

GDK: 114.7-- 01:22:174.7 ‘‘*Abies alba* Mill.’’: (497.12\*02 Pokljuka)(045)

Prispelo / Received: 3. 1. 2005  
Sprejeto / Accepted: 20. 1. 2005

Izvirni znanstveni članek  
Original scientific paper

## BIODIVERSITY OF TYPES OF ECTOMYCORRHIZAE IN A NORWAY SPRUCE STAND ON POKLJUKA

Urša Vilhar<sup>1</sup>, Igor Smolej<sup>2</sup>, Tadeja Trošt<sup>3</sup>, Lado Kutnar<sup>4</sup>, Hojka Kraigher<sup>5</sup>

### Abstract

Types of ectomycorrhizae were studied in soil cores from a young regeneration center in an autochthonous Norway spruce stand on Pokljuka (Triglav National Park, 1200 m.a.s.l.). Soil cores of equal volume (274 ml, 0 - 18 cm deep) were taken from 33 sampling plots. In the samples all the roots were counted and types of ectomycorrhizae briefly characterized. From these data diversity indices (species diversity (d) and Shannon-Weaver index of diversity (H)) were calculated. Interactions among mycorrhizae, light regime and survival of spruce seedlings were studied.

Out of about 50,000 root tips approximately 1 % were non-mycorrhizal, 63 % were old unviable mycorrhizae and 36 % were identifiable ectomycorrhizal root tips, forming 27 different types of ectomycorrhizae. Sixteen types of ectomycorrhizae were briefly characterized. The Shannon diversity index for types of ectomycorrhizae was high (3.13) with respect to the above-ground diversity of vegetation (1.7). The direct site factor was shown to be negatively correlated to *Piceirhiza cornuta*. The diffuse site factor was negatively correlated to *Cortinarius sp.* (obtusus type) and positively correlated to *Inocybe sp.* The ground vegetation cover was positively correlated to *Piceirhiza gelatinosa* and the total vegetation cover to *Elaphomyces sp.*

Key words: types of ectomycorrhizae, Norway spruce, natural regeneration, Pokljuka

## PESTROST TIPOV EKTOMIKORIZE V SMREKOVEM SESTOJU NA POKLJUKI

### Izvleček

V majhni vrzeli domnevno avtohtonega smrekovega sestoja na Pokljuki (Triglavski narodni park) smo proučevali tipe ektomikorize na smreki. Vzorce tal smo jemali na 33. zvezdasto razporejenih vzorčnih ploskvicah s sondo prostornine 274 ml iz globine 0-18 cm. Iz vsakega vzorca smo izločili vse koreninice smreke, jih prešteli, ter na kratko opisali prisotni tip ektomikorize. Izračunali smo Indeks bogastva vrst (d) in Shannonov indeks pestrosti (H). Zanimal nas je vpliv ekoloških dejavnikov (svetlobnih razmer, naravnega pomlajevanja, zastiranja vegetacije) na porazdelitev tipov ektomikorize.

Od skupno 50.000 korenin smreke je bilo približno 1 % nemikoriznih, 63 % je bilo nedoločljivih, pretežno starih tipov ektomikorize ter 36 % določljivih ektomikoriznih korenin, ki so skupaj tvorile 27 tipov ektomikorize. Predstavljenih je 16 kratkih opisov za do sedaj neopisane tipe ektomikorize. Shannonov indeks pestrosti za tipe ektomikorize (3,13) je visok glede na pestrost vegetacije (1,7). Ugotovili smo negativno korelacijo direktnega sončnega sevanja s tipom *Piceirhiza cornuta*. Difuzno sončno sevanje je v negativni odvisnosti s tipom *Cortinarius sp.* (obtusus tip) in v pozitivni odvisnosti s tipom *Inocybe sp.*. Zastiranje pritalne vegetacije je v pozitivni odvisnosti s tipom *Piceirhiza gelatinosa*, skupno zastiranje vegetacije pa je v pozitivni odvisnosti s tipom *Elaphomyces sp.*

Ključne besede: tipi ektomikorize, navadna smreka, naravno pomlajevanje, Pokljuka

<sup>1</sup> univ. dipl. inž. gozd., Slovenian Forestry Institute, Večna pot 2, 1000 Ljubljana, SLO, ursa.vilhar@gozdis.si

<sup>2</sup> mag., univ. dipl. inž. gozd., Slovenian Forestry Institute, Večna pot 2, 1000 Ljubljana, SLO

<sup>3</sup> mag., univ. dipl. biol., BF, Department of Biology, Večna pot 111, 1000 Ljubljana, SLO

<sup>4</sup> dr., univ. dipl. inž. gozd., Slovenian Forestry Institute, Večna pot 2, 1000 Ljubljana, SLO

<sup>5</sup> doc. dr., univ. dipl. inž. gozd., Slovenian Forestry Institute, Večna pot 2, 1000 Ljubljana, SLO, hojka.kraigher@gozdis.si

