Occurrence of fungal structures in bryophytes of the boreo-nemoral zone

Ligita Liepiņa*

Department of Botany and Plant Ecology, University of Latvia, Kronvalda Bulv. 4, Riga LV-1586, Latvia

*Corresponding author, E-mail: ligita.liepina@lu.lv

Abstract

A survey of arbuscular mycorrhizal structures in bryophyte species was conducted. In total, 43 bryophyte species belonging to 29 families were studied. A search was made for hyphae and vesicles resembling structures of arbuscular mycorrhizal (AM) fungi in bryophytes. AM fungal structures (arbuscules, vesicles, hyphal coils nonseptate intra and inter celular hyphae) were found only in epigeous hepatics. AM fungal structures were absent in 21 moss species and recorded in only four of the studied 21 hepatics species and one of the hornworts. Other fungal structures were also observed. Fungal structures were observed in bryophyte stem and leaf tissues, and in rhizoids. The AM association with bryophytes was observed to be symbiotic.

Key words: arbuscular mycorrhizal fungi, bryophyte, hepatics, moss, symbiosis.

Introduction

Bryophytes, which are classified into the divisions Marchantiophyta (liverworts), Anthocerotophyta (hornworts) and Bryophyta (mosses), are the oldest known land plants in the world (Zinsmeister, Mues,1987). Bryophytes play an important role in the dynamics of understory vegetation, nutrient cycling, soil structure and stability (Smith, Read 1997). The lack of vascular tissue in bryophytes species has led to a plethora of strategies in nutrient acquisition.

Arbuscular mycorrhizas, formed only by fungi in the division Glomeromycota (Goffinet 2009), are found in 85% of all plant families (Wang 2006). However, mycorrhizal fungus-bryophyte associations have also been reported, even in early studies on symbiotic associations (Rayner 1927; Kelley 1950; Gerdemann 1968; Harley 1969). Some liverworts and hornworts are known to form symbiotic relationships with arbuscular mycorrhizal (AM) fungi (Turnau et al. 1999; Schüßler 2000), which has been confirmed in studies using axenic cultures. Mycorrizal associations have been described between the fungus Glomus epigeios (G. versiforme), moss Funaria hygrometrica and companion plant Asparagus (Parke 1979), and between Anthoceros punctatus and Glomus tenue (Schüßler 2002), between Glomus tenue and Pellia sp. (Turnau et al. 1999). Read (2000) proposed that these fungal associations are ancient and important for the first plants to colonize land. Fosil evidence of Glomalen fungal structures associated with early bryophytes in Ordovician sediments that are 460 and 400 million years old support this contention (Redecker et al. 2000).

While the presence of AM structures in some bryophytes

has been demonstrated, information on the overall occurrence and the level of colonization of mycorrizal associations in this group of plants is lacking. The aim of the present study was to determine the occurrence of AM structures in 43 bryophyte species collected from different natural habitats in Latvia.

Materials and methods

In July 2006 to 2011, bryophytes samples from 43 bryophyte species belonging to 29 families were collected in four areas from a variety of substrates and habitats (decayed wood, bark, agricultural soil, forest soil, meadows, bogs and sandstone). The areas and habitats considered were: forest groves and ravines of the Slitere National park N 57°37′48.5", E 22°17′38.7", agricultural soil and roof bryophytes in Iecava N 56°41′16", E 23°42′04", broad leaved forest in Kaltene N 57°28′00", E 22°54′00", and ruderal bryophytes from Salaspils N 56°51′40", E 24°20′58". In the study area, mean annual temperature is 5.7 °C and precipitation is about 400 to 600 mm.

Samples of the entire current year gametophyte were cleared in 10% KOH (20 min at 90 °C), acidified in lactic acid, and stained for 20 min with 0.5% cotton blue. A total of 30 1-cm-long fragments were mounted on slides in glycerol and examined with Olympus BX41 compound microscope at 100 to 400 × magnification. The presence of the following AM fungal structures was recorded: arbuscules, vesicles, hyphal coils and intra- and intercelluar hyphae. Colonization level was measured according to Trouvelot et al. (1986).

Bryophyte tissues with observed AM fungi were

cultivated in trap cultures together with the host plant *Plantago lanceolata* for two months (Oehl 2003). Seeds of *P. lanceolata* were surface-sterilized [15 min with a 10% sodium hypochlorite solution (w/v)]. The AM fungal inoculum consisted of pieces of 1-cm-long thallus of *Conocephalum salebrosum* containing fungal hyphae. The inocula were placed in $27 \times 17 \times 20$ cm (length × width × height) pots containing a sterilized substrate (1 h at 120 °C) composed of sand:vermiculite (3 : 1, v/v). Each pot then received a transplant consisting in three *P. lanceolata* plants per pot. The plants were grown in a glasshouse for 2 months. Plants were watered from below by distilled water.

Bryophyte nomenclature followed Hill et al. (2006) for mosses and Grolle and Long (2000) for liverworts.

Results

Among the examined 43 bryophyte species belonging to 28 families, AM fungal structures were found in five species (11.6 %; Table 1) and septate fungi on thallus or stem tissue surface in 13 species (30.2 %). The majority of species (25 species, 58.1 %) lacked fungal associations. Mycorrhizal symbiosis associations were not present in epiphytic and epixylic bryophytes. Only epigeic bryophytes were found to have mycorrhizal associations.

AM intercellular and intracellular hyphae were found only in gametophytes (Table 1): thallus tissues of Marchantiophyta (simple and complex thalloid species) and thallus of Anthocerotophyta, but were absent in Bryophyta stem and leaf tissues and in Machantiophyta (leafly species). Both AM hyphae and vesicles were observed in *Conocephalum salebrosum* (Fig. 1A) and *Fossombronia floevolata* (Fig. 1B, C). Arbuscules were found only in tissues of *Conocephalum salebrosum*. Fungal colonization may affect morphology of rhizoids, however, the rhizoids of *Conocephalum salebrosum* containing nonseptate hyphae (Fig. 1D) were unchanged. In contrast, swollen rhizoids of *Kurzia pauciflora* were observed to have septate fungal colonisation. The hyphal entry points into the bryophyte were rhizoids.

Fungal endophytes occurred in cell walls of *Cephalozia* bicuspidata (Fig. 1E) and stem tissues of *C. pleniceps*. Septate fungi possibly belonging to Ascomycetes or Basidiomycetes were observed growing on tissues of 13 bryophyte species (Table 1): Aneura pinguis, Cephalozia bicuspidata, *C. pleniceps*, Homalia trichomanoides, Kurzia pauciflora, Trichocolea tomentella, Antitrichia curtipendula, Brachythecium rutabulum, Bryum argenteum, Ceratodon purpureus, Hylocomium splendens, Sphagnum magelanicum, and Syntrichia ruralis.

The mean bryophyte colonization level by AM aseptate endophytes varied from 5 to 45% (Fig. 2) and by septate endophytes from 10 to 25%. The fungal colonization level of five Hepaticophyta species was 45% or less. In general, the colonization level in the studied bryophyte species ranged from low to average. Experiments with trap cultures failed to show symbiosis between fungi from bryophyte tissues and the host plant *Plantago lanceolata*.

Discussion

As expected, only epigeic bryophytes were found to have mycorrhizal associations. Two different types of endophytes were found in bryophyte tissues: those with septate hyphae and those with aseptate hyphae. Septate fungi belonged to several ascomycete or basidiomycetes species The morphology of liverwort-basidiomycete associations has been described by several authors (Kottke et al. 2003; Duckett et al. 2006; Davey 2006; Duckett, Ligrone 2008). Cephalozia species, according to the published data, are nonmycorrhizal, but grow together with ascomycetes. We found a mosaic of colonized (septate hyphae) and uncolonized cells in stem tissues of Cephalozia species (Fig. 1E). The thin leafed liverworts Kurzia pauciflora, Trichocolea tomentella were colonized with septate fungi. Mosses (Bryophyta) formed associations only with septate fungi. Rabatin (1980) reported the association of G. tenuis and unidentified "coarse" AM fungi in fieldcollected specimens of the Pogonatum. Our investigation of Pogonatum urnigerum did not show the presence any fungal endophytes in the gametophytes.

Aseptate fungi, representing AM fungi from the Glomaceae family, form symbiosis with bryophyte tissues (Pressel 2010). In the present investigation, the large complex thalloid liverwort *M. polymorpha* subsp. *ruderalis* was nonmycorrhizal. *Conocephalum salebrosum* and *C. conicum* were moderately mycorrhizal. *Blasia pusilla* and several *Riccia* species did not have fungal endophytes. The simple thalloid liwervorts *P. endiiviifolia* and *F. floevolata* were found to be mycorrhizal. Two simple thalloid liwervort species *A. pinguis* and *F. floevolata* often grow side by side in the same biotope, but AM hyphae were found only in thalli of *F. floevolata*. Intensity of the symbiosis was at a medium level. *Aneura pinguis* was nonmycorrhizal, but contained other septate endophytes.

The only representative from Anthocerota (*Anthoceros agrestis*) was found to have a low mycorrhizal intensity, which corresponds to published data (Lignore 1988; Kottke et al. 2003).

