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ORIGINAL PAPER

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# Natural and synthesized ectomycorrhizas of the alpine dwarf willow *Salix herbacea*

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**Abstract** A new approach for selecting sampling sites of ectomycorrhizal roots is presented in order to describe ectomycorrhizas of *Salix herbacea*. Based on sporocarp mapping and statistical evaluation of the mapping data, sites for ectomycorrhizal root sampling were chosen underneath sporocarps of ectomycorrhizal *Cortinarius (Myxacium) favrei*, *Hebeloma repandum*, *Laccaria montana*, *Entoloma alpicola*, and *Russula norvegica*. Only in the samples beneath *C. favrei*, *E. alpicola,* and *L. montana* were corresponding ectomycorrhizas predominant and therefore described. *Cenococcum geophilum* ectomycorrhizas occurred throughout most samples and were also described. Numerous carpophores of the five selected ectomycorrhizal fungi were sampled for isolation purposes. Pure cultures were obtained of *H. repandum* and *C. favrei*, but laboratory syntheses of ectomycorrhizas were successful only with *H. repandum* and seedlings or cuttings of *S. herbacea.*

**Key words** *Salix herbacea* · Ectomycorrhizas · Sporocarp mapping · Synthesis experiments

## Introduction

Descriptions of ectomycorrhizas from alpine and arctic dwarf willows are few and mostly not very detailed (Fontana 1962; Antibus 1980; Antibus et al. 1981). This conspicuous lack of ectomycorrhizal studies in arcto-alpine habitats is due partly to difficulties with methodology. The method of Agerer (1991) for tracing mycelia from sporocarps to corresponding ectomycorrhizas is well established in lowland investigations (Agerer 1987–1990; Ingelby et al. 1990). However, in alpine studies the lack of rhizomorphs, the delicate ectomycorrhizal organs, and the soil body – a heterogeneous mixture of raw humus and gravelly stones (Graf 1994) – frequently prevent an unambiguous assignment of sporocarps and ectomycorrhizas. An additional complicating factor is the number of symbiotic fungal partners associated with alpine dwarf shrubs, which is often quite high within small areas (Favre 1955; Senn-Irlet 1993; Graf 1994). Thus, a new approach is needed for investigations of ectomycorrhizas of alpine plants.

Frequent ectomycorrhizal formers are found among fungi of the "mat" type, one of Ogawa's distinguishing life forms (Ogawa 1981). In such cases, the mats are usually restricted to areas of dense growth (Read 1992). It is very likely that these below ground areas correspond to the isolated, clumped occurrence of sporocarps of one fungal taxon. Thus, there is a high probability that the ectomycorrhizas underneath the sporocarps are formed predominantly or exclusively by this one taxon.

The objective of the present study was to test a new selection procedure for sampling sites of ectomycorrhizal roots in order to describe natural *Salix herbacea* L. ectomycorrhizas. The sites were selected using the results of 3 years of sporocarp mapping (Graf 1994). Thus, the method of Agerer (1991) for identifying ectomycorrhizas was modified to include a restrictive selection procedure for specific ectomycorrhizal sampling sites. In addition, syntheses with pure cultures of putative ectomycorrhizal fungi and *S. herbacea* were attempted and the successful symbioses are described.

## Material and methods

### Study site and mapping of sporocarps

The research area is located in the eastern Swiss Alps at an elevation of 2400–2500 m in the Valley of Radönt (Canton Grisons, Switzerland) between Davos and Susch, southeast of the Flüela Pass. From 1988 to 1990, fungal sporocarps were recorded on weekly excursions during the snow-free period (June to October)

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in snow-beds with *S. herbacea* (Graf 1994). Six permanent 50-$m^2$ plots were installed in *Salicetum herbaceae* Br.-Bl. plant communities (Braun-Blanquet 1964). The shapes of the plots conformed to the most homogeneous distribution of the dwarf willow (rectangular: $2 \times 25$ m, $4 \times 12.5$ m; T-shaped: $2 \times 15$ m $+ 4 \times 5$ m). Sporocarps of all macromycetes occurring within the plots were registered and mapped. A "record" was defined as a group of sporocarps, independent of the number, of the same taxon within an area of 5 cm diameter.

### Association analysis of sporocarps

For association analysis, only the plots with taxa of high abundance and clumped sporocarp production were considered. Thus, plot 3 with the taxa *Cortinarius (Myxacium) favrei* M.M. Moser ex Henderson, *Hebeloma repandum* Bruchet, and *Laccaria montana* Singer, and plot 6 with the taxa *Entoloma alpicola* (J. Favre) Noordel. and *Russula norvegica* Reid fulfilled the required criteria.

For the analysis of interspecific association, a grid of $50 \times 50$ cm was applied to each plot to check the presence of the recorded ectomycorrhizal taxa. The results were placed in a contingency or species association table (Pielou 1977). The $2 \times 2$ table contains observed values for each of the cells (a, b, c, d) from a sample of size *N*.

| | Species B | | |
|---|---|---|---|
| Species A | Present | Absent | |
| Present | a | b | $a+b=m$ |
| Absent | c | d | $c+d=n$ |
| | $a+c=r$ | $b+d=s$ | |
| | | | $m+n=r+s=N$ |

The $\chi^2$-test was computed as:

$$\chi^2 = \frac{N(|ad-bc|-N/2)^2}{mnrs}$$

The significance levels were at 3.82 (5%) and 6.64 (1%) for positive (co-occurrence) and negative association (exclusion). To measure the strength of association, the Ochiai index (OI) was calculated to test relationships between species pairs without considering the number of joint absences (Ochiai 1957). This index is based on the geometric mean of the joint occurrences of the two species compared with the total occurrence of species A and B, respectively, and is calculated as

$$OI = \frac{a}{\sqrt{(a+b)}\sqrt{(a+c)}}$$

with 0 indicating absolute exclusion and 1 indicating absolute co-occurrence.