**CONTENTS****VSEBINA**

<b>1</b>	<b>INTRODUCTION.....</b>	<b>73</b>
	UVOD	
<b>2</b>	<b>MATERIAL AND METHODS.....</b>	<b>73</b>
	MATERIAL IN METODE	
<b>3</b>	<b>RESULTS AND DISCUSSION.....</b>	<b>75</b>
	REZULTATI IN DISKUSIJA	
<b>4</b>	<b>CONCISE DESCRIPTIONS OF AS YET UNDESCRIBED TYPES .....</b>	<b>79</b>
	OPIS DO SEDAJ NEOPISANIH TIPOV	
<b>5</b>	<b>CONCLUSIONS.....</b>	<b>82</b>
	ZAKLJUČKI	
<b>6</b>	<b>POVZETEK.....</b>	<b>82</b>
<b>7</b>	<b>REFERENCES.....</b>	<b>83</b>
	VIRI	
	<b>ACKNOWLEDGEMENTS.....</b>	<b>85</b>
	ZAHVALA	

## **1 INTRODUCTION**

### **UVOD**

Below ground mycelia of mycorrhizal fungi represent a linking web for allocation of resources between plant species (READ 1998). Survival of shaded ectomycorrhizal trees has been shown to depend on the mycelial networks, connecting different sources of nutrients in a forest ecosystem (SIMARD 1996; LINDAHL *et al.* 1998), whereby different types of ectomycorrhizae have a different role in nutrient acquisition and translocation. Forest management practices that create intense disturbance and loss of organic matter or promote the introduction of non-ectomycorrhizal host species (ROBIČ *et al.* 1988) can decrease the ability of plants to form linkages with ectomycorrhizal fungi (AMARANTHUS / PERRY 1994). Mycelium extending from the adjacent stands may aid rapid regeneration of small forest openings preserving spatial and temporal continuity provided by ectomycorrhizal fungal linkages among plants.

These linkages may be especially critical in cold climates where seedlings require rapid, early ectomycorrhizal formation to take advantage of the short growing season and obtain the nutrients and water to survive the long cold winter and early frosts.

The success of natural regeneration of Norway spruce is classically related to light dependent temperature regime of the site (DIACI *et al.* 2000a). In our study we have tried to correlate interactions among mycorrhizae, soil properties, light regime and survival of spruce seedlings. In order to achieve this, types of ectomycorrhizae needed to be characterized and their abundance cross-linked to other data. The presented study is limited to study interactions among mycorrhizae, light regime and survival of spruce seedlings. Therefore, types of ectomycorrhizae Norway spruce stand on Pokljuka were characterized.

## **2 MATERIAL AND METHODS**

### **MATERIALI IN METODE**

Types of ectomycorrhizae were studied in soil cores from 33 sampling plots from a young regeneration center (size of the gap was 0.03 ha) in the permanent forest research plot (VILHAR 2001) on the Pokljuka plateau (Triglav National Park, 1200 m.a.s.l., NW Slovenia), established in an autochthonous Norway spruce stand (Figure 1). The site belongs to the association *Rhytidiadelpho lorei-Piceetum* (WRABER 1953 *n. nud.*) ZUPANČIČ

(1976) 1981 *em.* 1999), while the soils show a heterogeneous distric cambisol to podsol mixture (URBANČIČ / KUTNAR 1988). The design of sampling plots (size 0.5 x 0.5 m) followed the main compass directions (one each 2 m).

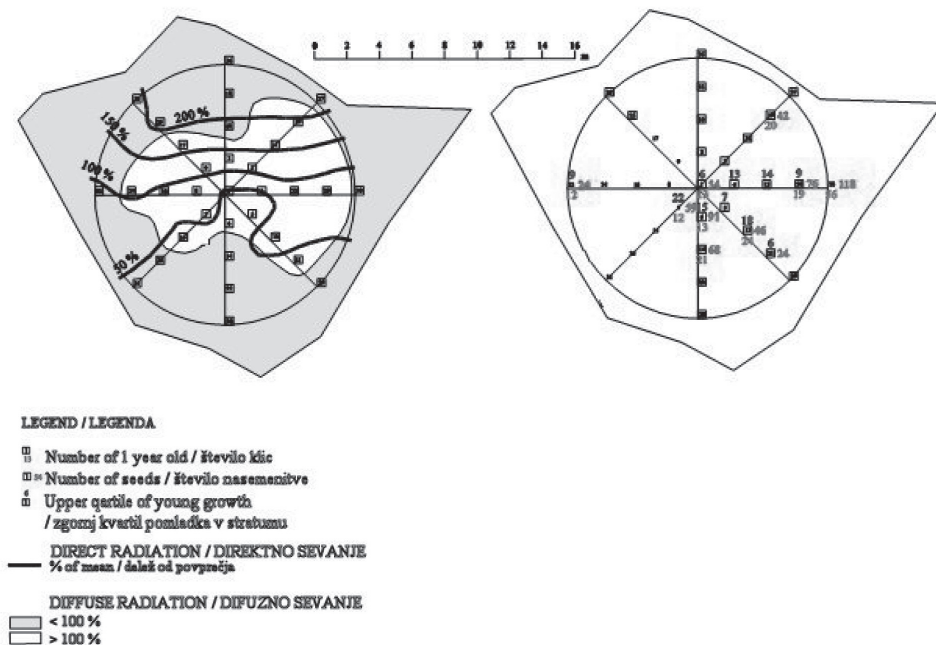


Figure 1: Research plot with star-like arrangement of sampling plots (DIACI *et al.* 2000a; DIACI *et al.* 2000b; reprinted with permission of the publisher)