According to Lignore (2007), the hepatics *C. conicum* and *C. salebrosum* contain Glomeromycoetan endophytes, which were identified by molecular techniques. In the present study, AM structures (nonseptate hyphae, vesicles, arbuscules) were found in thalli of *C. conicum*, *C. salebrosum*, *F. floevolata* and *P. endiviifolia*, indicating functionally active mycorrhizal symbiosis. Functional structures always were present in the parenchymal tissue around the midrib in live tissues. Jakucs et al. (2003) suggest that the absence of arbuscules in mosses colonized by AM fungi may be due to seasonal fluxes in nutrient avaiability or the ephemeral Table 1. Bryophyte species and fungal structures found

Arbuscules / vssides Intracellular vssides Basidimoyota substrate Authocerotophyta intracellular intracember intrace intreace intreace intrace intrace intrace intrace intreace intrace i	Bryophyte species	Glomeromycota		Ascomycota /	Ecological type /
vesiclesnonseptate hypha/ htracellularSeptate hypha/ on tissue surface intracellularAnthocerotophytaAnthocerotophytaAnthocerotophyta (L) Dum.+-Anterore signific (L) Dum+Bisai pusilla LCiphalozia bicargidata (L) Dum+Ciphalozia bicargidata (L) Dum+Ciphalozia bicargidata (L) Dum+Concephalum salebrosum Szwcyk.++Concephalum salebrosum Szwcyk.++Pallatia (L) DumConcephalum salebrosum Szwcyk.++Prallatia (L) DumPrallatia fagalifylia (L) DumPriphylic / treePriphylic / treePriphylic / treePriphylic / treePriphylic / tree-<	* * * *	Arbuscules /	Intracellular	Basidimovcota	substrate
intracellular on tissue surface conseptite hyphae Anthocerotophyta Anthocerotophyta Arechantophyta (Liverworts) - - Charlow Colspan="2">Charlow Colspan="2"		vesicles	nonseptate hyphae /	Septate hyphae	2
Anthoceros ageristis (Paton) Damsholt - + - Epigeic / clay Marchantiophyta (Liverworts) - - + Epigeic / lay Aneura pinguis (L) Dam. - - + Epigeic / wamp Cephalozia pinetores (Aust.) Indb. - - + Epigeic / wamp Concephalum solutors (L) Dum. - + + Epigeic / wamp Concephalum solutors (L) Dumort.) - + + Epigeic / lay Concephalum solutors Sraveyk., + + - Epigeic / clay Prullania dilatata (L) Dum. - - - Epigeic / clay Frullania dilatata (L) Dum. - - Epiphytic / tree Frullania distata (L) Dum. - - Epiphytic / tree Frullania distata (L) Dum. - - Epiphytic / tree Marchanta polymorpha subsp. ruderalis 1. - - Epiphytic / deaying trees Marchanta polytic (Ibcks) Corole - - Epiphytic / deaying trees Marchanta polytic (Ibcks) Dum. - - Epiphytic / deaying trees Marchanta polytic (Ibcks) Mitt. <td></td> <td></td> <td>intracellular</td> <td>on tissue surfac</td> <td>æ</td>			intracellular	on tissue surfac	æ
Anhocerotophyta Anhocerotophyta Anthocerotophyta Antencaros agressis (Paton) Damsholt - Aneatra tophyta (Liverworts) Aneatra tophyta (Liverworts) Bissia pusible L - Cephalozia bicuspidata (L.) Dum. - Concephalum constant (L.) Dumot.) - - + Denocephalum constant (L.) Dumot.) - - + Possonbronia floevolata Lindb. + Prallania diadata (L.) Dum. - Prallania diadata (L.) Dum. - Frallania diadata (L.) Dum. - Frallania diadata (L.) Dum. - Prallania diagatifica (L.) Dum. - Frallania diadata (L.) Dum. - - - Homala trichonanoides (Hedw.) B., S. et G. - Harchantia polymorpha subsp. ruderalis L. - - - Epigeic / clay Mardantia polymorpha subsp. ruderalis L. - - Hardana dingatific Hoch.) S. Gray - - Karaja parking Markondo Hoch.) S. Stray - - Mariba constri func			nonseptate hyphae		
Anthocoros agrestis (Paton) Damsholt - + - Epigeic / clay Marchantophyta (Livervorts) - - + Epigeic / clay Ratera ripuigi (L) Dum. - - + Epigeic / swamp Cephalozis bicispidata (L) Dum. - + Epigeic / swamp Concocphalum conteum (L) Dumort.) - + + Epigeic / clay Concocphalum schrosum Szewsk, S. + + - Epigeic / clay Concocphalum schrosum Szewsk, S. + + - Epigeic / clay Concocphalum adorski Hedws, B.S. et G. - - + Epiphytic / tree Homalia trichomanoido (Hedws), B.S. et G. - - + Epiphytic / tree Homalia trichomorbia flocophytic (Schrad.) Dum. - - - Epigeic / swamp Lophocola heterophytic (Schrad.) Dum. - - - Epigeic / clay Redita atrifolida (Okcks). Große - - - Epigeic / clay Redita atrifolida (Okcks). Große - - - Epigeic / clay Redita atrufielda (Okcks). Mitt. - -	Anthocerotophyta				
Marchantiophyta (Liverworts) - - + Epigeic / marsh Bisaia pusilla L - - - Epigeic / clay Cephalozia bicaspidata (L) Dum. - - + Epigeic / swamp Concephalum conicum (L) Dumot.) - + + Epigeic / clay Concephalum conicum (L) Dumot.) + + + Epigeic / clay Concephalum conicum (L) Dumot.) + + + Epigeic / clay Encoloseski & Colorzykoski - - - Epigeic / clay Frultania fagilifica (L) Dum. - - - Epiphylic / tree Frultania fagilifica (L) Dum. - - - Epiphylic / tree Frultania fagilifica (L) Dum. - - - Epipskic / decaying trees Carcia paterials L - - - Epipskic / decaying trees Marchantia polymorpha subsp. ruderalis L - - Epipskic / decaying trees Metzgeria furcata (L.) Dum - - Epipskic / decaying trees Metzgeria furcata (L.) Dum - - Epipkic / clay R	Anthoceros agrestis (Paton) Damsholt	-	+	_	Epigeic / clay
Aneura pinguis (L.) Dum. – – – – – – – – – – Epigeic / day Eghalozia bicaspidata (L.) Dum. – – – – – – Epigeic / day Cephalozia bicaspidata (L.) Dum. – – – + Epigeic / swamp Connecephalum salebrosum Szweyk, + + + – – Epigeic / day Connecphalum salebrosum Szweyk, + + + – – Epigeic / day Enconcephalum salebrosum Szweyk, + + + – Epigeic / day Enconcephalum salebrosum Szweyk, + + + – Epigeic / day Enconcephalum salebrosum Szweyk, + + + – Epigeic / day Enconcephalum salebrosum Szweyk, + + + – Epigeic / day Enconcephalum salebrosum Szweyk, + + + – Epigeic / day Enconcephalum salebrosum Szweyk, + + + – Epigeic / day Enconcephalum salebrosum Szweyk, + + + – Epigeic / day Enconcephalum salebrosum Szweyk, + + + – Epigeic / day Enconcephalum salebrosum Szweyk, + + + – Epigeic / day Frullania fragilfölfa (L.) Dum. – – – – – – Epipyhric / tree Frallania fragilfölfa (L.) Dum. – – – – Epipyhric / tree Epipatic / Dum, – – – – Epipyhric / tree Marchantia polymorpha subsp. ruderalis L. – – – Epipylic / decaying trees Marchantia polymorpha subsp. ruderalis L. – – – Epipylic / day Marchantia polymorpha subsp. ruderalis L. – – – Epipylic / day Marchantia polymorpha subsp. ruderalis L. – – – Epipylic / day Marchantia polymorpha subsp. ruderalis L. – – – Epipylic / decaying trees Marchantia polymorpha subsp. ruderalis L. – – – Epigeic / day Marchantia polymorpha subsp. ruderalis L. – – – Epigeic / day Marchantia polymorpha subsp. ruderalis L. – – – Epigeic / day Ruderali (Tiokok) Mitt. – – – – Epigeic / day Ruderali qualmata (I.) Dum. – + Epigeic / day Radua compliantat (I.) Dum. – – – Epigeic / day Ruderali palmatat (I.) Dum. – – – Epigeic / day Ruceralia palmatat (I.) Dum. – – – Epigeic / day Ruceradia palmatat (Hedw) Carruth. – – – – Epigeic / day Ruceradia palmatat (Hedw) Carruth. – – – – Epigeic / day Ruceradia palmatat (Hedw) Brid. – – – – Epigeic / forest soil Bryophytic / tree Bryoma magenteum Hedw. Brid. – – – – Epigeic / forest soil Bryophytic / tree Strichouna soparium Hedw. Brid. – – –	Marchantiophyta (Liverworts)				10 /
Blasia pusilla L. – – – – Epigeic / clay Caphalozia bicuspidata (L.) Dum. – – – + Epigeic / swamp Concephalum subtrosum Szweyk., + + + – – Epigeic / swamp Concephalum subtrosum Szweyk., + + + – – Epigeic / clay Eocologia bicuspidata (L.) Dum. – – – + Epigeic / clay Eocologia facevolata Lindb. + + + + – – Epigeic / clay Frullania ditata (L.) Dum. – – – – Epippityic / tree Frullania ditata (L.) Dum. – – – – Epippityic / tree Frullania ditata (L.) Dum. – – – – Epippityic / tree Frullania ditata (L.) Dum. – – – – Epippityic / tree Frullania ditata (L.) Dum. – – – – Epippityic / tree Frullania ditata (L.) Dum. – – – – Epippityic / tree Frullania ditata (L.) Dum. – – – – Epippityic / tree Frullania ditata (L.) Dum. – – – – Epippityic / tree Homalia trichomanoides (Hedw) B., S. et G. – – – – Epipgic / decaying trees Marckantia polymorpha subsp. ruderalis L. – – – – Epipgic / clay Ecologia heterophylla (Schrad.) Dum. – – – – Epippityic / decaying trees Marckantia polymorpha subsp. ruderalis L. – – – Epippityic / decaying trees Marckantia polymorpha subsp. ruderalis L. – – – Epippityic / decaying trees Marckantia polymorpha subsp. ruderalis L. – – – Epippityic / decaying trees Marckantia polymorpha subsp. ruderalis L. – – – Epippityic / decaying trees Marckantia polymorpha subsp. ruderalis L. – – – Epippityic / decaying trees Marckantia polymorpha subsp. ruderalis L. – – – Epippityic / decaying trees Marckantia polymorpha subsp. ruderalis L. – – – Epippityic / tree Mylia anomala (Hook.) S. Gray – – – Epippityic / tree Mylia anomala (Lobok.) Gray – – – Epippityic / tree Riccai fluitans L. emend. Lorbeer – – – – Epippityic / tree Riccai fluitans L. emend. Lorbeer – – – – Epippityic / decaying trees Trichocolea tomentella (Echth.) Dum. – – – – Epippityic / clay Riccai fluitans L. emend. Lorbeer – – – – Epippityic / tree Bryompta (Moses) Autirchia cartificpadula (Hedw.) Brid. – – – – Epippityic / forest soil Bryophyta (Moses) Carcatodo puppureus (Hedw.) Brid. – – – Epippityic / tree Bryophy	Aneura pinguis (L.) Dum.	-	-	+	Epigeic / marsh