### Sampling and processing of natural ectomycorrhizas

In the summer of 1991, five soil cores of 25 $cm^2$ surface area and 5 cm depth were taken of each of the five selected ectomycorrhizal fungi, including their epigeous sporocarps. Samples were bagged, transported to the laboratory on the same day and examined for hyphal connections leading from sporocarps to fungal mantles under a Wild M8 dissecting microscope. Ectomycorrhizas were placed in water and cleaned of soil particles before being described morphologically, photographed with a Wild MPS microscope, fixed in 6% formaldehyde, and stored at 4 °C in the dark.

### Synthesis experiments

Small tramal pieces of each of the five selected ectomycorrhizal fungi were cut from freshly collected sporocarps and placed in Petri dishes on modified Melin Norkrans (MMN) agar maintained at 20 °C in the dark (Marx and Bryan 1975). Mycelial cultures were cut into small pieces and transferred to sterilized 500-ml Erlenmeyer flasks containing 150 ml MMN solution (including glucose 10 g/l and malt 3 g/l). After 2 months incubation, liquid mycelial cultures were homogenized with a blender. Aliquots of this solution (50 ml) were injected into previously autoclaved 500-ml Erlenmeyer flasks containing a Vermiculite-peat moss mixture (200 ml:30 ml) with 150 ml MMN (including glucose 10 g/l and malt 3 g/l). Non-sterile 1-l pots were similarly prepared. The fungal inocula were allowed to grow for 6 weeks prior to seedling introduction.

From 1989 to 1991, seeds of *S. herbacea* were collected in the autumn and kept at 4 °C for immediate use or at –20 °C for longer storage. After surface sterilization for 3–5 min with $H_2O_2$ (30%), seeds were placed on water agar in Petri dishes for germination and incubated at room temperature in daylight. After the development of the cotyledons, the seedlings were transferred to MMN agar to screen for possible contaminants (Brunner and Brunner 1990). Seedlings were introduced 2–3 weeks after germination into pre-inoculated 500-ml Erlenmeyer flasks under sterile conditions. Synthesis experiments were carried out in a growth chamber with a 16-h photoperiod (PAR 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$) at 20 °C and 70% humidity for 11–13 months.

Cuttings from 6-month-old seedlings with a height of 15 mm and at least three leaves were used for synthesis experiments under non-sterile conditions in pre-inoculated 1-l pots. Pots were maintained for 15 months in the greenhouse at $20 \pm 5$ °C in daylight. They were watered weekly and supplied every 4th week with 30 ml MMN (without glucose and malt). Ectomycorrhizal rootlets were cleaned with sterile water, described morphologically, photographed, fixed in 6% formaldehyde, and stored at 4 °C in the dark.

### Microscopic analysis

For microscopic analysis of natural and synthesized ectomycorrhizas, the rootlets were dehydrated in alcohol, embedded in glycolmethacrylate, sectioned longitudinally (1.5 μm) with a Reichert-Jung 2050 microtome and stained with Giemsa for chitinoid material. Photographs were taken using a Leitz Aristoplan microscope. The microscopic description of the ectomycorrhizas mainly follows the terminology of Agerer (1991) and Ingelby et al. (1990).

## Results

### Sporocarp mapping, association analysis and abundance

Evaluation of the sporocarp mapping data from 1988–1990 produced specific spatial patterns for each of the 53 ectomycorrhizal taxa registered (Graf 1994). Clumped and isolated sporocarp production of taxonomically well-defined species was observed particularly for *Cortinarius favrei*, *Entoloma alpicola*, *Hebeloma repandum*, *Laccaria montana*, and *Russula norvegica* (Figs. 1, 2). Isolated clumping occurred most obviously in plot 3 for *C. favrei*, *H. repandum*, and *L. montana* (Fig. 1) and in plot 6 for *E. alpicola* and *R. norvegica* (Fig. 2).

The aggregation of exclusively one taxon was confirmed in various plots (Table 1); the Ochiai indices of the selected taxa were low, pointing to mutual exclusion. Interspecific association analysis confirmed significant exclusion between *C. favrei* and *L. montana* in