Slika 1: Skica ploskve z zvezdasto razporejenimi ploskvicami (DIACI *et al.* 2000a; DIACI *et al.* 2000b; ponatisnjeno z dovoljenjem založnika)

Analyses of mycorrhizae were done in soil cores of 274 ml, 0 - 18 cm deep, 1 per square plot. The sampling was done in August 1997 (17 samples), October 1999 (12 samples) and in June 2000 (5 samples). The samples were kept in plastic bags in the refrigerator at 4 – 8 °C till further processing. Samples were carefully washed, all the roots (of 1 mm length or more) were counted and types of ectomycorrhizae briefly characterized (AGERER 1987-2002; GRONBACH 1988; BERG 1989; KRAIGHER 1996). Non-turgescent types were placed into a single category of old unidentifiable types. Selected types were concisely described by (TROŠT *et al.* 1999). Brief descriptions of the types of ectomycorrhizae which have not been previously characterized are presented in our results. Diversity indices (species diversity (d) and Shannon-Weaver index of diversity (H)) were calculated after (ATLAS / BARTHA 1981).

Diffuse and direct site light factors (potential direct irradiation in hours from April to August) according to (ANDERSON 1964) were assessed with horizontoscope as described in (DIACI *et al.* 2000b). The original method was modified and updated by applying photography and computerized image analysis.

At all plots, cover estimates of ground vegetation were made for all plant species in five vertical layers: moss, lower and upper herb layers, lower and upper shrub layers (KUTNAR 2000). In all plots the number of one-year-old seedlings, number of seedlings up to 10 cm and number of saplings higher than 10 cm was counted or estimated as described (DIACI *et al.* 2000b).

The correlation between selected types of ectomycorrhizae (occurring in most plots) and variables, describing radiation and natural spruce regeneration was analyzed using Spearman's rank correlation coefficient (STATISTICA for Windows 1984-1995).

### 3 RESULTS AND DISCUSSION REZULTATI IN DISKUSIJA

In total 51,049 root tips were counted, 1 % of which were non-mycorrhizal, 63 % were old unviable mycorrhizae and 36 % were identifiable ectomycorrhizal root tips, forming 27 different types of ectomycorrhizae (Figure 2).

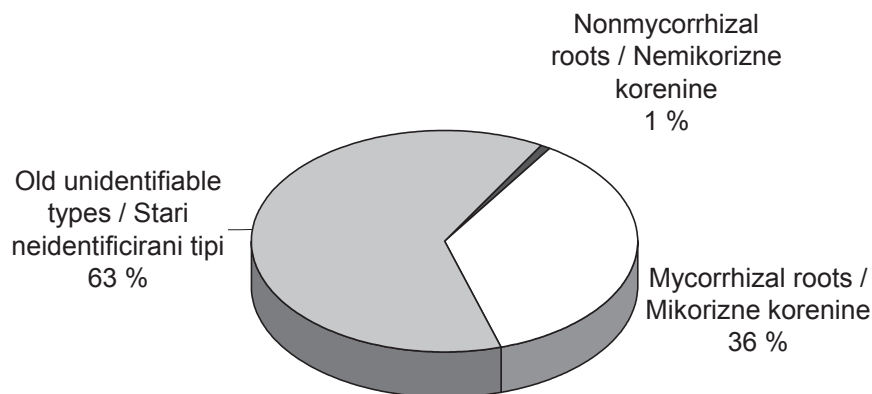


Figure 2: Number of counted old unviable mycorrhizae, non-mycorrhizal and identifiable ectomycorrhizal root tips

Slika 2: Število starih, neturgescenčnih mikoriznih korenin, nemikoriznih ter mikoriznih korenin

Three types could be identified by anatomical characteristics to the species level and 9 to the group or genus level. Further 3 types showed characteristics similar but not identical to the already described types (in figures marked with ~). Five types of ectomycorrhizae were preliminarily described by (TROŠT *et al.* 1999).