Cephalozia bicuspidata (L.) Dum. - + Epigeic / swamp Cephalozia plenicejs (Aust) Lindb. - + Epigeic / lay Concoephalum solicum (L. Dumot.) + + Epigeic / clay Buczkowski & Odrzykoski - - Epigeic / clay Buczkowski & Odrzykoski - - Epigeic / clay Sesombronia floevolata Lindb. + + - Epigeic / clay Fruilania ditatata (L.) Dum. - - - Epiphytic / tree Fundiat irichomanoids (Hedw) B., S. et G. - - + Epiphytic / tree Homalia trichomanoids (Hedw) Dum. - - - Episcic / eavaing trees Marchantia polymorpha subsp. ruderalis L. - - - Episcic / clay Metzgeria furcata (L.) Dum - - Episcic / swamp Nowellia curvifola (Dicks.) Mitt. - - Episcic / swamp Nowellia curvifola (Dicks.) Sum. - - - Episcic / clay Episcic / clay Racta glauca L. - - - Episcic / clay Episcic / clay Episci / forest soli Episcic / fores	Blasia pusilla L.	-	-	_	Epigeic / clay
Cophalozia pleniceps (Aust.) Lindb++Fpigeic / swampConocephalum conicum (L. Dumort.)-++-Fpigeic / dayBuczkowski & OdrzykoskiEpigeic / dayBusckowski & OdrzykoskiEpigeic / dayFrullania dilatata (L.) DumEpigeic / dayFrullania dilatata (L.) DumEpiphytic / treeHomalia trichomanoides (Hedw) B., S. et G+Epipotic / swampLophocolea heterophylla (Schrad.) DumEpistic / decaying treesMarchantia polymorpha subsp. ruderalis LEpistic / deaying treesMarchantia polymorpha subsp. ruderalis LEpistic / deaying treesMarchanta polymorpha subsp. ruderalis LEpistic / swampNowellia curvifolia (Dicks.) MutEpipeic / swampNowellia curvifolia (Dicks.) MutEpistic / deaying treesPellia endivitolia (Lobck.) StaryEpistic / forest soilBregorita (Moks.) StaryEpistic / forest soilRiccia glauca L	Cephalozia bicuspidata (L.) Dum.	-	-	+	Epigeic / swamp
Concephalum contcum (L. Dumort.)-+-Epigeic / clayConcephalum salebrosum Szweyk,++-Epigeic / clayBuczkowski & OdrzykoskiEpipeic / clayFrullania folgulata Lindb.++-Epipeic / clayFrullania folgulata Lindb.++-Epiphytic / treeFrullania forgulata Lindb.++-Epiphytic / treeHomalia trichomanoides (Hedw.) B., S. et G+Epiphytic / treeKurzia pauciflora (Dicks.) Grolle+Epipeic / swampLophocola heterophylla (Schrad.) DumEpipeic / clayemend. BurgeffEpipeic / clayMetzgeria furcata (L.) DumEpipeic / clayNowellia curvifolia (Dicks.) MittEpiphytic / treeMylia anomala (Hook.) S. GrayEpipeic / clayRadula complanata (L.) DumEpipeic / clayRadula complanata (L.) DumEpipeic / clayRiccia fluitans L. emend. LorbeerEpipeic / clayRiccia fluitans L. emend. LorbeerEpigeic / clayRiccia fluita	Cephalozia pleniceps (Aust.) Lindb.	-	-	+	Epigeic / swamp
Concephalum salebrosum Szweyk,++-Epigeic / clayBuczkowski & OdrzykoskiBuczkowski & OdrzykoskiFossombroni floevolata Lindb.++-Epigeic / clayFrullania dilatata (L.) DumEpiphytic / treeFrullania dilatata (L.) DumEpiphytic / treeHomalia trichomanoides (Hedw.) B.S. et G+Epipeic / swampLophocolea heterophylla (Schrad.) DumEpipkic / decaying treesMarchantia polymorpha subsp. ruderalis IEpipkic / decaying treesemend. BurgeffEpipeic / swampNowellia curvifolia (Dicks.) MittEpigeic / swampNowellia curvifolia (Dicks.) DumEpigeic / clayRiccia fluitans L. emend. LorbeerEpigeic / clayRiccia fluitans L. emend. Mohle.)Epigeic / clayRiccia fluitans L. emend. Hedw.)Epigeic / clayRiccia fluitans L. emend. Hedw.)Epigeic / clayRiccia fluitans L. emend. Hedw.) <td>Conocephalum conicum (L. Dumort.)</td> <td>-</td> <td>+</td> <td>-</td> <td>Epigeic / clay</td>	Conocephalum conicum (L. Dumort.)	-	+	-	Epigeic / clay
Buczkowski & Odrzykoski Posombronia floevolata Lindb. + + + - Epipeti, C day Prollaria dilatata (L.) Dum Epiphyti, / tree Frullania dilatata (L.) Dum Epiphyti, / tree Frullania dilata (L.) Dum Epiphyti, / tree Karcia paucifigar (Dicks, B., S. et G + Epiphytic / tree Marchantia polymorphs subsp. ruderalis L Epigei, / asvanp Lophocolea heterophylla (Schrad.) Dum Epipeti, / asvanp Marchantia polymorpha subsp. ruderalis L Epipeti, / asvanp Movellia curvifolia (Dicks.) Nutt Epipeti, / asvanp Movellia curvifolia (Dicks.) Nutt Epipyti, / decaying trees Pellia endivitifolia (Dicks.) Nutt Epipyti, / decaying trees Pellia endivitifolia (Dicks.) Nutt Epipyti, / decaying trees Pellia endivitifolia (Dicks.) Dum + Epipei, / asvanp Riccia fultans L. emend. Lorbeer Epipyti, / decaying trees Riccia fultans L. emend. Lorbeer Epipyti, / decaying trees Riccia fultans L. emend. Lorbeer Epipyti, / decaying trees Riccia fultans L. emend. Lorbeer Epipyti, / decaying trees Riccia fultans L. emend. Lorbeer Epipyti, / decaying trees Riccia fultans L. emend. Lorbeer Epipyti, / decaying trees Riccia fultans L. emend. Lorbeer Epipyti, / decaying trees Riccia fultans (Hedw.) Carruth Epipyti, / decaying trees Riccia fultans Bayes Epipyti, / decaying trees Riccia fultans Bayes Epipyti, / decaying trees Riccia fultans Bayes Epipyti, / decaying trees Riccia fultans fultand (Hedw.) B. et S Epipyti, / decaying trees Rutricha curtifiendual (Hedw.) Schwaegt Epipyti, / decaying trees Rutricha curtifiendual (Hedw.) Schwaegt Epipyti, / tree Rutricha curtifiendual (Hedw.) As, s	Conocephalum salebrosum Szweyk.,	+	+	_	Epigeic / clay
Fossombronia floevolata Lindb.++-Epigeic / clayFrullania figilióla (L.) DumEpiphytic / treeHumalia trichomanoides (Hedw.) B., S. et G+Epiphytic / treeKurzia pauciflora (Dicks.) Grolle+Epigeic / swampLophocolea heterophylla (Schrad.) DumEpisytic / treeMarchantia polymorpha subsp. ruderalis IEpisytic / deaving treesMetzgeria furcata (L.) DumEpisytic / deaving treesMetzgeria furcata (L.) DumEpisytic / deaving treesNowellia curvifolia (Dicks.) MittEpigeic / clayRadula complanta (L.) DumEpigeic / clayRadula complanta (L.) DumEpigeic / clayRadula complanta (L.) DumEpigeic / clayRiccia glauca LEpigeic / clayRiccia glauca LEpisytic / treeTrichocolea tomentella (Ehrh.) DumEpisytic / treeRiccia glamata (Hedw.) CarruthEpisytic / clayRiccaria glamata (Hedw.) Seid.<	Buczkowski & Odrzykoski				10 /
Frullania dilatata (L.) DumFpiphytic / treeHomalia trichomanoides (Hedw,) B., S. et G+Epiphytic / treeHomalia trichomanoides (Hedw,) B., S. et G+Epiphytic / treeKarria pauciffora (Dicks,) Grolle+Epigeic / swampLophocolea heterophylla (Schrad,) DumEpisytic / decaying treesMarchantia polymorpha subsp. ruderalis LEpigeic / claymemed. BurgeffEpigeic / leavangMowellia curvipfica (Dicks,) MittEpigeic / leavangNowellia curvipfica (Dicks,) MittEpigeic / clayRadua complanata (L) DumEpigeic / clayRadua complanata (L) DumEpigeic / clayRiccia fluitans L. emend. LorbeerEpigeic / clayRiccia fluitans L. emend. LorbeerEpigeic / dayRiccia fluitans L. emend. LorbeerEpigeic / dayAutocontium palatste (Hedw) Skaget. <t< td=""><td>Fossombronia floevolata Lindb.</td><td>+</td><td>+</td><td>-</td><td>Epigeic / clay</td></t<>	Fossombronia floevolata Lindb.	+	+	-	Epigeic / clay
Frullania fragilifolia (L.) Dum. - - - Epiphytic / tree Homalia trichomanoides (Hedw.) B., S. et G. - - + Epipeir, Swamp Lophocolea heterophylla (Schrad.) Dum. - - - Epipsylic / tree Marchantia polymorphs usbsp. ruderalis L. - - - Epipsylic / decaying trees Metzgeria furcata (L.) Dum - - - Epiphytic / tree Mylia anomala (Hook) S. Gray - - - Epipeir (-// swamp Nowellia curvifolia (Dicks.) Mitt. - - - Epipeir (-// swamp Rola and complanata (L.) Dum. - + - Epigeic / day Riccia gluta complanata (L.) Dum. - + - Epigeir (-// day Riccia gluta L. - - - Epipeir (-// day Riccia gluta L. - - - Epipeir (-// day Riccia gluta L. - - - Epipeir (-// day Riccia gluta L. - - + Epipeir (-/ day Riccia gluta L. - - - Epipeir (-/ day </td <td>Frullania dilatata (L.) Dum.</td> <td>-</td> <td>-</td> <td>_</td> <td>Epiphytic / tree</td>	Frullania dilatata (L.) Dum.	-	-	_	Epiphytic / tree