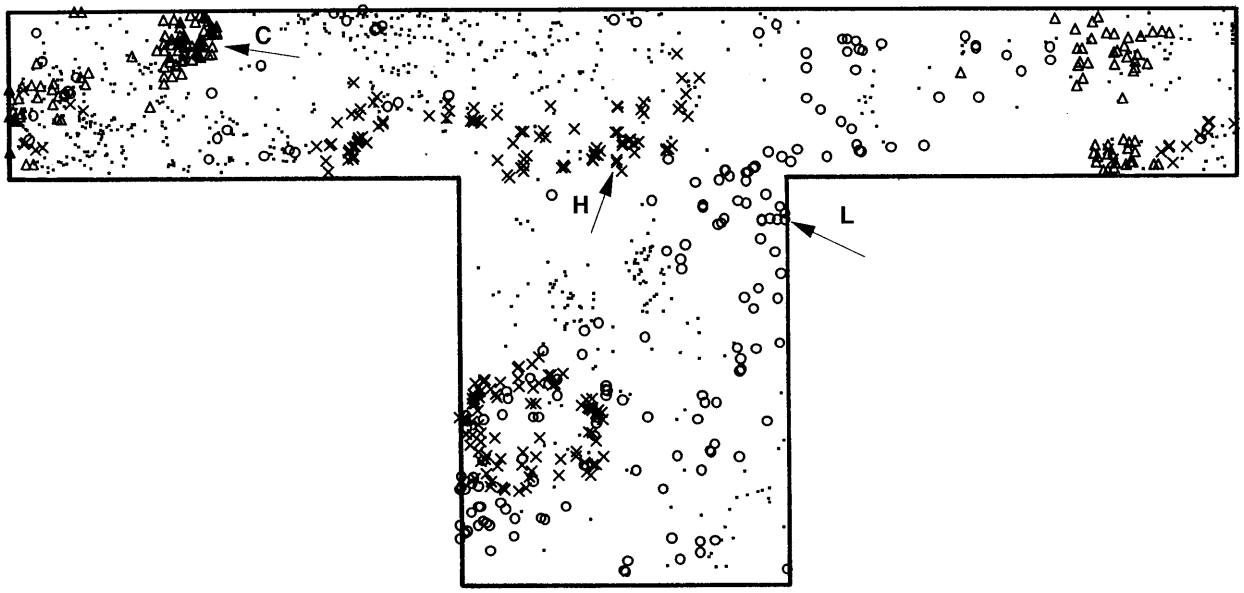



**Fig. 1** Spatial distribution patterns of all recorded sporocarps of ectomycorrhizal taxa (•) found in 1988–1990, with special emphasis on *Cortinarius favrei* (*C*, △), *Hebeloma repandum* (*H*, ×), and *Laccaria montana* (*L*, ○), in plot 3 (2×15 m+4×5 m) and the locations of ectomycorrhizal root sampling (*arrows*)

plot 3, and *E. alpicola* and *R. norvegica* in plot 6. However, no significant results were obtained for *C. favrei* and *H. repandum* and *H. repandum* and *L. montana* (Table 1). In accordance with the sporocarp mapping, association analyses, and species abundance, root samples for ectomycorrhizal investigations were taken in plot 3 (*C. favrei*, *H. repandum*, *L. montana*) and plot 6 (*E. alpicola*, *R. norvegica*).

**Table 1** Matrix of $\chi^2$-test indicating exclusion, and Ochiai index of selected ectomycorrhizal fungi in plots 3 and 6. Ochiai index: values close to 0 indicate exclusion, values close to 1 association

| Plot | | $\chi^2$ | Ochiai index |
|---|---|---|---|
| 3 | *Cortinarius favrei/Hebeloma repandum* | 0.249 | 0.20 |
| | *Cortinarius favrei/Laccaria montana* | 6.297* | 0.09 |
| | *Hebeloma repandum/Laccaria montana* | 0.001 | 0.30 |
| 6 | *Russula norvegica/Entoloma alpicola* | 9.622** | 0.02 |

* Significance level 5%; $\chi^2 > 3.82$
** Significance level 1%; $\chi^2 > 6.64$

## Natural ectomycorrhizas

Unambiguous assignment of sporocarps and ectomycorrhizas was possible for *C. favrei*, *E. alpicola* and *L. montana*, based on the predominant occurrence of ectomycorrhizas underneath corresponding sporocarps. For *H. repandum* and *R. norvegica*, different types of ectomycorrhizas were included in each of the five samples and no obvious hyphal connections between spor-

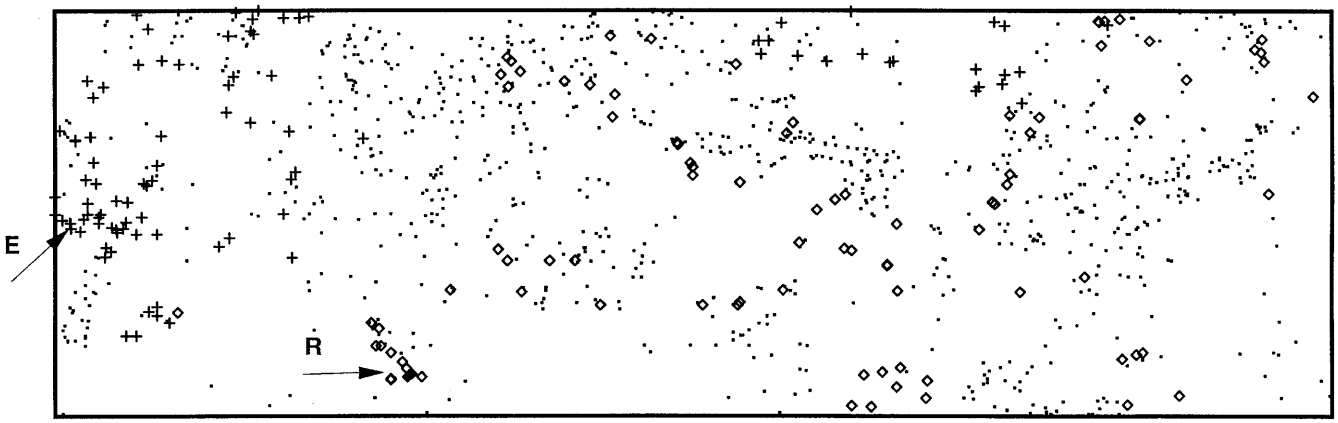
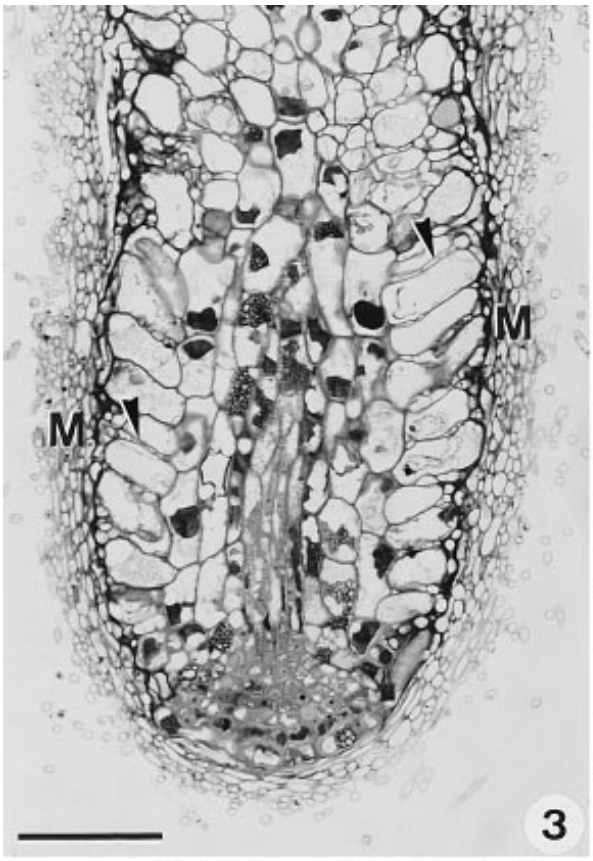