Table 1: Types of ectomycorrhizae  
Preglednica 1: Tipi ektomikorize

Types of ectomycorrhizae / Tipi ektomikorize	No. of root tips / Št. korenin	%	Reference / Vir opisa
<i>Cenococcum geophilum</i>	1618	8.8	AGERER (1987-1999)
<i>Hydnellum peckii</i>	42	0.2	AGERER (1987-1999)
<i>Hygrophorus olivaceoalbus</i>	45	0.2	AGERER (1987-1999)
~ <i>Piceirhiza cornuta</i>	302	1.6	(TROŠT <i>et al.</i> 1999)
~ <i>Pinirhiza epidermoides</i>	674	3.7	(TROŠT <i>et al.</i> 1999)
~ <i>Pinirhiza stellatulata</i>	24	0.1	(TROŠT <i>et al.</i> 1999)
<i>Cortinarius (obtusus type)</i>	233	1.3	See description / Glej opis
<i>Elaphomyces</i> sp.	3148	17.2	See description / Glej opis
<i>Inocybe</i> sp.	482	2.6	See description / Glej opis
<i>Lactarius</i> sp., Q-type	645	3.5	See description / Glej opis
<i>Lactarius</i> sp., P-type	1002	5.5	See description / Glej opis
<i>Thelephora</i> sp.	378	2.1	See description / Glej opis
<i>Tomentella</i> spp.	712	3.9	See description / Glej opis
<i>Tricholoma</i> sp.	47	0.3	See description / Glej opis
<i>Tylospora</i> spp.	7230	39.4	See description / Glej opis
Type SLO-UV 1058	234	1.3	See description / Glej opis
Type SLO-UV 1060	19	0.1	See description / Glej opis
Type SLO-UV 1065	396	2.2	See description / Glej opis
Type SLO-UV 1093	331	1.8	See description / Glej opis
Type SLO-UV 1108	10	0.1	See description / Glej opis
Type SLO-UV 1109	24	0.1	See description / Glej opis
Type SLO-UV 1122	39	0.2	See description / Glej opis
Type SLO-UV 1139	12	0.1	See description / Glej opis
Type SLO-UV 1164	365	2.0	See description / Glej opis
Type SLO-UV 1201	156	0.9	See description / Glej opis
Type SLO-TT 714	16	0.1	(TROŠT <i>et al.</i> 1999)
Type SLO-TT 724	164	0.9	(TROŠT <i>et al.</i> 1999)

Table 2: Species richness (d) and Shannon-Weaver index of diversity (H)  
 Preglednica 2: Indeks bogastva vrst (d) in Shannonov indeks pestrosti (H)

No. of ectomycorrhizal types / št. tipov ektomikorize	27
No. of ectomycorrhizal roots / št. ektomikoriznih korenin	18,340
Species richness / Indeks bogastva vrst (d)	7.51
Shannon index of diversity / Shannonov indeks pestrosti (H)	3.13

The Shannon diversity index for types of ectomycorrhizae was high (3.13) with respect to the Shannon diversity index for types of ectomycorrhizae in an old forest stand (2.23), clear cut (1.48) and the above-ground diversity of vegetation on the same site (1.7) (URBANČIČ / KUTNAR 1988; KRAIGHER 1999). Spatial and temporal linkages with ectomycorrhizal mycelium between the old and the new stand resulted in extreme diversity in the mycorrhizosphere in a young regeneration center, regardless of low diversity among natural pure spruce stand (VILHAR 2001).

There was no significant correlation between natural regeneration of spruce and total number of counted roots, number of old unviable ectomycorrhizal root tips or number of types per plot. The number of non-mycorrhizal root tips was positively correlated with the number of one-year-old seedlings ( $R = 0.36^*$ ) and seedlings up to 10 cm ( $R = 0.39^*$ ). Since the non-mycorrhizal roots were mostly translocating roots of dimensions over 2 mm, we assume they belonged mostly to the old trees encircling the gap or to the remaining roots of the cut trees from within the gap.

Table 3: Spearman's rank correlation coefficient (R) between variables indicating vegetation cover, direct and diffuse solar radiation and the counted root tips of ectomycorrhizal types. Only statistically significant trends are presented ( $p < 0.05$ ).

Preglednica 3: Spearmanov koeficient korelacije (R) med spremenljivkami, ki nakazujejo svetlobne razmere in zastiranje vegetacije ter številčnostjo tipov ektomikorize. Predstavljeni so statistično znančilni trendi ( $p < 0.05$ )

Type of ectomycorrhizae / Tip ektomikorize	Variable / Spremenljivka	N	Spearman's R	t(N-2)	p-level
<i>~Piceirhiza cornuta</i>	Direct site factor	33	-0.392	-2.376	0.024
	Diffuse site factor				
<i>Inocybe</i> sp.		33	0.503	3.238	0.003
<i>Cortinarius</i> sp. ( <i>obtusus</i> type)		33	-0.357	-2.129	0.041
<i>Hygrophorus olivaceoalbus</i>	Ground vegetation cover (without spruce seedlings)	33	0.400	2.433	0.021
	Total vegetation cover	33	0.392	2.374	0.024
<i>Elaphomyces</i> sp.					

For only a limited number of ectomycorrhizal types correlation to radiation factors are statistically significant. Direct site light factor is negatively correlated to *Piceirhiza cornuta*. Diffuse site light factor is negatively correlated to *Cortinarius* sp. (*obtusus* type) and positively correlated to *Inocybe* sp. Ground vegetation cover (without spruce seedlings) was positively correlated to *Piceirhiza gelatinosa* and total vegetation cover to *Elaphomyces* sp.. The results of the irradiation studies at the plot show that Norway spruce can successfully germinate and survive the first years if the direct site factor is not abundant and the roots of the seedlings come in touch with the root system of the old trees (DIACI *et al.* 2000b). When the critical period for seedling establishment is over, the importance of other site factors increase (more podsolised soil, higher content of organic matter and sparse forest vegetation coverage (*ibid*)).

Since direct correlations between ectomycorrhizal types and spruce seedlings were not significant, we assume that a complex interaction of ecological factors, e.g. micro relief, soil properties, radiation, vegetation, host species (KRAIGHER 2000), coarse woody debris (ALLEN 1991) and human impact (pasture, recreation,...) (PILTAVER 2000) influence the spatial distribution of ectomycorrhizae.



