types of litter. The former was the single most widely distributed species and was recorded from both types of litter and at all three study sites.

Table 1. Occurrence of protostelids on samples of litter collected from three study sites in northern India. Data are numbers of samples (n = 5) from which the species was recorded. A = aerial litter and G = ground litter.

Species	A	G
Cavostelium apophysatum	0	1
Echinostelium bisporum	0	1
Endostelium zonatum	2	0
Nematostelium gracile	1	0
Nematostelium ovatum	0	2
Protostelium arachisporum	0	1
Protostelium mycophaga	2	3
Schizoplasmodiopsis amoeboidea	2	1
Schizoplasmodiopsis pseudoendospora	4	4
Schizoplasmodiopsis vulgare	0	1
Schizoplasmodium cavostelioides	3	1
Soliformovum irregularis	2	0
Total number of species	7	9

The highest number of species isolated from one sample was seven, for a sample of aerial litter collected in the study site near Shimla. Six of the ten samples yielded at least three different species, but only a single species was

recorded from three of the samples. Although total species richness was higher for the set of ground litter samples, the mean number of species for all samples from this microhabitat was the same (3.2) as for the aerial litter microhabitat.

Discussion

All of the protostelids recovered in the present study also have been reported from temperate habitats in North America (e.g. Baker, 1975; Best and Spiegel, 1984; Moore and Spiegel, 1995; Moore and Spiegel, 2000a). *Schizoplasmodiopsis pseudoendospora* and *Protostelium mycophaga*, the two species recorded from the most samples in the present study, also were among the most abundant species occurring in temperate habitats in northwest Arkansas (Moore and Spiegel, 2000a), and the total number of species (15) recovered in the latter study is comparable to number (12) we recorded.

As a general observation, the assemblages of protostelids associated with litter microhabitats in temperate montane forests of northern India appear to exhibit levels of species richness and diversity comparable to those reported for temperate habitats in North America. Although limited in extent, the preliminary data obtained in the present study represent a contribution towards the goal of developing a more complete understanding of the distribution and ecology of protostelids in terrestrial ecosystems. More importantly, the results we obtained provide a basis from which further studies can be launched.

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