**Fig. 2** Spatial distribution patterns of all recorded sporocarps of ectomycorrhizal taxa (•) found in 1988–1990, with special emphasis on *Entoloma alpicola* (*E*, +), and *Russula norvegica* (*R*, ◊), in plot 6 (4×12.5 m) and the locations of ectomycorrhizal root sampling (*arrows*)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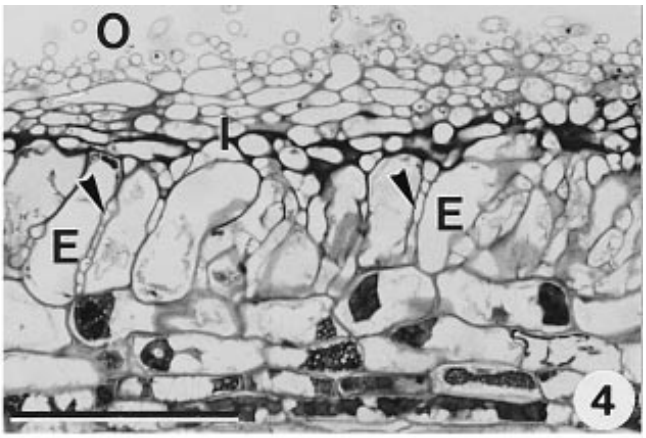
M
3


O
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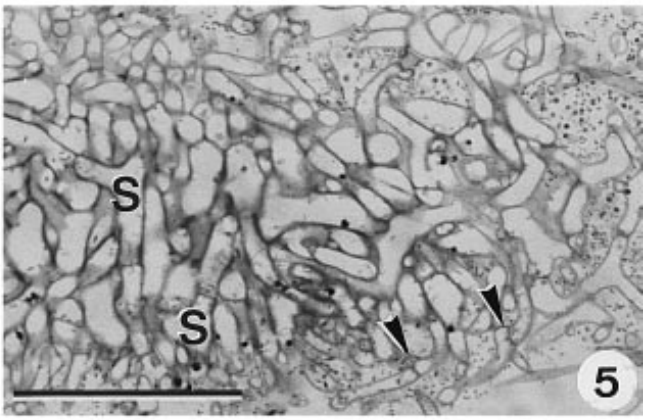
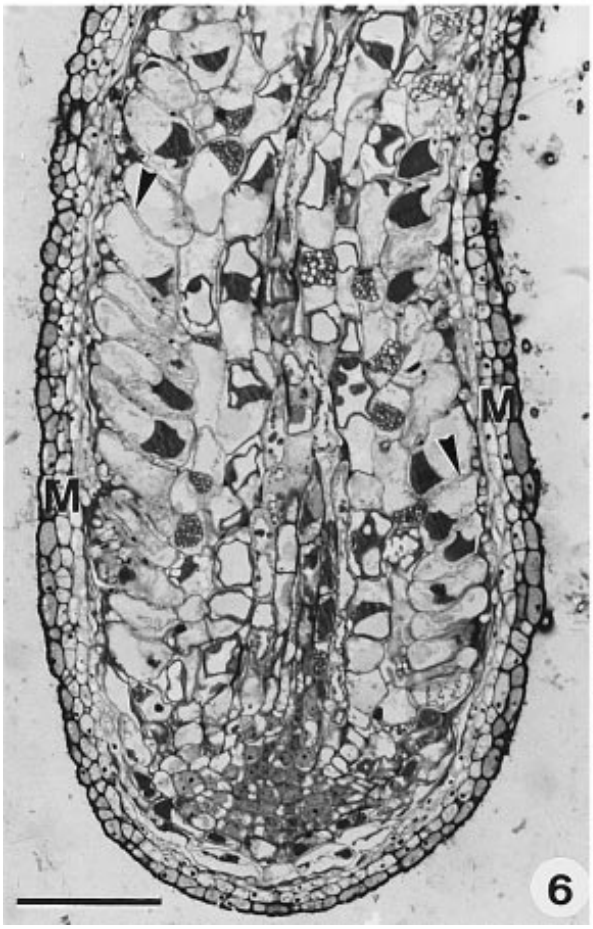
E
4