## 4 CONCISE DESCRIPTIONS OF AS YET UNDESCRIBED TYPES

### OPIS DO SEDAJ NEOPISANIH TIPOV

Table 4: Concise descriptions of as yet undescribed types and their schematic presentations

Preglednica 4: Opis do sedaj neopisanih tipov ter njihova shematska predstavitev

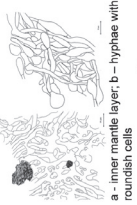
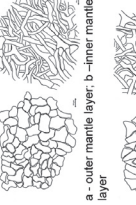
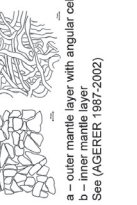
Type ID	Description	Ramification & growth	Colour, surface, size	Emanating elements	Outer mantle anatomy	Inner mantle anatomy	Anatomy of living hyphae	Anatomy of rhizomorphs	Schematic presentations & special elements (Scale bar = 10 µm)
Tip	Opsis	Razraščanje in oblika	Barva, površina, velikost	Izhajajoči elementi	Anatomija plašča – zunanji sloj	Anatomija plašča – notranji sloj	Anatomija izhajajočih elementov	Anatomija rizomorf	Shematski prikaz, referenca in posebnosti (merilce = 10 µm)
<i>Corriformus</i> ( <i>indivusus</i> type)	(AGERER 1987; AGERER 1987-2002), pl.12	irregularly-tortuous	White (ends brownish spots), woolly	numerous rhizomorphs growing off in flat angles	plectenchymatous; 3-5 µm in diam.	plectenchymatous; 4-5 µm in diam.	numerous, with repeatedly bent, 5 µm in diam.	undifferentiated, anastomoses, contact clamps	See (AGERER 1987-2002)
<i>Elaphomyces</i> sp.	(GRONBACH 1989); AGERER 1987-2002), pl.10	monopodial –pyramidal, straight to slightly bent	dark brown, ends light smooth, shiny	numerous hyphae specially on distal part attached to soil particles, bent or curved cystidia	plectenchymatous, hyphae repeatedly dichotomously, arranged net-like, 2.5-3 µm in diam.	plectenchymatous, with gelatinous matrix, hyphae repeatedly branched, anastomoses, no special pattern discernible, 1.5-2.5 µm close to septa and up to 7 µm at thicker spots	slightly bent, repeatedly branched, anastomoses, 2.5-3 µm in diam.	not observed	See (AGERER 1987-2002)
<i>Inocybe</i> sp.	(AGERER 1987-2002), pl. 94, 96	monopodial –pyramidal, straight to slightly bent	light gray to silver, ends: straight to slightly bent, reticulate	hyphae specially on distal part attached to soil particles	plectenchymatous, hyphae repeatedly branched, roundish enlargements or roundish end-cells	plectenchymatous, irregularly arranged, no special pattern discernible	occasional roundish enlargements or roundish end-cells, contact clamps	not observed	
<i>Lectarius</i> sp., P-type, SLO-UV 1094	monopodial –pinnate, straight to slightly bent	gray-yellow, ends light brown, critical cells visible	gray-yellow, ends light brown, critical cells visible	hyphae specially on distal part attached to soil particles	pseudoparenchymatous, with epidermoid cells	plectenchymatous, repeatedly branched, no special pattern discernible, 3 - 4 µm in diam.	not observed	not observed	
<i>Lectarius</i> sp., P-type, SLO-UV 1085	monopodial –pinnate, straight to slightly bent	gray-yellow, ends light brown, critical cells visible	gray-yellow, ends light brown, critical cells visible	hyphae specially on distal part attached to soil particles	pseudoparenchymatous, with angular cells	plectenchymatous, hyphae repeatedly branched, with occasional parallel arrangement, 3 - 4 µm in diam.	not observed	not observed	
<i>Thelephora</i> sp.	(BERG 1989); AGERER 1987-2002), pl. 48	monopodial –pinnate, straight to slightly bent	light brown to dark brown, smooth, shiny	numerous hyphae and cystidia, on distal part dark brown rhizomorphs	plectenchymatous, hyphae repeatedly branched, 3-7 µm in diam.	plectenchymatous, hyphae repeatedly branched, with anastomoses and no special pattern discernible, 3-5 µm	bent, repeatedly branched, with anastomoses and occasional clamps, 4 µm in diam.	not observed	See (AGERER 1987-2002)
<i>Tormentilla</i> spp.	(AGERER 1987-2002), pl. 11, 137, 138	monopodial –pinnate, straight	black, ends black, reticulate	hyphae with attached soil particles	pseudoparenchymatous, hyphae arranged star-like	plectenchymatous, hyphae arranged star-like, some containing black fragments	dark hyphae, contact clamps, 2-3 µm in diam.	not observed	See (AGERER 1987-2002)


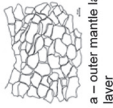

Table 4: Concise descriptions of as yet undescribed types and their schematic presentations (continuation)

