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

Urša Vilhar[1], Igor Smolej[2], Tadeja Trošt[3], Lado Kutnar[4], Hojka Kraigher[5]

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

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VSEBINA

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 autochtonous 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).

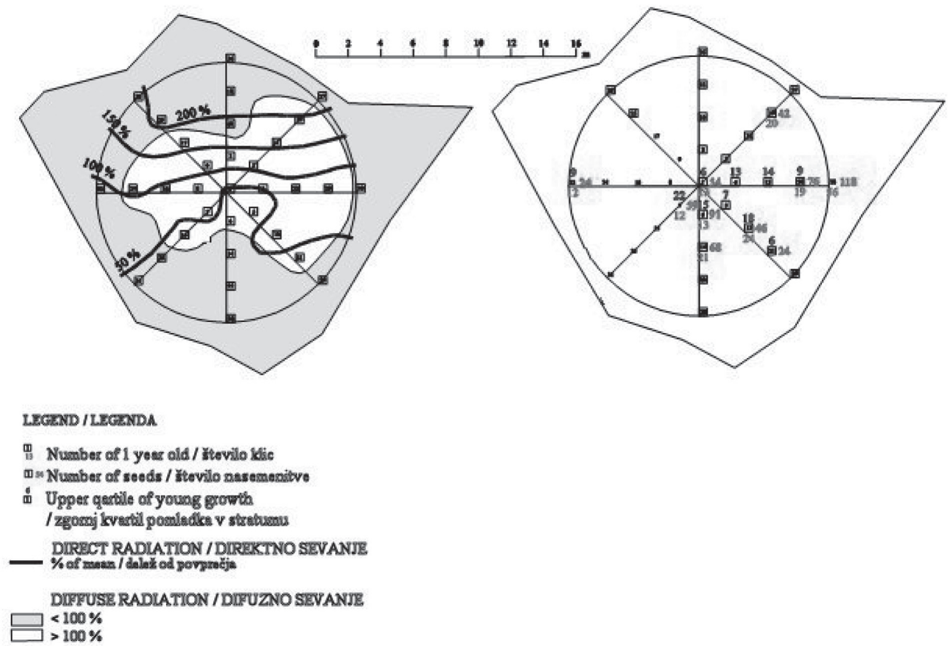


Figure 1: Research plot with star-like arrangement of sampling plots (DIACI *et al.* 2000a; DIACI *et al*. 2000b; reprinted with permission of the publisher)
Slika 1: Skica ploskve z zvezdasto razporejenimi ploskvicami (DIACI *et al.* 2000a; DIACI *et al*. 2000b; ponatisnjeno z dovoljenjem založnika)

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).

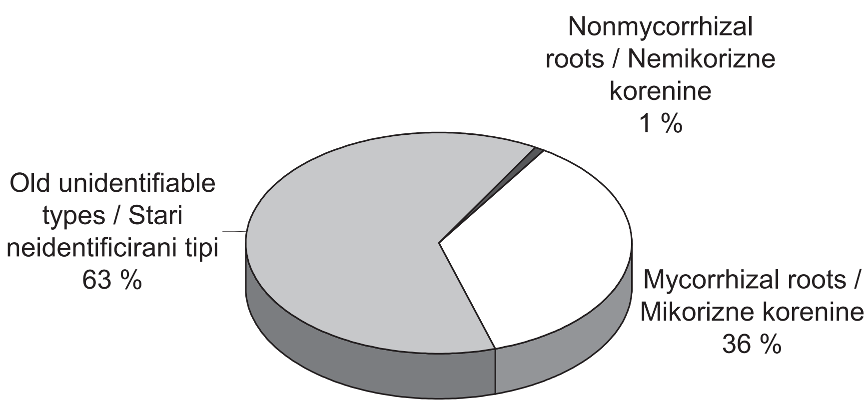


Figure 2: Number of counted old unviable mycorrhizae, non-mycorrhizal and identifiable ectomycorrhizal root tips
Slika 2: Število starih, neturgescentnih mikoriznih korenin, nemikoriznih ter mikoriznih korenin

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
Cenococcum geophilum	1618	8.8	AGERER (1987-1999)
Hydnellum peckii	42	0.2	AGERER (1987-1999)
Hygrophorus olivaceoalbus	45	0.2	AGERER (1987-1999)
~Piceirhiza cornuta	302	1.6	(TROŠT *et al* 1999)
~Pinirhiza epidermoides	674	3.7	(TROŠT *et al* 1999)
~Pinirhiza stellanulata	24	0.1	(TROŠT *et al* 1999)
Cortinarius (obtusus type*)*	233	1,.3	See description / Glej opis
Elaphomyces sp.	3148	17.2	See description / Glej opis
Inocybe sp.	482	2.6	See description / Glej opis
Lactarius sp., Q-type	645	3.5	See description / Glej opis
Lactarius sp., P-type	1002	5.5	See description / Glej opis
Thelephora sp.	378	2.1	See description / Glej opis
Tomentella spp.	712	3.9	See description / Glej opis
Tricholoma sp.	47	0.3	See description / Glej opis
Tylospora 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 *et al* 1999)
Type SLO-TT 724	164	0.9	(TROŠT *et al* 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 mycorhyzosphere 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 zančilni trendi ($p<0.05$)