S
S
5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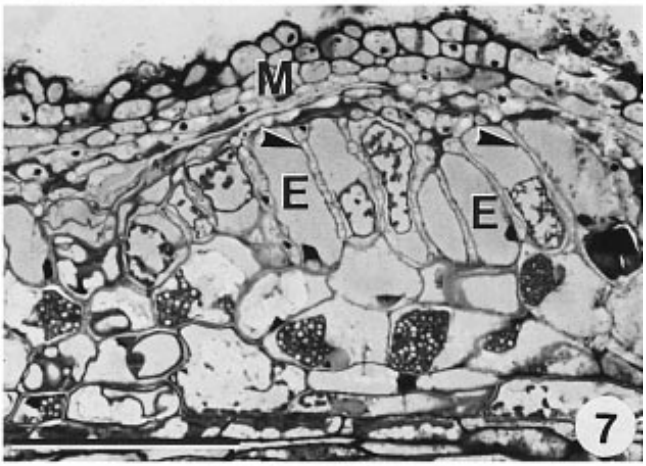
6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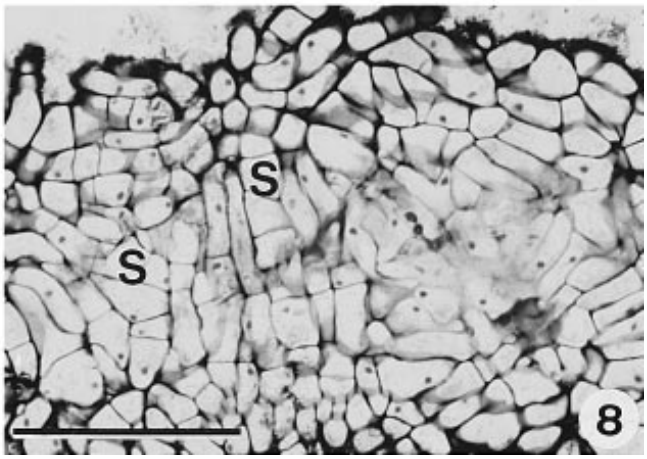

S
S
8

ocarps and mantles were detected. Thus, no clear assignment was possible and these two taxa were excluded from further investigations. Ectomycorrhizas formed by *Cenococcum geophilum* L. were noted in several soil samples and considered for further processing.

*Entoloma alpicola* ectomycorrhizas (Figs. 3–5) are more or less regularly monopodial, up to 0.4 mm in diameter and 3 mm long. The root tips are swollen and occasionally tortuous. The surface is villous and enveloped in white mycelium. No rhizomorphs were observed. The colour varies from brownish-yellow to light brown. The mantle is 15–35 μm thick, differentiated into a prosenchymatous outer layer with branched and diverging hyphae (up to 5.0 μm in diameter), and a synenchymatous inner layer with shortened, tortuous to nearly globose hyphal cells (5–25 μm long, 3–8 μm wide). The Hartig net consists of hyphal cells lined up in one, occasionally two, rows between the first layer of epidermal cells. It is uniform, and paraepidermal. Epidermal cells are distinctly radially elongated. Clamp connections are present in the prosenchymatous tissue of the outer mantle. Voucher material is deposited in Birmensdorf WSL (fg 19131).

*Cenococcum geophilum* ectomycorrhizas (Figs. 6–8) are unbranched, up to 0.4 mm in diameter, 3 mm long, and straight to slightly bent. The surface is smooth to delicately scrobiculate, with frequent black hyphae radiating from the mantle surface. No rhizomorphs were observed. The colour is dull black. The mantle is 15–25 μm thick, two-layered, synenchymatous with shortened to isodiametric hyphal cells (5–15 μm long, 3–8 μm wide). The outer layer consists of heavily thickened cells, whereas the cells of the inner layer are non-thickened. The Hartig net consists of hyphal cells lined up in one, but occasionally in two rows between the first layer of epidermal cells. It is uniform, and paraepidermal. Epidermal cells are distinctly radially elongated. Clamp connections are not present. Voucher material is deposited in Birmensdorf WSL (fg 19111).

*Cortinarius favrei* ectomycorrhizas (Figs. 9, 10) are unbranched, up to 0.3 mm in diameter and 4 mm long. The root tips are occasionally tortuous and slightly swollen. The surface is delicately villous and enveloped in white mycelium. No rhizomorphs were observed. The colour is orange-yellow, with the tips a shade darker. The mantle is 30–40 μm thick, differentiated in a prosenchymatous outer layer with more or less elongated hyphae (up to 3.0 μm in diameter) and a compact synenchymatous inner layer with shortened, tortuous to nearly globos hyphal cells (3–16 μm long, 3–10 μm wide). The Hartig net consists of hyphal cells lined up in one or two rows between the first layer of epidermal cells. It is uniform and paraepidermal. Epidermal cells are distinctly radially elongated. Clamp connections are present only on the surface hyphae of the mantle. Voucher material is deposited in Birmensdorf WSL (fg 19121).

*Laccaria montana* ectomycorrhizas (Fig. 11) are unbranched, up to 0.3 mm in diameter, 5 mm long, and sinuous. The surface is smooth to delicately downy, and regularly covered with a white mycelium. No rhizomorphs were observed. The colour varies within different shades of brownish-orange. The mantle is 5–12 μm thick, sparsely developed, one-layered, and synenchymatous (2–5 μm in diameter). The Hartig net consists of hyphal cells lined up in one row between the first layer of epidermal cells. It is paraepidermal, but not uniform. Epidermal cells are slightly radially elongated. Clamp connections are present only on the surface hyphae of the mantle. Voucher material is deposited in Birmensdorf WSL (fg 19151).