Preglednica 4: Opis do sedaj neopisanih tipov ter njihova shematska predstavitev

<i>Tylospora</i> spp.	(GRONBACH 1988); <i>Piceirhiza</i> (AGERER 1987-2002), pl. 32	monopodial - pyramidal, straight	brown, ends smooth, conical cells visible	not observed	plectenchyomatous with gelatinous matrix, hyphae repeatedly branched, 1-4 like arranged, 3-4 µm in diam.	plectenchyomatous, hyphae repeatedly branched, no special pattern discernible, 1,5-4 µm in diam.	hyphae bent, dichotomous branched, with gelatinous cover, occasionally present intrahyphae, 3-4 µm in diam.	not observed	See (AGERER 1987-2002)
Type SLO-UV 1058		monopodial - pinnate, straight	dark gray, ends dark gray, smooth	dense cover of white rhizomorphs, presumably not emanating from the mantle	plectenchyomatous with gelatinous matrix, hyphae parallel, occasionally star-like arranged, with roundish enlargements, 2,2-5 µm in diam.	plectenchyomatous, hyphae repeatedly branched, no special pattern discernible, 1,5-4 µm in diam.	hyphae repeatedly dichotomous branched, 2,5-4 µm, at roundish enlargements up to 7,5 µm	not observed	 a – inner mantle layer, b – hyphae with clamps and emanating hyphae with roundish enlargements
Type SLO-UV 1060		simple, unbranched, straight	yellow, ends yellow-white, smooth	not observed	plectenchyomatous with gelatinous matrix, hyphae parallel, occasionally ring-like arranged, with roundish enlargements, 2,2-5 µm in diam.	plectenchyomatous, hyphae occasionally ring-like arranged	not observed	 outer mantle layer	
Type SLO-UV 1065		monopodial, straight to slightly bent	gray, ends rose-pink, smooth	hyphae, repeatedly branched, star-like arranged or like arranged or no special pattern discernible, on ramification spots attached	plectenchyomatous, hyphae occasionally roundish or angular, 5-5,5 µm in diam.	hyphae repeatedly branched or no special pattern discernible, 2,5-3 µm in diam.	not observed	 outer mantle layer	
Type SLO-UV 1108		monopodial - pinnate, straight	light gray, ends light gray, smooth	not observed	plectenchyomatous with gelatinous matrix, hyphae occasionally parallel arranged, 2,5-3 µm in diam.	plectenchyomatous	not observed	 outer mantle layer	
									 a – mantle layer, b – inner mantle layer

Table 4: Concise descriptions of as yet undescribed types and their schematic presentations (continuation)

Preglednica 4: Opis do sedaj neopisanih tipov ter njihova shematska predstavitev

Type SLO-UV 1109	monopodial – pinnate, straight	dark brown, shiny; ends yellow, smooth	not observed	pseudoparenchymatous with epidermoid cells	Transition between pseudoparenchymatous and plectenchymatous, 2.5-3 µm in diam.	not observed		outer mantle layer with epidermoid cells; inner mantle layer: transition between pseudoparenchymatous and plectenchymatous
Type SLO-UV 1122	monopodial – pinnate, straight	gray, shiny; ends white, smooth	not observed	pseudoparenchymatous with angular or epidermoid cells	plectenchymatous, hyphae repeatedly branched, no special pattern discernible, 2-4 µm in diam.	hyphae repeatedly branched with roundish enlargements on ramification locations, 3.5-4 µm, enlargements up to 7.5 µm in diam.		a – outer mantle layer; b – inner mantle layer
Type SLO-UV 1164	monopodial – pyramidal, straight	Black, ends black, reticulate	black, rhizomorphs and white hyphae	Plectenchymatous, hyphae star-like arranged	Plectenchymatous, hyphae no special pattern discernible, 2-3 µm in diam.	hyphae repeatedly branched, hyphal enlargements close to ramification, 1.5- 2.5 µm in diam.		inner mantle layer

## 5 CONCLUSIONS ZAKLJUČKI

The diversity indices of ectomycorrhizae in soil cores from our site in a young growth forest were higher than in an old forest stand and nearly two times higher than the diversity index, calculated for the vegetation cover from the same site. Low diversity of vegetation in a natural pure spruce stand has no effect on the extreme diversity of mycorrhizosphere.

The number of non-mycorrhizal root tips was positively correlated with the number of one-year-old seedlings and seedlings up to 10 cm, but there was no significant correlation between natural regeneration of spruce and total number of counted roots, number of old unviable ectomycorrhizal root tips or number of types per plot.

For some of the ectomycorrhizal types correlation to radiation factors and vegetation cover was proven. *Piceirhiza cornuta* is negatively correlated to the direct site factor. *Cortinarius* sp. (obtusus type) is negatively correlated and *Inocybe* sp. positively correlated to the diffuse site factor. *Piceirhiza gelatinosa* was positively correlated to the ground vegetation cover (without spruce seedlings) and *Elaphomyces* sp. to the total vegetation cover.