Homalia irichomanoides (Hedw.) B., S. et G. – – – + Epiphytic / tree Kurzia pauciflora (Dicks.) Grolle – – – – Epipxilic / decaying trees Marchanita polymorpha subsp. ruderalis L. – – – – Epipxilic / decaying trees Marchanita polymorpha subsp. ruderalis L. – – – – Epiphytic / tree Metzgeria furcata (L.) Dum – – – – Epiphytic / tree Mylia anomala (Hook.) S. Gray – – – Epipeic / decaying trees Pellia endivitfolta (Dicks.) Mitt. – – – – Epipeic / decaying trees Pellia endivitfolta (Dicks.) Dum. – + – Epipeic / decaying trees Pellia endivitfolta (Dicks.) Dum. – + – Epipeic / decaying trees Pellia endivitfolta (Dicks.) Dum. – + – Epipeic / decaying trees Pellia endivitfolta (Dicks.) Dum. – + + Epipeic / decaying trees Pellia endivitfolta (Dicks.) Tree Riccia futians L. emend. Lorbeer – – – Epipxilic / tree Riccia futians L. emend. Lorbeer – – – Epipxilic / decaying trees Piphytic / tree Riccia futians L. emend. Lorbeer – – – Epipxilic / deaying trees Irichacolae tomentella (Ehrh.) Dum. – – – + Epipeic / day Riccia futians L. emend. Lorbeer – – – Epipxilic / decaying trees Paysing (Mosses) Anttirichia curtipendula (Hedw.) Carruth. – – – + Epipeic / day Antarichum tenellum (Röhl.) B. et S. – – – – Epipytic / tree Artichum tenellum (Röhl.) B. et S. – – – – Epipeic / day Aulacomium palustre (Hedw.) Schwaegr. – – – Epipeic / day Aulacomium palustre (Hedw.) Schwaegr. – – – Epipeic / forest soil Brachythecium rutabulum (Hedw.) B., S. et G. – – – + Epipeic / soil Ceratodon purpureus (Hedw.) Brid. – – – – Epipeic / soil Cinclidium stygium Sw. – – – – Epipeic / forest soil Ditrichum flexicaule (Schwaegr.) Hampe – – – Epipeic / forest soil Ditrichum flexicaule (Schwaegr.) Hampe – – – Epipeic / forest soil Ditrichum flexicaule (Schwaegr.) Hampe – – – Epipeic / forest soil Leucobryum glaucum (Hedw.) B., S. et G. – – – Epipeic / forest soil Neckera complanata (Hedw.) Magstr. – – – Epipeic / forest soil Puccotau complanata (Hedw.) Magstr. – – – Epipeic / forest soil Puccotau complanata (Hedw.) Angs	Frullania fragilifolia (L.) Dum.	-	-	_	Epiphytic / tree
Kurzia pauciflora (Dicks.) Grolle - - + Epigeic / swamp Lophocolea heterophylla (Schrad.) Dum. - - Epigylic / decaying trees Marchanita polymorpha subsp. ruderalis L. - - Epigeic / clay Metzgeria furcata (L.) Dum - - Epigeic / swamp Nowellia curvifolia (Dicks.) Mitt. - - - Epigeic / decaying trees Pellia endivifolia (Dicks.) Dum. - - - Epigeic / decaying trees Radula complanata (L.) Dum. - - - Epigeic / decaying trees Riccia glauca L. - - - Epigeic / decaying trees Riccia glauca L. - - - Epigeic / day Riccardia palmata (Hedw.) Carruth. - - - Epigeic / day Riccardia palmata (Hedw.) Brid. - - + Epigeic / forest soil Bryophyta (Mosses) - - - Epigeic / clay Autirichia curtipendula (Hedw.) Brid. - - + Epigeic / forest soil Bryuphyta (Mosses) - - + Epigeic / forest soil <td>Homalia trichomanoides (Hedw.) B., S. et G.</td> <td>_</td> <td>-</td> <td>+</td> <td>Epiphytic / tree</td>	Homalia trichomanoides (Hedw.) B., S. et G.	_	-	+	Epiphytic / tree
Lophocolea heterophylla (Schrad.) DumEpigv/lic / decaying treesMarchantia polymorpha subsp. ruderalis LEpigei / clayemend. BurgeffEpigei / clayMetzgeria furcata (L.) DumEpigei / swampNowellia curvifoia (Dicks.) MittEpigei / clayRadula complanata (L.) DumEpigei / clayRiccia fluitans L. emend. LorbeerEpigei / clayRiccardia palmata (Hedw.) CarruthEpigei / clayRiccardia palmata (Hedw.) BridEpigei / clayAulaconnium palustre (Hedw.) BridEpigei / clayAulaconnium palustre (Hedw.) BridEpigei / clayBryun argenteum HedwEpigei / clayBryun argenteum HedwEpigei / soilCircatodon purpureus (Hedw.) BridEpigei / soilCircatoson purpureus (Hedw.) BridEpigei / soil <td>Kurzia pauciflora (Dicks.) Grolle</td> <td>-</td> <td>-</td> <td>+</td> <td>Epigeic / swamp</td>	Kurzia pauciflora (Dicks.) Grolle	-	-	+	Epigeic / swamp
Marchantia polymorpha subsp. ruderalis LEpigeic / clayMetzgeria furcata (L.) DumEpigeit / treeMylia anomala (Hook). S. GrayEpigeic / swampNowellia curvifolia (Dicks.) MittEpigeic / clayRadula complanata (L.) Dum+-Epigeic / clayRadula complanata (L.) DumEpigeic / clayRiccia fultinas L. emed. LorbeerEpigeic /	Lophocolea heterophylla (Schrad.) Dum.	-	-	-	Epixylic / decaying trees
emend. Burgeff Metzgeria furcata (L.) Dum – – – Epiphytic / tree Mylia anomala (Hook.) S. Gray – – – Epipeic / swamp Nowellia curvifolia (Dicks.) Mitt. – – – Epipeic / clay Radula complanata (L.) Dum. – + – Epipeic / clay Radula complanata (L.) Dum. – – – – Epipeic / clay Raiccia glauca L. Riccia glauca L. Riccardia palmata (Hedw.) Carruth. – – – – Epipeic / clay Riccardia palmata (Hedw.) Carruth. – – – – Epipeic / clay Riccardia palmata (Hedw.) Carruth. – – – – Epipeic / clay Riccardia palmata (Hedw.) Brid. – – – + Epipeic / forest soil Bryophyta (Mosses) Antirichia curtipendula (Hedw.) Brid. – – – – Epipeic / clay Raicchythecium rutabulum (Hedw.) Brid. – – – Epipeic / clay Riccardia palmata (Hedw.) Schwaegr. – – – Epipeic / clay Riccardia palmata (Hedw.) Schwaegr. – – – Epipeic / clay Riccardia palmata (Hedw.) Brid. – – – + Epipeic / forest soil Brachythecium rutabulum (Hedw.) Brid. – – – – Epipeic / clay Riccardia palmata (Hedw.) Brid. – – – – Epipeic / clay Riccardia palmata (Hedw.) Brid. – – – Epipeic / clay Riccardia palmata (Hedw.) Brid. – – – Epipeic / forest soil Brachythecium rutabulum (Hedw.) Brid. – – – Epipeic / forest soil Brachythecium rutabulum (Hedw.) Brid. – – – – Epipeic / forest soil Brachythecium rutabulum (Hedw.) Brid. – – – – Epipeic / forest soil Brachythecium rutabulum (Hedw.) Brid. – – – – Epipeic / forest soil Brachythecium rutabulum (Hedw.) Brid. – – – – Epipeic / forest soil Brachythecium rutabulum (Hedw.) Brid. – – – – Epipeic / forest soil Brachythecium stepianes (Hedw.) Brid. – – – – Epipeic / forest soil Brachythecium stepianes (Hedw.) Brid. – – – – Epipeic / forest soil Ditrichum flexicaule (Schwaegr.) Hampe – – – – Epipeic / forest soil Neckera complanata (Hedw.) Hüb. – – – – Epipeic / forest soil Neckera complanata (Hedw.) Hüb. – – – Epipeic / forest soil Neckera complanata (Hedw.) Fuseux – – – Epipeic / forest soil Neckera complanata (Hedw.) Fuseux – – – – Epipeic / forest soil Neckera complanata (Hedw.) Heauv. – – – – Epipeic / forest soil Pogonatum unigerum (Hedw.) Beauv.	Marchantia polymorpha subsp. ruderalis L.	-	-	-	Epigeic / clay
Metzgeria furcata (L.) DumEpiphytic / treeMylia anomala (Hook) S. GrayEpigeic / swampNowellia curvifolia (Dicks.) MittEpisylic / decaying treesPellia endivitifolia (Dicks.) Dum+-Epigeic / clayRadula complanata (L.) DumEpipeic / clayRiccia fluitans L. emend. LorbeerEpigeic / clayRiccardia palmata (Hedw.) CarruthEpigeic / clayRiccardia palmata (Hedw.) Carruth+Epigeic / clayTrichocolea tomentella (Ehrh.) Dum+Epigeic / clayAttrichum tenellum (Röhl.) B. et SEpigeic / clayAulacomium palustre (Hedw.) Sn.dEpigeic / clayAulacomium palustre (Hedw.) Sn.g. et GEpigeic / soilCeratodon purpureus (Hedw.) BridEpigeic / soilCeratodon purpureus (Hedw.) B., S. et G+Epigeic / soilCinclidium stygium SwEpigeic / soilDicranum scoparium HedwEpigeic / forest soilDicranum soparium HedwEpigeic / forest	emend. Burgeff				10 /
Mylia anomala (Hook.) S. Gray - - Epigeic / swamp Nowellia curvifolia (Dicks.) Mitt. - - Episylic / decaying trees Pellia endivifolia (Dicks.) Dum. - + - Epigeic / clay Radula complanata (L.) Dum. - - - Epigeic / clay Riccia fluitans L. emend. Lorbeer - - - Epigeic / clay Riccia fluitans L. emend. Lorbeer - - - Epigeic / clay Riccia fluitans L. emend. Lorbeer - - - Epigeic / clay Riccia fluitans L. emend. Lorbeer - - - Epigeic / clay Riccardia palmata (Hedw.) Carruth. - - + Epigeic / forest soil Bryophyta (Mosses) - - + Epigeic / forest soil Aulaconnium palustre (Hedw.) Brid. - - - Epigeic / clay Aulaconnium palustre (Hedw.) Schwaegr. - - + Epigeic / soil Carratodon purpureus (Hedw.) Brid. - - + Epigeic / soil Ciracidon purpureus (Hedw.) Brid. - - - Epi	Metzgeria furcata (L.) Dum	-	-	-	Epiphytic / tree
Nowellia curvifolia (Dicks.) MittEpixylic / decaying treesPellia endiviifolia (Dicks.) Dum+-Epigeic / clayRadula complanata (L.) DumEpigeic / clayRiccia fluitans L. emend. LorbeerEpigeic / clayRiccardia palmata (Hedw.) CarruthEpigeic / clayRiccardia palmata (Hedw.) CarruthEpigeic / clayRiccardia palmata (Hedw.) CarruthEpigeic / clayRiccardia palmata (Hedw.) Brid+Epigeic / clayAntitrichia curtipendula (Hedw.) BridEpigeic / clayAntitrichia curtipendula (Hedw.) SchwaegrEpigeic / clayAulaconnium palustre (Hedw.) SchwaegrEpigeic / clayBrachythecium rutabulum (Hedw.) B., S. et G+Epigeic / soilCircatidon purpureus (Hedw.) BridEpigeic / soilCircatodon purpureus (Hedw.) BridEpigeic / forest soilDicranum scoparium HedwEpigeic / soilCircatodon purpureus (Hedw.) BridEpigeic / forest soilNecker	Mylia anomala (Hook.) S. Gray	-	-	-	Epigeic / swamp