◀ **Figs. 3–8** Light micrographs of natural ectomycorrhizas of *Salix herbacea* with *Entoloma alpicola* and *Cenococcum geophilum*; *bars* 50 μm

**Fig. 3** Median longitudinal section of *E. alpicola* ectomycorrhiza. Fungal hyphae form a compact mantle (*M*) around the rootlet and a Hartig net (*arrowheads*)

**Fig. 4** Median longitudinal section of *E. alpicola* ectomycorrhiza. The mantle is two-layered with a prosenchymatous outer (*O*) and a synenchymatous inner mantle (*I*). The Hartig net is paraepidermal (*arrowheads*) and epidermal cells (*E*) are radially elongated and slightly oblique

**Fig. 5** Tangential longitudinal section of *E. alpicola* ectomycorrhiza. The inner mantle consists of a net synenchymatous tissue (*S*). Clamp connections are present in the prosenchymatous tissue (*arrowheads*) of the outer mantle

**Fig. 6** Median longitudinal section of *C. geophilum* ectomycorrhiza. Fungal hyphae form a compact mantle (*M*) around the rootlet and a Hartig net (*arrowheads*)

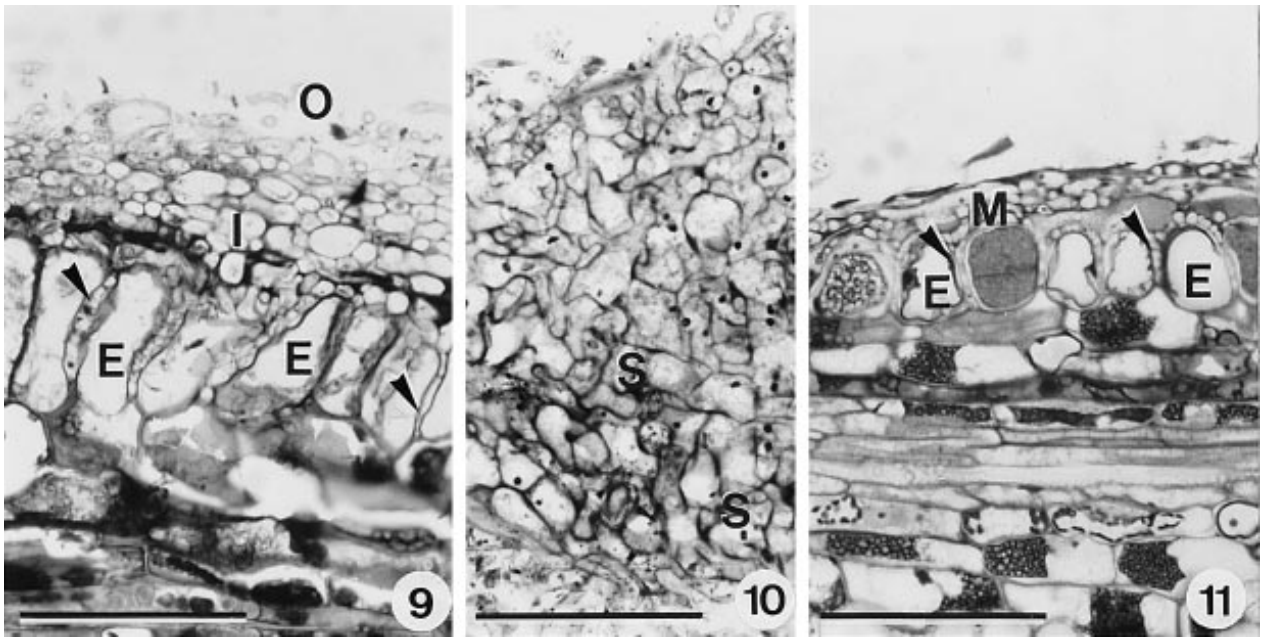
**Fig. 7** Median longitudinal section of *C. geophilum* ectomycorrhiza. The mantle is two-layered (*M*) and synenchymatous, with thickened cells in the outer layer and non-thickened cells in the inner layer. The Hartig net is paraepidermal (*arrowheads*) and epidermal cells (*E*) are radially elongated

**Fig. 8** Tangential longitudinal section of *C. geophilum* ectomycorrhiza. The mantle consists of a synenchymatous tissue (*S*). Clamp connections are absent

## Synthesized ectomycorrhiza

Mycelial cultures obtained from sporocarp tissue were successful only with *H. repandum* and *C. favrei*. In the Erlenmeyer flasks after 11 months and in the pots after 15 months only *H. repandum* formed typical ectomycorrhizal rootlets with seedlings and cuttings. *Cortinarius favrei* did not develop ectomycorrhizal structures after 14–15 months of incubation in either system, although hyphae were observed on the surface of the rootlets.

*Hebeloma repandum* ectomycorrhizas (Figs. 12–15) are unbranched, very infrequently monopodial, up to 0.3 mm in diameter, 1–3 mm long and straight to slightly bent. The surface is smooth, occasionally slightly squamose, and covered with irregular, downy mycelium. No rhizomorphs were observed. The colour is dull brownish-yellow. Small scales are darker brownish to rusty coloured. The mantle is 20–40 μm thick, differ-




**Figs. 9–11** Light micrographs of natural ectomycorrhizas of *Salix herbacea* with *Cortinarius favrei* and *Laccaria montana*; *bars* 50 μm

**Fig. 9** Median longitudinal section of *C. favrei* ectomycorrhiza. The mantle is two-layered with a prosenchymatous outer (*O*) and a synenchymatous inner mantle (*I*). The Hartig net is paraepidermal (*arrowheads*) and epidermal cells (*E*) are radially elongated and slightly oblique

**Fig. 10** Tangential longitudinal section of *C. favrei* ectomycorrhiza. The inner mantle consists of an irregular synenchymatous tissue (*S*)