## 6 POVZETEK

Micelij ektomikoriznih gliv predstavlja osnovno povezovalno komponento med drevjem, dekompozitorji v gozdnih tleh in pritalno vegetacijo v gozdnih ekosistemih. Obravnavali smo tipe ektomikorize na smreki, ki se pojavljajo v majhni vrzeli odraslega, domnevno avtohtonega smrekovega sestoja na Pokljuki (Triglavski narodni park). Vzorce tal smo jemali na zvezdasto razporejenih vzorčnih ploskvicah s sondo prostornine 274 ml iz globine 0-18 cm, izločili vse koreninice smreke, jih prešteli ter razvrstili glede na prisotnost ektomikorize. Tipe ektomikorize smo identificirali oziroma, če to ni bilo možno, na kratko opisali. Izračunali smo Indeks bogastva vrst (d) in Shannonov indeks pestrosti (H). Zanimal nas je vpliv ekoloških dejavnikov (svetlobnih razmer, naravnega pomlajevanja, zastiranja vegetacije) na porazdelitev tipov ektomikorize.

Od skupno 50.000 korenin smreke je bilo približno 1 % nemikoriznih, 63 % je bilo nedoločljivih, pretežno starih tipov ektomikorize, ter 36 % določljivih ektomikoriznih korenin, ki so skupaj tvorile 27 tipov ektomikorize. Trem tipom smo na podlagi anatomskih

značilnosti določili vrsto, 9 smo jih uvrstili v rod ali skupino. Trije tipi so imeli podobne značilnosti, kot že opisani tipi, a ne povsem identičnih. Te smo označili z znakom (~). Predstavljenih je 16 kratkih opisov za do sedaj neopisane tipe ektomikorize.

Shannonov indeks pestrosti za tipe ektomikorize je 3,13. Če primerjamo ugotovljeni indeks za populacijo mikoriznih gliv s Shannonovim indeksom pestrosti, ugotovljenim za pritalno vegetacijo, ki znaša 1,71, sklepamo, da relativno majhna pestrost rastlinstva še ne pomeni majhne raznovrstnosti med glivami, niti v celotni biocenozi. Z našim popisom ugotovljeni Shannonov indeks pestrosti izraža veliko vrstno pestrost mikoriznih gliv oziroma biokomponente v gozdnih tleh na majhni površini. Predvidevamo, da na pomlajevanje v manjših vrzelih vpliva časovna in prostorska povezanost starega in novonastajajočega sestoja z micelijem ektomikoriznih gliv. Ta povezava je odločilnega pomena predvsem v ekstremnejših rastiščnih pogojih, saj hitra kolonizacija ektomikoriznih gliv prispeva k izboljšanju preživetja mladja v stresnih pogojih okolja.

Pri proučevanju prostorske porazdelitve tipov ektomikorize v povezavi z ekološkimi dejavniki (svetlobne razmere, zastiranje vegetacije) smo ugotovili le nekaj statistično značilnih povezav. Direktno sončno sevanje je v negativni odvisnosti s tipom *Piceirhiza cornuta*. Difuzno sončno sevanje je v negativni odvisnosti s tipom *Cortinarius* sp. (*obtusus* tip) in v pozitivni odvisnosti s tipom *Inocybe* sp. Zastiranje pritalne vegetacije (brez pomladka smreke) je v pozitivni odvisnosti s tipom *Piceirhiza gelatinosa*, skupno zastiranje vegetacije pa je v pozitivni odvisnosti s tipom *Elaphomyces* sp. Neposrednih povezav med tipi ektomikorize ter številom smrekovega pomladka nismo ugotovili, zato sklepamo, da na prostorsko porazdelitev tipov ektomikorize vpliva kompleks ekoloških dejavnikov (mikrorelief, talne razmere, svetlobne razmere, vegetacija, mrtva lesna biomasa, vplivi človeka, ...).

## 7 REFERENCES

### VIRI

- AGERER, R. 1987-2002. Colour Atlas of Ectomycorrhizae, 1<sup>st</sup> - 11<sup>th</sup> delivery. München, Einhorn Verlag.
- ALLEN, M.F. 1991. The ecology of mycorrhizae. Cambridge, Cambridge University press. s. 180.
- AMARANTHUS, M.P., PERRY, D.A. 1994. The functioning of ectomycorrhizal fungi in the field: linkages in space and time. Plant and soil 159. s. 133-140.
- ANDERSON, M.C. 1964. Studies on woodland light climate I. The photographic computation of light conditions. Journal of Ecology 52. s. 27-41.
- ATLAS, R., BARTHA, R. 1981. Introduction to microbiology. Reading, Addison-Wesley Publishing Company. s. 242-244.