Pellia endiviifolia (Dicks.) Dum. - + - Epigeic / clay Radula complanata (L.) Dum. - - - Epigeic / clay Riccia fluitans L. emend. Lorbeer - - - Epigeic / clay Riccardia palmata (Hedw.) Carruth. - - - Epigeic / clay Riccardia palmata (Hedw.) Carruth. - - - Epigeic / clay Riccardia palmata (Hedw.) Carruth. - - + Epigeic / clay Riccardia palmata (Hedw.) Carruth. - - + Epigeic / clay Mitcripted (Mosses) - - + Epigeic / forest soil Bryophyta (Mosses) - - + Epigeic / clay Aulacomnium palustre (Hedw.) Schwaegr. - - - Epigeic / clay Aulacomnium palustre (Hedw.) B.S. et G. - - + Epigeic / soil Ceratodon purpureus (Hedw.) Brid. - - - Epigeic / soil Circatidium stygium Sw. - - - Epigeic / soil Ditrahum flexicaule (Schwaegr.) Hampe - - Epigeic / fore	Nowellia curvifolia (Dicks.) Mitt.	-	-	-	Epixylic / decaying trees
Radula complanata (L.) DumEpiphytic / treeRiccia fluitans L. emend. LorbeerEpigeic / clayRiccia glauca LEpigeic / clayRiccardia palmata (Hedw.) CarruthEpisylic / decaying treesTrichocolea tomentella (Ehrh.) Dum+Epigeic / forest soilBryophyta (Mosses)+Epigeic / forest soilAntitrichia curtipendula (Hedw.) Brid+Epigeic / clayAulacomnium palustre (Hedw.) SchwaegrEpigeic / forest soilBrachythecium rutabulum (Hedw.) B., S. et G+Epigeic / forest soilBrachythecium rutabulum Sw+Epigeic / soilCeratodon purpureus (Hedw.) Brid+Epigeic / soilDicrahum scoparium HedwEpigeic / soilDicrahum scoparium HedwEpigeic / forest soilDitrichum flexicaule (Schwaegr.) HampeEpigeic / forest soilDitrichum slendens (Hedw.) B., S. et GEpigeic / forest soilDitrichum slendens (Hedw.) B., S. et GEpigeic / forest soilDitrichum slendens (Hedw.) B., S. et GEpigeic / soilDitrichum slendens (Hedw.) B., S. et GEpigeic / forest soilDicranum scoparium HedwEpigeic / forest soil </td <td>Pellia endiviifolia (Dicks.) Dum.</td> <td>-</td> <td>+</td> <td>-</td> <td>Epigeic / clay</td>	Pellia endiviifolia (Dicks.) Dum.	-	+	-	Epigeic / clay
Riccia fluitans L. emend. LorbeerEpigeic / clayRiccia glauca LEpigeic / clayRiccardia palmata (Hedw.) CarruthEpisylic / decaying treesTrichocolea tomentella (Ehrh.) Dum+Epigeic / forest soilBryophyta (Mosses)+Epigeic / clayAntitrichia curtipendula (Hedw.) Brid+Epigeic / clayAulacomnium palustre (Hedw.) SchwaegrEpigeic / forest soilBrachythecium rutabulum (Hedw.) B., S. et G+Epigeic / soilCeratodon purpureus (Hedw.) Brid+Epigeic / soilCinclidium stygium Sw+Epigeic / soilDicranum scoparium HedwEpigeic / forest soilDitrichum flexicaule (Schwaegr.) HampeEpigeic / forest soilHylocomium splendens (Hedw.) B., S. et GEpigeic / sandstoneHylocomium slendens (Hedw.) B., S. et GEpigeic / forest soilDitrichum flexicaule (Schwaegr.) HampeEpigeic / forest soilNeckara complanata (Hedw.) MagstrEpigeic / forest soilLeucobryum glaucum (Hedw.) AngstrEpigeic / forest soilPelogonium subjeditum HedwEpigeic / forest soilPelogonium subjeditum HedwEpigeic /	Radula complanata (L.) Dum.	-	-	_	Epiphytic / tree
Riccia glauca LEpigeic / clayRiccardia palmata (Hedw.) CarruthEpixylic / decaying treesTrichocolea tomentella (Ehrh.) Dum+Epigeic / forest soilBryophyta (Mosses)+Epigeic / forest soilAntirichia curtipendula (Hedw.) Brid+Epigeic / clayAtrichum tenellum (Röhl.) B. et SEpigeic / clayAulacomnium palustre (Hedw.) SchwaegrEpigeic / forest soilBrachythecium rutabulum (Hedw.) B., S. et G+Epigeic / soilCeratodon purpureus (Hedw.) Brid+Epigeic / soilCinclidium stygium SwEpigeic / soilDicranum scoparium HedwEpigeic / forest soilDitrichum flexicaule (Schwaegr.) HampeEpigeic / forest soilDitrichum glaucum (Hedw.) AngstrEpigeic / forest soilLeucobryum glaucum (Hedw.) AngstrEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilPleurozium scheberi (Brid.) MittEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPlagonnium cuspidatum HedwEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soil	Riccia fluitans L. emend. Lorbeer	-	-	-	Epigeic / clay
Riccardia palmata (Hedw.) CarruthEpixylic / decaying treesTrichocolea tomentella (Ehrh.) Dum+Epigeic / forest soilBryophyta (Mosses)Antitrichia curtipendula (Hedw.) Brid+Epigeic / clayAtrichum tenellum (Röhl.) B. et SEpigeic / clayAulacomnium palustre (Hedw.) SchwaegrEpigeic / forest soilBryum argenteum Hedw+Epigeic / soilCeratodon purpureus (Hedw.) Brid+Epigeic / soilCinclidium stygium SwEpigeic / soilDicranum scoparium HedwEpigeic / forest soilDitrichum flexicaule (Schwaegr.) HampeEpigeic / soilHylocomium splendens (Hedw.) AngstrEpigeic / forest soilLeucobryum glaucum (Hedw.) AngstrEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilPlagiomnium cuspidatum HedwEpigeic / forest soilPlagomnum cuspidatum HedwEpigeic / forest soilPlagomangun angustifolium (C.Jens. ex Russ.) C. JensEpigeic / swampSphagnum angelanicum BridEpigeic / swampSphagnum angelanicum BridEpigeic / swampSphagnum angelanicum BridEpig	Riccia glauca L.	-	-	_	Epigeic / clay
Trichocole tomentella (Ehrh.) Dum+Epigeic / forest soilBryophyta (Mosses)Antitrichia curtipendula (Hedw.) Brid+Epiphytic / treeAtrichum tenellum (Röhl.) B. et SEpigeic / clayAulacomnium palustre (Hedw.) SchwaegrEpigeic / forest soilBrachythecium rutabulum (Hedw.) B., S. et G+Epigeic / soilCeratodon purpureus (Hedw.) Brid+Epigeic / soilCeratodon purpureus (Hedw.) Brid+Epigeic / soilCinclidium stygium SwEpigeic / forest soilDicranum scoparium HedwEpigeic / forest soilDitrichum flexicaule (Schwaegr.) HampeEpigeic / forest soilDitrichum glaucum (Hedw.) B., S. et G+Epigeic / forest soilLeucobryum glaucum (Hedw.) AngstrEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPogonatum urnigerum (Hedw.) P.BeauvEpigeic / forest soilPogonatum urnigerum (Hedw.) ReauvEpigeic / soiatSynhagnum angustifolium (C.Jens. ex Russ.) C. JensEpigeic / swampSynhagnum angustif	Riccardia palmata (Hedw.) Carruth.	-	-	-	Epixylic / decaying trees
Bryophyta (Mosses) Antitrichia curtipendula (Hedw.) Brid. - - + Epiphytic / tree Atrichum tenellum (Röhl.) B. et S. - - - Epigeic / clay Aulacomnium palustre (Hedw.) Schwaegr. - - - Epigeic / forest soil Brachythecium rutabulum (Hedw.) B., S. et G. - - + Epigeic / soil Ceratodon purpureus (Hedw.) Brid. - - + Epigeic / soil Circlidium stygium Sw. - - + Epigeic / soil Dicranum scoparium Hedw. - - - Epigeic / soil Ditrichum flexicaule (Schwaegr.) Hampe - - - Epigeic / forest soil Ditrichum flexicaule (Schwaegr.) Hampe - - - Epigeic / forest soil Leucobryum glaucum (Hedw.) Ångstr. - - - Epigeic / forest soil Neckera complanata (Hedw.) Hüb. - - - Epigeic / forest soil Pleurozium schreberi (Brid.) Mitt. - - - Epigeic / forest soil Pogonatum urnigerum (Hedw.) P.Beauv. - - - Epigeic / fores	Trichocolea tomentella (Ehrh.) Dum.	-	-	+	Epigeic / forest soil
Antitrichia curtipendula (Hedw.) Brid+Epiphytic / treeAtrichum tenellum (Röhl.) B. et SEpigeic / clayAulacomnium palustre (Hedw.) SchwaegrEpigeic / forest soilBrachythecium rutabulum (Hedw.) B., S. et G+Epigeic / soilCeratodon purpureus (Hedw.) Brid+Epigeic / soilCinclidium stygium Sw+Epigeic / soilDicranum scoparium HedwEpigeic / forest soilDitrichum flexicaule (Schwaegr.) HampeEpigeic / forest soilHylocomium splendens (Hedw.) B., S. et GEpigeic / forest soilLeucobryum glaucum (Hedw.) AngstrEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPogonatum urnigerum (Hedw.) P.BeauvEpigeic / forest soilPogonatum urnigerum (Hedw.) Gaertn., Meyer et ScherbEpigeic / swampSyntarichia ruralis (Hedw.) Gaertn., Meyer et ScherbEpigeic / swampSyntarichia ruralis (Hedw.) Gaertn., Meyer et Scherb+Epigeic / swampSyntarichia ruralis (Hedw.) Gaertn., Meyer et Scherb+Epigeic / swampSyntarichia ruralis (Hedw.) Gaertn., Meyer et Scherb+Epigeic /	Bryophyta (Mosses)				10
Atrichum tenellum (Röhl.) B. et SAtrichum tenellum (Röhl.) B. et SEpigeic / forest soilBrachythecium rutabulum (Hedw.) B., S. et G+Epigpit/c / treeBryum argenteum Hedw+Epigeic / soilCeratodon purpureus (Hedw.) Brid+Epigeic / soilCinclidium stygium SwEpigeic / soilDicranum scoparium HedwEpigeic / forest soilDitrichum flexicaule (Schwaegr.) HampeEpigeic / forest soilDitrichum gleucum (Hedw.) A., S. et G+Epigeic / forest soilLeucobryum glaucum (Hedw.) AngstrEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPogonatum urnigerum (Hedw.) P.BeauvEpigeic / forest soilPognatum urnigerum (Hedw.) Gaertn., Meyer et ScherbEpigeic / claySyntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb+Epigeic / soilCorractio acture activities (Ledw.) Gaertn., Meyer et Scherb+Epigeic / soil	Antitrichia curtipendula (Hedw.) Brid.	-	-	+	Epiphytic / tree