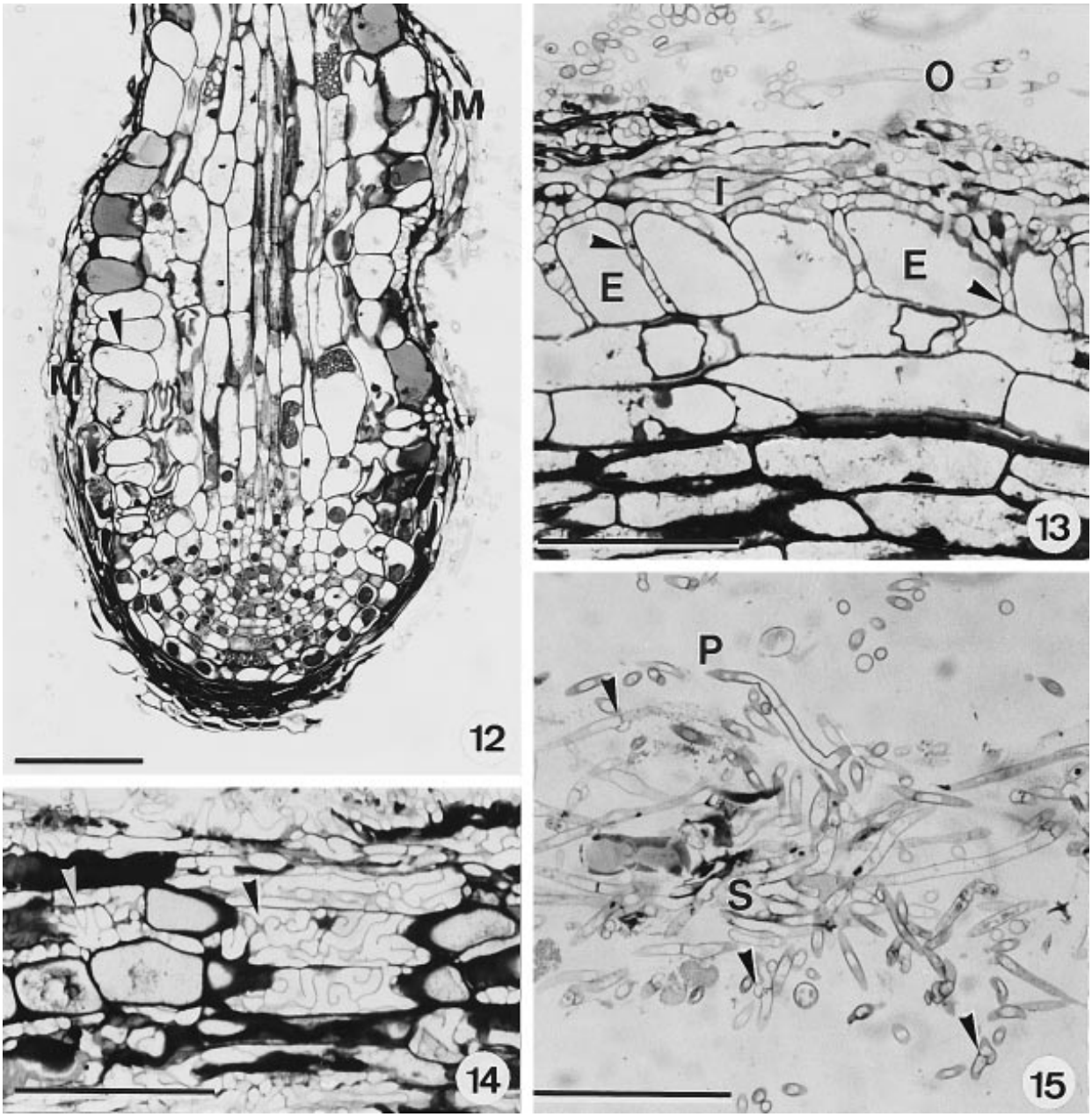
**Fig. 11** Median longitudinal section of *L. montana* ectomycorrhiza. The mantle is sparsely developed and one-layered (*M*). The Hartig net is paraepidermal (*arrowheads*) and epidermal cells (*E*) are only slightly radially elongated

entiated in a prosenchymatous outer layer with irregularly branched hyphae (3–5 μm in diameter) and a synenchymatous inner layer with shortened, tortuous hyphal cells (5–13 μm long, 3–6 μm wide). The Hartig net consists of hyphal cells lined up in one row (rarely two) between the first layer of epidermal cells. It is uniform, and paraepidermal. Epidermal cells are slightly radially elongated. Clamp connections are present in the prosenchymatous tissue of the outer mantle. Culture isolates of *H. repandum* are deposited in Birmensdorf WSL (50.01). Voucher material is deposited in Birmensdorf WSL (fg 19141).

## Discussion

The successful identification of ectomycorrhizas with Agerer's (1991) method is very difficult with alpine dwarf willows. The ectomycorrhizas of alpine and arctic *Salix* are very delicate compared with those of sturdy gymnosperms and most angiosperms (Fontana 1962; Antibus 1980; Antibus et al. 1981; Graf 1994). The fine roots with their ectomycorrhizal mantles rarely surpass 3 mm in length and 0.3 mm in diameter. The mantle surface is mostly smooth and lacks rhizomorphs or strongly developed hyphae leading to the corresponding sporocarp. Roots of the dwarf willows and their ectomycorrhizal mycelia grow through a strongly heterogeneous soil structure, unlike lowland conditions where ectomycorrhizal roots are embedded in a quite homogeneous soil body. The alpine habitat of *S. herbacea* is characterized by a thin humus layer followed by a coarse grained main root chamber with a high share of bedrock (Graf 1994). In addition, based on sporocarp mapping, ectomycorrhizal associates of *S. herbacea* are remarkably numerous, represented by up to 33 species within areas of 50 $m^2$.