- BERG, B. 1989. Charakterisierung und Vergleich von Ektomykorrhizen gekalkter Fichtenbestände. Univ. München. München, LMU München s.
- DIACI, J., KUTNAR, L., RUPEL, M., SMOLEJ, I., URBANČIČ, M., KRAIGHER, H. 2000a. Interactions of Ecological Factors and Natural Regeneration in an Altimontane Norway Spruce (*Picea abies* (L.) Karst.) Stand. *Phyton* 40. 4: s. 17-26.
- DIACI, J., SMOLEJ, I., RUPEL, M. 2000b. Raziskave svetlobnih razmer in zakonitosti pomlajevanja smreke na trajni raziskovalni ploskvi Šijec. Rizosfera: raziskave gozdnih tal in rizosfere ter njihov vpliv na nekatere fiziološke parametre gozdnega drevja v izbranih gozdnih ekosistemih, sestojnih tipih in razvojnih fazah gozda = The Rhizosphere: studies of forest soils and the rhizosphere and their influences on chosen physiological parameters of forest trees in selected forest ecosystems, forest types and developmental phases of the forest. H. Kraigher, I. Smolej. Ljubljana, Gozdarski inštitut Slovenije. 118: 221-243 s.
- GRONBACH, E. 1988. Charakterisierung und Identifizierung von Ektomykorrhizen in einem Fichtenbestand mit Untersuchungen zur Merkmalsvariabilität in sauer beregneten Flächen. *Bibl. Mycologica* 125. s. 216.
- KRAIGHER, H. 1996. Tipi ektomikorize - taksonomija, pomen in aplikacije. *Zbornik gozdarstva in lesarstva* 49. s. 33-66.
- KRAIGHER, H. 1999. Diversity of Types of Ectomycorrhizae on Norway Spruce in Slovenia. *Phyton* 39. 3: s. 279-322.
- KRAIGHER, H. 2000. Pomen micelija mikoriznih gliv v gozdnih tleh = the role of the mycorrhizal mycelium in forest soils. Rizosfera: raziskave gozdnih tal in rizosfere ter njihov vpliv na nekatere fiziološke parametre gozdnega drevja v izbranih gozdnih ekosistemih, sestojnih tipih in razvojnih fazah gozda = The Rhizosphere: studies of forest soils and the rhizosphere and their influences on chosen physiological parameters of forest trees in selected forest ecosystems, forest types and developmental phases of the forest. H. Kraigher, I. Smolej. Ljubljana, Gozdarski inštitut Slovenije. 118: 110-118 s.
- KUTNAR, L. 2000. Vegetacijske razmere na raziskovalnih ploskvah na Pokljuki in pri Kočevski Reki. Rizosfera: raziskave gozdnih tal in rizosfere ter njihov vpliv na nekatere fiziološke parametre gozdnega drevja v izbranih gozdnih ekosistemih, sestojnih tipih in razvojnih fazah gozda = The Rhizosphere: studies of forest soils and the rhizosphere and their influences on chosen physiological parameters of forest trees in selected forest ecosystems, forest types and developmental phases of the forest. H. Kraigher, I. Smolej. Ljubljana, Gozdarski inštitut Slovenije. 118: 65-76 s.
- LINDAHL, B., STEINLID, J., OLSSON, S., FINLAY, R. 1998. Translocation of <sup>32</sup>P between interacting mycelia of a wood-decomposing fungus and ectomycorrhizal fungi in microcosm systems. *New Phytologist* 144. s. 183-193.
- PILTAVER, A. 2000. Popis gliv na trajni raziskovalni ploskvi Šijec in v njeni okolici na Pokljuki. Rizosfera: raziskave gozdnih tal in rizosfere ter njihov vpliv na nekatere fiziološke parametre gozdnega drevja v izbranih gozdnih ekosistemih, sestojnih tipih in razvojnih fazah gozda = The Rhizosphere: studies of forest soils and the rhizosphere and their influences on chosen physiological parameters of forest trees in selected forest ecosystems, forest types and developmental phases of the forest. H. Kraigher, I. Smolej. Ljubljana, Gozdarski inštitut Slovenije. 118: 65-67 s.
- READ, D.J. 1998. Plants on the web. *Nature* 396. s. 22-23.
- ROBIČ, D., VILHAR, U., KRAIGHER, H. 1988. Gozdnogojitveni vidiki kompeticije v rizosferi zatravljenega antropogenega altimontanskega smrekovja. *Zbornik referatov Gorski gozd. XIX. Gozdarski študijski dnevi, Logarska dolina.* 255-268 s.
- SIMARD, S.W. 1996. Interspecific carbon transfer in ectomycorrhizal tree species mixtures. USA, Oregon State University: 210 s.

STATISTICA for Windows 1984-1995. Tulsa, StatSoft, Inc.s.

TROŠT, T., AGERER, R., URBANČIČ, M., KRAIGHER, H. 1999. Biodiversity of Ectomycorrhizae in a Norway Spruce Stand on Pokljuka. *Phyton* 39. 4: s. 225-232.

URBANČIČ, M., KUTNAR, L. 1988. Diversity of soil conditions and ground cover vegetation in forest on the moraines of Pokljuka plateau. *Zbornik referatov Gorski gozd. XIX. Gozdarski študijski dnevi, Logarska dolina.* 223-241 s.

VILHAR, U. 2001. Pestrost tipov ektomikorize na naravnem mladju smreke na Pokljuki. Ljubljana, University of Ljubljana: 72 s.

ZUPANČIČ, M. 1999. Vegetation of the Pokljuka plateau. "Root - soil interactions in trees - abstracts", COST Action E6 Eurosilva, Forest Tree Physiology Research, Gozd Martuljek, Slovenia. 73 s.

## **ACKNOWLEDGEMENTS**

### **ZAHVALA**

The study was part of the program Forest Biology, Ecology & Technology, financed by the Ministry of Education, Science and Sports of the Republic of Slovenia. We would like to thank Tone Kralj for development of software for computerized image analysis, Matej Rupel for counting and field work and prof. dr. Jurij Diaci for providing the equipment for irradiation measurements and valuable suggestions and comments. Urša Vilhar received the Prešeren Award for her Diploma Thesis on the study of types of ectomycorrhizae.