Aulacomnium palustre (Hedw.) SchwaegrEpigeic / forest soilBrachythecium rutabulum (Hedw.) B., S. et G+Epigeic / soilBryum argenteum Hedw+Epigeic / soilCeratodon purpureus (Hedw.) Brid+Epigeic / soilCinclidium stygium SwEpigeic / forest soilDicranum scoparium HedwEpigeic / forest soilDitrichum flexicaule (Schwaegr.) HampeEpigeic / forest soilLeucobryum glaucum (Hedw.) Ångstr+Epigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilPlagiomnium cuspidatum HedwEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPogonatum urnigerum (Hedw.) P.BeauvEpigeic / forest soilSphagnum angustifolium (C.Jens. ex Russ.) C. JensEpigeic / swampSphagnum angelanicum BridEpigeic / swampSyntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb+Epigeic / soil	Atrichum tenellum (Röhl.) B. et S.	-	-	_	Epigeic / clay
Brachythecium rutabulum (Hedw.) B., S. et G+Fpiphytic / treeBryum argenteum Hedw+Epigeic / soilCeratodon purpureus (Hedw.) Brid+Epigeic / soilCinclidium stygium SwEpigeic / marshDicranum scoparium HedwEpigeic / forest soilDitrichum flexicaule (Schwaegr.) HampeEpigeic / forest soilHylocomium splendens (Hedw.) B., S. et G+Epigeic / forest soilLeucobryum glaucum (Hedw.) ÄngstrEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPogonatum urnigerum (Hedw.) P.BeauvEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPogonatum urnigerum (Hedw.) P.BeauvEpigeic / swampSphagnum magelanicum BridEpigeic / swampSyntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb+Epigeic / soil	Aulacomnium palustre (Hedw.) Schwaegr.	-	-	_	Epigeic / forest soil
Bryun argenteum Hedw+Epigeic / soilCeratodon purpureus (Hedw.) Brid+Epigeic / soilCinclidium stygium SwEpigeic / marshDicranum scoparium HedwEpigeic / forest soilDitrichum flexicaule (Schwaegr.) HampeEpigeic / sondstoneHylocomium splendens (Hedw.) B., S. et G+Epigeic / forest soilLeucobryum glaucum (Hedw.) ÅngstrEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPleurozium angustifolium (C.Jens. ex Russ.) C. JensEpigeic / claySphagnum magelanicum BridEpigeic / swampSyntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb+Epigeic / swampStrategie caluatioEpigeic / swamp	Brachythecium rutabulum (Hedw.) B., S. et G.	_	-	+	Epiphytic / tree
Ceratodon purpureus (Hedw.) Brid+Epigeic / soilCinclidium stygium SwEpigeic / marshDicranum scoparium HedwEpigeic / forest soilDitrichum flexicaule (Schwaegr.) HampeEpigeic / sandstoneHylocomium splendens (Hedw.) B., S. et G+Epigeic / forest soilLeucobryum glaucum (Hedw.) ÅngstrEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilPlagiomnium cuspidatum HedwEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPogonatum urnigerum (Hedw.) P.BeauvEpigeic / forest soilSphagnum angustifolium (C.Jens. ex Russ.) C. JensEpigeic / swampSphagnum magelanicum BridEpigeic / swampSyntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb+Epigeic / soil	Bryum argenteum Hedw.	-	-	+	Epigeic / soil
Cinclidium stygium SwEpigeic / marshDicranum scoparium HedwEpigeic / forest soilDitrichum flexicaule (Schwaegr.) HampeEpigeic / sandstoneHylocomium splendens (Hedw.) B.,S. et G+Epigeic / forest soilLeucobryum glaucum (Hedw.) ÅngstrEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPogonatum urnigerum (Hedw.) P.BeauvEpigeic / forest soilPhagnum angustifolium (C.Jens. ex Russ.) C. JensEpigeic / swampSphagnum magelanicum BridEpigeic / swampSyntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb+Epigeic / soil	<i>Ceratodon purpureus</i> (Hedw.) Brid.	_	-	+	Epigeic / soil
Dicranum scoparium HedwEpigeic / forest soilDitrichum flexicaule (Schwaegr.) HampeEpigeic / sandstoneHylocomium splendens (Hedw.) B.,S. et G+Epigeic / forest soilLeucobryum glaucum (Hedw.) ÅngstrEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPogonatum urnigerum (Hedw.) P.BeauvEpigeic / forest soilPogonatum urnigerum (Hedw.) P.BeauvEpigeic / claySphagnum angustifolium (C.Jens. ex Russ.) C. JensEpigeic / swampSphagnum magelanicum Brid+Epigeic / swampSyntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb+Epigeic / soil	Cinclidium stygium Sw.	-	-	_	Epigeic / marsh
Ditrichum flexicaule (Schwaegr.) HampeEpigeic / sandstoneHylocomium splendens (Hedw.) B.,S. et G+Epigeic / forest soilLeucobryum glaucum (Hedw.) ÅngstrEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilPlagiomnium cuspidatum HedwEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPogonatum urnigerum (Hedw.) P.BeauvEpigeic / claySphagnum angustifolium (C.Jens. ex Russ.) C. JensEpigeic / swampSphagnum magelanicum Brid+Epigeic / swampSyntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb+Epigeic / soil	Dicranum scoparium Hedw.	-	-	_	Epigeic / forest soil
Hylocomium splendens (Hedw.) B.,S. et G+Epigeic / forest soilLeucobryum glaucum (Hedw.) ÅngstrEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilNeckera complanata (Hedw.) HübEpigeic / forest soilPlagiomnium cuspidatum HedwEpigeic / forest soilPleurozium schreberi (Brid.) MittEpigeic / forest soilPogonatum urnigerum (Hedw.) P.BeauvEpigeic / claySphagnum angustifolium (C.Jens. ex Russ.) C. JensEpigeic / swampSphagnum magelanicum Brid+Epigeic / swampSyntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb+Epigeic / soil	Ditrichum flexicaule (Schwaegr.) Hampe	_	_	_	Epigeic / sandstone
Leucobryum glaucum (Hedw.) Ångstr. - - Epigeic / forest soil Neckera complanata (Hedw.) Hüb. - - Epigeic / forest soil Neckera complanata (Hedw.) Hüb. - - Epighytic / tree Plagiomnium cuspidatum Hedw. - - - Epigeic / forest soil Pleurozium schreberi (Brid.) Mitt. - - - Epigeic / forest soil Pogonatum urnigerum (Hedw.) P.Beauv. - - - Epigeic / clay Sphagnum angustifolium (C.Jens. ex Russ.) C. Jens. - - - Epigeic / swamp Sphagnum magelanicum Brid. - - + Epigeic / swamp Syntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb. - - + Epigeic / soil	Hylocomium splendens (Hedw.) B.,S. et G.	-	-	+	Epigeic / forest soil
Neckera complanata (Hedw.) Hüb. – – – Epiphytic / tree Plagiomnium cuspidatum Hedw. – – – Epigeic / forest soil Pleurozium schreberi (Brid.) Mitt. – – – Epigeic / forest soil Pogonatum urnigerum (Hedw.) P.Beauv. – – – Epigeic / clay Sphagnum angustifolium (C.Jens. ex Russ.) C. Jens. – – – Epigeic / swamp Sphagnum magelanicum Brid. – – + Epigeic / swamp Syntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb. – – + Epigeic / soil	Leucobryum glaucum (Hedw.) Ångstr.	-	-	_	Epigeic / forest soil
Plagiomnium cuspidatum Hedw. - - - Epigeic / forest soil Pleurozium schreberi (Brid.) Mitt. - - - Epigeic / forest soil Pogonatum urnigerum (Hedw.) P.Beauv. - - - Epigeic / clay Sphagnum angustifolium (C.Jens. ex Russ.) C. Jens. - - - Epigeic / swamp Sphagnum magelanicum Brid. - - + Epigeic / swamp Syntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb. - - + Epigeic / soil	Neckera complanata (Hedw.) Hüb.	_	-	_	Epiphytic / tree
Pleurozium schreberi (Brid.) Mitt. - - - Epigeic / forest soil Pogonatum urnigerum (Hedw.) P.Beauv. - - - Epigeic / clay Sphagnum angustifolium (C.Jens. ex Russ.) C. Jens. - - - Epigeic / swamp Sphagnum magelanicum Brid. - - + Epigeic / swamp Syntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb. - - + Epigeic / soil Transplic pelluvide Hadre - - + Epigeic / soil	Plagiomnium cuspidatum Hedw.	-	_	_	Epigeic / forest soil
Pogonatum urnigerum (Hedw.) P.Beauv. - - Epigeic / clay Sphagnum angustifolium (C.Jens. ex Russ.) C. Jens. - - Epigeic / swamp Sphagnum magelanicum Brid. - - + Epigeic / swamp Syntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb. - - + Epigeic / soil Transplic pelluside Hedw. - - + Epigeic / soil	Pleurozium schreberi (Brid.) Mitt.	-	-	_	Epigeic / forest soil
Sphagnum angustifolium (C.Jens. ex Russ.) C. Jens. - - - Epigeic / swamp Sphagnum magelanicum Brid. - - + Epigeic / swamp Syntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb. - - + Epigeic / soil Transplic pelluside Under - - + Epigeic / soil	Pogonatum urnigerum (Hedw.) P.Beauv.	-	-	_	Epigeic / clav
Sphagnum magelanicum Brid. - + Epigeic / swamp Syntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb. - + Epigeic / soil Transplie pelluside Hedw. - + Epigeic / soil	Sphagnum angustifolium (C.Jens. ex Russ.) C. Jens.	. –	_	-	Epigeic / swamp
Syntrichia ruralis (Hedw.) Gaertn., Meyer et Scherb. – – – + Epigeic / soil	Sphagnum magelanicum Brid.	-	-	+	Epigeic / swamp
	Syntrichia ruralis (Hedw.) Gaertn., Mever et Scher	Ъ. –	-	+	Epigeic / soil
Tetraphis penuciuu nedw. – – – Epixvlic / decaving trees	Tetraphis pellucida Hedw.	-	-	-	Epixylic / decaying trees
Tortula lingulata Lindb. – – – Epigeic / sandstones	Tortula lingulata Lindb.	-	_	-	Epigeic / sandstones