Thus, Agerer's method to locate ectomycorrhizas by tracing mycelial strands from sporocarps (Ingelby et al. 1990; Agerer 1991) is not applicable in alpine investigations as it stands. Modification of the method requires the selection of sampling sites of suitable sporocarps, which most likely occur clumped but isolated from sporocarps of other fungal taxa within homogeneous carpets of the alpine dwarf willow, and thus detailed sporocarp mapping and statistical evaluation. The modification described here is based on Ogawa's description (Ogawa 1981) of a fungal growth form classified as "irregular mycelial mat" (distinct from "fairy ring" and "dispersed colony" types). Sporocarps (and ectomycorrhizas) fruit within this area of concentrated mycelial mats. Representatives of this life type in alpine dwarf willows are most likely members of the genus *Cortinarius*, and probably also *Entoloma* and *Laccaria* (Ogawa 1981; Agerer 1987; Read 1992). Taxa of *Russula* and *Hebeloma* rather form mycelia of the dispersed colony type, which agrees with the observation that root samples underneath sporocarps of *H. repandum*




**Figs. 12–15** Light micrographs of synthesizes ectomycorrhizas of *Salix herbacea* with *Hebeloma repandum*; *bars* 50 μm

**Fig. 12** Median longitudinal section. Fungal hyphae form a mantle (*M*) around the rootlet and a Hartig net (*arrowhead*)

**Fig. 13** Median longitudinal section. The mantle is two-layered with a prosenchymatous outer (*O*) and a synenchymatous inner mantle (*I*). The Hartig net is paraepidermal (*arrowheads*) and epidermal cells (*E*) are slightly radially elongated

**Fig. 14** Tangential longitudinal section of the Hartig net showing the multibranched finger-like hyphae (*arrowheads*)

**Fig. 15** Tangential longitudinal section. The inner mantle consists of a net synenchymatous tissue (*S*). Clamp connections (*arrowheads*) are present in the prosenchymatous tissue (*P*) of the outer mantle

and *R. norvegica* included various ectomycorrhizal types, and that interspecific association analyses between these two taxa were not significant (Graf 1994).

So far, no data are available from arcto-alpine zones which allow correlation of above ground sporocarp pattern and below ground ectomycorrhiza distribution, and results from coniferous forests do not provide data of this type (Jansen and De Nie 1988; Danielson and Pruden 1989; Taylor and Alexander 1990; Mehmann et al. 1995). However, results of Laiho (1970), Agerer (1990), and Dahlberg and Stenlid (1994) indicate a correlation between above and below ground for certain species, which provides an incentive to test the new approach. Biochemical and molecular biological analyses, such as the PCR method, are promising tools to answer specific questions in the near future.

Descriptions and drawings of ectomycorrhizas found on alpine willow (*S. reticulata* L., *S. serpyllifolia* Scop.) given by Fontana (1962) following the classification of Dominik (1959) distinguish four different types of ectomycorrhizas (including *C. geophilum*) without providing further identification of the fungal partners; a weakly developed or epidermal Hartig net is common to all four types described. Antibus (1980) detected two dominant morphological types in association with an arctic willow (*S. rotundifolia)* in Alaska. One was described as having a smooth, reddish-white mantle and the other as having a smooth, white mantle. Both types had Hartig nets reaching the innermost cortical layer, indicating possible ectomycorrhizal association with plants other than *Salix* since angiosperms have paraepidermal Hartig nets (Godbout and Fortin 1985). A third, black ectomycorrhiza type formed by *C. geophilum* with a Hartig net restricted to the epidermal layer is similar to that reported in the present study.

The first successful synthesis experiments with a dwarf willow (*S. rotundifolia*) were carried out by Antibus et al. (1981) with *H. pusillum* J. Lange, *E. sericeum* (Bull.) Quél., and *C. geophilum*. Here, the morphology of the *H. pusillum* type was almost identical with that synthesized between *S. herbacea* and *H. repandum* in the present study, or *H. crustuliniforme* (Bull. ex St. Amans) Quél. (unpublished data), suggesting that *Salix–Hebeloma* types are similar. In addition, synthesized ectomycorrhizas of *C. geophilum* or *E. sericeum* with *S. rotundifolia* (Antibus et al. 1981) were almost identical with natural ectomycorrhizas observed between *S. herbacea* and *C. geophilum* or *E. alpicola*.

So far, no adequate material is available for the comparison of natural ectomycorrhizas of *S. herbacea* with *C. favrei* and *L. montana*. Ectomycorrhizas of *Cortinarius* and *Laccaria* synthesized with *Populus tremuloides* Michx. (Godbout and Fortin 1985) show some similarity to the *S. herbacea* symbiosis with the corresponding fungal taxa in the present study. Natural, as well as synthesized, ectomycorrhizas of arcto-alpine *Dryas* species are not comparable to those of arcto-alpine dwarf *Salix* because of their cortical and epidermal Hartig nets, respectively (Debaud et al. 1981; Melville et al. 1987a,b; Melville et al. 1988). However, the mantle structure of the ectomycorrhizas between *Hebeloma* and *Dryas* are similar to each other and to those of *Salix*.

The verification of ectomycorrhizal relationships between *S. herbacea* and *C. favrei*, *E. alpicola*, *L. montana* and the successful synthesis of ectomycorrhizas between this dwarf willow and *H. repandum* are the first data reported for this plant and its ectomycorrhizal structures.

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