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

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

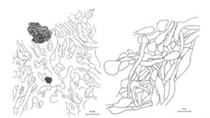
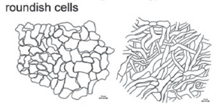
Type ID Tip	Description Opis	Ramification & growth Razraščanje in oblika	Colour, mantle surface, size Barva, površina plašča, velikost	Emanating elements Izhajajoči elementi	Outer mantle anatomy Anatomija plašča – zunanji sloj	Inner mantle anatomy Anatomija plašča – notranji sloj	Anatomy of emanating hyphae Anatomija izhajajočih elementov	Anatomy of rhizomorphs Anatomija rizomorfov	Schematic presentations & special elements (Scale bar = 10 µm) Shematski prikaz, referenca in posebnosti (merilce = 10 µm)
Cortinarius sp. (*obtusus* type)	(AGERER 1987), (AGERER 1987-2002), pl.12	irregularly-pinnate, tortuous	White (ends with brownish spots), woolly	numerous hyphae, rhizomorphs, growing off in flat angles	plectenchymatous; 3-5 µm in diam.	plectenchymatous; 4-5 µm in diam.	numerous, with contact clamps, 4-5 µm in diam.	undifferentiated, rare anastomoses, contact clamps	See (AGERER 1987-2002)
Elaphomyces sp.	(GRONBACH 1988): *Piceirhiza glutinosa*, (AGERER 1987-2002), pl.31	monopodial – pyramidal, straight to slightly bent	dark brown, ends light brown, smooth, shiny	numerous hyphae specially on ramification spots, with attached soil particles, bent or curved cystidia	plectenchymatous, hyphae repeatedly branched 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 bend, repeatedly branched, with anastomoses, 2,5-3 µm in diam.	not observed	See (AGERER 1987-2002)
Inocybe sp.	(AGERER 1987-2002), pl. 94, 96	monopodial – pyramidal, straight to slightly bent	light gray to silver, ends: sliver-white, reticulate	hyphae specially on ramification spots, with attached soil particles	plectenchymatous, hyphae repeatedly branched, occasional roundish enlargements or roundish end-cells	plectenchymatous, hyphae irregularly arranged, no special pattern discernible	occasional roundish enlargements or roundish end-cells, contact clamps	not observed	 a - inner mantle layer; b – hyphae with roundish cells
Lactarius sp., Q-type, SLO-UV 1094		monopodial – pinnate, straight to slightly bent	gray-yellow, ends yellow, smooth, cortical cells visible	hyphae specially on ramification spots, with attached soil particles	pseudoparenchymatous, with epidermoid cells	plectenchymatous, hyphae repeatedly branched, no special pattern discernible, 3 - 4 µm in diam.		not observed	 a - outer mantle layer; b –inner mantle layer
Lactarius sp., P-type, SLO-UV 1085		monopodial – pinnate, straight to slightly bent	grey-yellow, ends light brown, smooth, cortical cells visible	hyphae specially on ramification spots, with attached soil particles	pseudoparenchymatous, with angular cells	plectenchymatous, hyphae repeatedly branched, with occasional parallel arrangement, 3 - 4 µm in diam.		not observed	 a – outer mantle layer with angular cells; b – inner mantle layer
Thelephora sp.	(BERG 1989), (AGERER 1987-2002), pl. 48	monopodial – pinnate, straight to slightly bent	light brown to dark brown, ends: light brown, smooth, shiny	numerous hyphae and cystidia, on older parts 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 contact clamps, 3-4 µm in diam.	not observed	See (AGERER 1987-2002)
Tomentella spp.	(AGERER 1987-2002), pl. 111, 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 cells 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

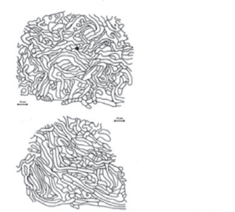
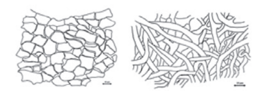
Tylospora spp.	(GRONBACH 1988): *Piceirhiza guttata*, (AGERER 1987-2002), pl. 32	monopodial – pyramidal, straight	brown, ends light brown, smooth, cortical cells visible	not observed	plectenchymatous with gelatinous matrix, hyphae repeatedly branched, net-like arranged, 3-4 µm in diam.	plectenchymatous, 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 rhizomorfs, presumably not emanating from the mantle	plectenchymatous with gelatinous matrix, hyphae parallel, occasionally star-like arranged, with roundish enlargements, 2-2,5 µm in diam.	plectenchymatous, 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, unramified, straight	yellow, shiny, ends yellow-white, smooth	not observed	plectenchymatous with gelatinous matrix hyphae parallel, occasionally ring-like arranged, with roundish enlargements, 2-2,5 µm in diam.	plectenchymatous, hyphae occasionally ring-like arranged		not observed	 outer mantle layer
Type SLO-UV 1065		monopodial – pyramidal, straight to slightly bent	gray, ends rose-pink, smooth	hyphae, repeatedly branched, star-like arranged or no special pattern discernible, on ramification spots attached soil particles	plectenchymatous, hyphae occasionally roundish or angular, 5-5,5 µm in diam.	hyphae repeatedly branched, star-like arranged or no special pattern discernible, 2,5-3 µm in diam.	hyphae dichotomous branched, with roundish enlargements, 4-5 µm in diam.	not observed	 outer mantle layer
Tip SLO-UV 1108		monopodial – pinnate, straight	light gray, ends light gray, smooth	not observed	plectenchymatous with gelatinous matrix, hyphae occasionally parallel arranged, 2,5-3 µm in diam.	plectenchymatous	hyphae repeatedly branched, 3-4 µm in diam.	not observed	 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

Tip 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 rhizomorfs and white hyphae	Plectenchymatous, hyphae star-like arranged	Plectenchymatous, hyphae no special pattern discernible, 2-5 µm in diam.	hyphae repeatedly branched, hyphal cells have thicker walls on locations 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 mycorhyzosphere.

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,…).

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