Fig. 1. *Conocephalum salebrosum* and AM-like fungi growing from cell to cell (A). AM in *Fossonmbronia floevolata* thallus with a penetration site of a fungal hypha (B). *Fossombronia floevolata* with AM fungal hypha and vesicle (C). Rhizoids of *Conocephalum salebrosum* with AM fungal hyphae (D). *Cephalozia bicuspidata* with fungal endophytes growing in cell walls (E). H, hyphae; HC, hyphal coils; V, vesicle.

nature af arbuscules. The observed hyphae passed directly through the cell walls of the liverworts. Rhizoids were the entrance points for fungal hyphae. We confirmed that the hyphae observed in this study belong to Glomeromycotan fungi. Most of the hepatics were non-mycorrhizal. In those that were mycorrhizal, the presence of arbuscules indicated functional symbiosis. These findings support the notion that the AM fungi-bryophyte associations are functional and species specific.

The occurrence of AM symbiosis in bryophytes may depend on defense systems such as allelopathy and fungicide activity (Pocock 1985). Several liwerwort



Fig. 2. Average bryophyte colonisation level by aseptate (AM) and septate fungal endophytes.

species (*Conocephalum conicum*, *Marchantia polymorpha*, *Plagiochila* sp., *Radula* sp.) show some antifungal activity and *Trichocolea tomentella* has mild antifungal activity. *Bryum argenteum* and *Ceratodon purpureus* have strong antifungal activity (Asakawa 2007; Singh 2007), imparted by cell walls containing polyphenolic-rich compounds that are either suitable as a substrate or toxic to the majority of microorganisms (Davey et al. 2006).

While epiphytic and epixylic bryophytes lacked AM symbiosis, the epiphytes *Brachythecium rutabulum* and *Antitrichia curtipendula* and epixylic *Tetraphis pellucida* from Bryophyta did not have septate endophytes in stem tissues. However, septate and non septate endophytes were never found together in the same bryophyte. Some epigeic Bryophyta species from some habitats lacked AM, for example, single individuals of *C. conicum* and *P. endiviifolia*, in very wet habitats and *M. polymorpha* subsp. *ruderalis* in a nutrient-rich agricultural habitat. This is consistent with the idea that mycorrhzial associations depend on edaphic factors (Brundrett 1991).

Several authors have experimentally established arbuscular-mycorrhiza like symbiosis between fungi belonging to the order Glomales and bryophytes (Parke 1980; Schüβler 2000; Zhang 2007; Fonseca 2006). However, our experiments with trap cultures failed to show symbiosis between fungi from bryophyte and the host plant *Plantago lanceolata*. In the present study, it is likely that the time for symbiosis establishment was too short for roots colonization. Some members of the Glomeromycota are capable of producing spores very early three to four weeks after the primary root colonization, whereas others require more than six months to begin the process (Sieverding 1991; Velazquez et al. 2011).

However to further understand the physiology, anatomy,

and etiology of these interactions, it is necessary to culture bryophytes and bryophylous fungi and create artificial axenic systems for study.

Acknowledgements

Thanks is given to Dr. David G. Long for help in the field and discussions about bryophyte symbiosis, Prof. Janusz Blaszkowski about comments to pictures and to Prof. Guntis Brūmelis and Prof. Gederts Ievinsh and anonymous reviewers for comments on the manuscript.

References

- Asakawa Y. 2007. Biologically active compounds from bryophytes. Pure Appl. Chem. 4: 557–580.
- Brundrett M. 1999. *Mycorrhizas in Natural Ecosystems*. Publisher, City. P. 144.
- Carafa A., Duckett J.G., Lignore R. 2003. Subterranen gametophytic axes of endophytic association with asseptate fungi. *New Phytol.* 160: 185–197.
- Davey M., Currah R. 2006. Interactions between mosses (Bryophyta) and fungi. *Can. J. Bot.* 84: 1509–1519.
- Duckett J.G., Carafa A., Lignore R. 2006. A highly differentiated glomeromycotean association with the mucilage-secreting antipodean livervort Treubia; clues to the origins of mycorrhizas. *Am. J. Bot.* 93: 797–813.
- Duckett J.G., Russell J., Lignore R. 2006. Basidiomycetous endophytes in jungermannialean (leafy) liverworts have novel cytologyand species-specific host ranges: a cytological and experimental study. *Can. J. Bot.* 84: 1057–1093.
- Duckett J.G., Ligrone R. 2008. Basidiomycetous endophytes in New Zealand Aneuraceae (simple thalloid liverworts, Metzgeriidae) and the derived status of the monotypic genus *Verdoornia. Botany* 86: 346–358.
- Fonseca H., Berbara R. Pereira M. 2006. *Lunularia cruciata*, a potential *in vitro* host for *Glomus proliferum* and *G. intraradices*. *Mycorrhiza* 16: 503–508.
- Gerdemann J.W. 1968. Vesicular-arbuscular mycorrhiza and plant growth. *Annu. Rev. Phytopathol.* 6: 397–481.
- Glime J.M. 2007. *Bryophyte Ecology. Vol. 1. Physiological Ecology.* Ebook sponsored by Michigan Technological University and the International Association of Bryologists. Accessed 04.04.2012. on http://www.bryoecol.mtu.edu/
- Goffinet B., Shaw A.J. 2009. Bryophyte Biology. Cambridge University Press, Cambridge. P. 565.
- Grolle R., Long D. 2000 Bryological Monograph. An annoted check-list of the Hepaticae and Anthocerotae of Europe and Macronesia. *J. Bryol.* 22: 103–140.
- Grosso S.M., Scheirer D. C. 1981. Scanning electron microscopic observations of a moss-fungus association. *Bryologist* 84: 348–350.
- Harley J.L., Smith S.E. 1983. *Mycorrhizal Symbiosis*. Academic Press, London.
- Hill M.O., Bell N., Bruggeman-Nannenga M.A., Brugués M., Cano M.J., Enroth J., Flatberg K.I., Frahm J.-P., Gallego M.T., Garilleti R., Guerra J., Hedenäs L., Holyoak D.T., Hyvönen J., Ignatov M.S., Lara F., Mazimpaka V., Muñoz J., Söderström L. 2006. Bryological Monograph. An annotated checklist of the mosses of Europe and Macaronesia. J. Bryol. 28: 198–267.

Jakucs E., Naar Z., Szedlay G., Orban S. 2003. Glomalen and septate

endophytic fungi in *Hypopterigium* mosses (Bryopsida). *Cryptogam. Mycol.* 24: 27–37.

- Kamal S.C.S. 1970. Rhizosphere mycoflora of some bryophytes. Annales Institute Pasteur (Paris) 119: 752–755.
- Ligrone R. 1988. Ultrastructure of a fungal endophyte in *Phaeroceros laevis* (L.) prosc. (Anthocerotophyta). *Bot. Gaz.* 149: 92–100
- Ligrone R., Carafa A., Lumini E., Bianciotto V., Bonfante P., Duckett G. 2007. Glomeromycotean associations in liverworts: a molecular, cellular, and taxonomic analysis. *Am. J. Bot.* 94: 1756–1777.
- Ligrone R., Lopes C. 1989. Cytology and development of a mycorrhiza-like infection in the gametophyte of *Conocephalum conicum* (L.) Dum (Marchantiales, Hepatophyta). *New Phytol.* 111: 423–433
- Oehl F., Sieverding E., Ineichen K., Ris E.A., Boller T., Wiemken A. 2003. Community structure of arbuscular mycorrhizal fungi at different soil depths in extensively and intensively managed agroecosystems. *New Phytol.* 165: 273–283.
- Parke J.L., Linderman R.G. 1980. Association of vesiculararbuscular mycorrhizal fungi with the moss *Funaria hygrometrica. Can. J. Bot.* 58: 1898–1904.
- Pocock K., Duckett J.G. 1985. Fungi in hepatics. *Bryol. Times* 31: 2–3.
- Pocock K., Duckett J.G. 1985. On the occurence of branched and swollen rhizoids in British hepatics: Their relationships with the substratum and associations with fungi. *New Phytol.* 99: 281–304.
- Pressel S., Bidartondo M.I., Lignore R., Duckett J. 2010. Fungal symbioses in bryophytes: New insights in the twenty first century. *Phytotaxa* 9: 238–53.
- Rabatin S.C. 1980. The occurrence of the vesicular-arbuscular mycorrhizal fungus *Glomus tenuis* with moss. *Mycologia* 72: 191–195.
- Rayner M. 1927. Mycorrhiza. Weldon and Wesley, London.
- Read D.J. Duckett J.D. Francis R., Ligrone R., Russell A. 2000. Symbiotic fungal associations in "lower" land plants. *Phil. Trans. Royal Soc. London B* 355: 815–831.

- Redecker D., Kodner R., Graham L.E. 2000. Glomalean fungi from the Odovician. *Science* 289: 1920–1921.
- Russel J., Bulman S. 2004. The liverwort *Marchantia foliaceae* forms a specialised symbiosis with arbuscular fungi in the genus *Glomus*. *New Phytol.* 165: 567–579.
- Schüßler A. 2000. *Glomus claroideum* forms an arbuscular mycorrhiza-like symbiosis with the hornwort *Anthoceros punctatus*. *Mycorrhiza* 10: 15–21.
- Schüβler A., Schwarzott D., Walker C. 2001. A new fungal phylum, the Glomeromycota: phylogeny and evolution. *Mycol. Res.* 105: 1413–1421.
- Sieverding E. 1991. Vesicular-arbuscular Mycorrhizal Management in Tropical Agroecosystems. Deutsche Gesellschaft für Technische Zusammenarbeit, GTZ N° 224 Eschborn. P. 371.
- Singh H.B. 1974. Rhizosphere fungal flora of bryophytes. *Botanique* 7: 131–136.
- Singh M., Rawat A.K.,Govindarajan R. 2007. Antimicrobial activity of some Indian mosses. Fitoterapia 78: 156–158.
- Trouvelot A., Kough IL., Gianinazzi-Pearson V. 1986. Mesure du taux de mycorization VA d'un système radiculaire. Recherche de methods d'estimation ayant une signification fonvtionelle. In: Gianinazzi-Pearson V, Gianinazzi S (eds) *Physiological and Genetical Aspects of Mycorrhizae*. INRA Press, Paris, pp. 217–221.
- Turnau K, Ronikier M, Unrug J 1999. Role of mycorrhizal links between plants in establisment of liverworts thalli in natural habitats. *Acta Soc. Bot. Pol.* 68: 63–68.
- Velázquez S., Cabello M. 2011. Occurrence and diversity of arbuscular mycrrhizal fungi in trap cultures from El Palmer National Park soils. *Eur. J. Soil Biol.* 47: 230–235.
- Wang, B., Qiu, Y.L. 2006. Phylogenetic distribution and evolution of mycorrhizas in land plants. *Mycorrhiza* 16: 299–363.
- Zhang Y., Guo L.D. 2007. Arbuscular mycorrhizal structure and fungi associated with mosses. *Mycorrhiza* 17: 319–25.
- Zinsmeister H.D., Mues R. 1987. Moose als Reservoir bemerkenswertersekundärer inhaltsstoffe. *GIT Fachz. Lab.* 31: 499–512.