

Ectomycorrhizal fungi associated with ponderosa pine and Douglas-fir: a comparison of species richness in native western North American forests and Patagonian plantations from Argentina

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Abstract The putative ectomycorrhizal fungal species registered from sporocarps associated with ponderosa pine and Douglas-fir forests in their natural range distribution (i.e., western Canada, USA, and Mexico) and from plantations in south Argentina and other parts of the world are listed. One hundred and fifty seven taxa are reported for native ponderosa pine forests and 514 taxa for native Douglas-fir forests based on available literature and databases. A small group of genera comprises a high proportion of the species richness for native Douglas-fir (i.e., *Cortinarius*, *Inocybe*, and *Russula*), whereas in native ponderosa pine, the species richness is more evenly distributed among several genera. The comparison between ectomycorrhizal species richness associated with both trees in native forests and in Patagonia (Argentina) shows far fewer species in the latter, with 18 taxa for the ponderosa pine and 15 for the Douglas-fir. Epigeous species richness is clearly dominant in native Douglas-fir, whereas a more balanced relation epigeous/hypogeous richness is observed for native ponderosa pine; a similar trend was observed for Patagonian plantations. Most fungi in Patagonian Douglas-fir plantations have not been recorded in plantations elsewhere, except *Suillus lakei* and *Thelephora terrestris*, and only 56% of the fungal taxa recorded in Douglas-fir plantations around the world are known from native forests, the other

taxa being new associations for this host, suggesting that new tree + ectomycorrhizal fungal taxa associations are favored in artificial situations as plantations.

Keywords Ectomycorrhizas · Exotic plantations · Fungal species richness · *Pinus ponderosa* · *Pseudotsuga menziesii*

Introduction

Ponderosa pine (*Pinus ponderosa* Dougl.) and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) are conifers native to western North America. Both have a wide natural distribution and associate with many ectomycorrhizal (EM) fungal species. Ponderosa pine occurs from 52°N in British Columbia (Canada) to 25°N in northern Mexico and from the Pacific coast, following the border between Oregon and California, to the east up to central Nebraska (Oliver and Ryker 1991). Douglas-fir has a wider distribution, from 55°N in central British Columbia to 19°N in the north of Mexico and from the Pacific coast to the Rocky Mountains (Hermann and Lavender 1990). These two species are the most widely planted conifers in the Patagonian Andes of Argentina, where they grow very well and adapt to a variety of soils and climate. About 53,000 ha of ponderosa pine (Gonda 2001) have been planted between 36°30'00"S (Manzano Amargo, Neuquén province) and 44°10'47"S (Río Pico, Chubut province) and westward to the 400-mm isohyet (Gonda, personal communication). Some 5,000 ha of Douglas-fir (Davel 1998) have been planted along the piedmont of the Patagonian Andes, in a north–south strip from 40° to 43°S and 71° to 71°40'W, with precipitation ranging from 600 mm in the south up to 900 mm in the north. Although ponderosa pine has not been widely

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planted around the world, Douglas-fir has been successfully introduced in many countries, being the most widely planted species in western Europe: France with 330,000 ha according to 1993 data, Belgium with 15,000 ha (1994 data), The Netherlands with 16,000 ha (1990 data), Germany with 152,000 ha (1980 data), Spain with 30,000 ha (1993 data), and England with 49,000 ha (1985 data; Vega Alonso et al. 1998, website). It has also been planted in New Zealand, where it represents 5% of the exotic forest resources of that country and to a lesser extent in Australia. In South America, Chile has plantations reaching 12,090 ha in 1993 (INFOR 1996). On the contrary, ponderosa pine plantations in Patagonia remain the only area outside the natural range of this species.

Ectomycorrhizae are fundamental for the normal growth and survival of species in the Pinaceae (Meyer 1973; Harley and Smith 1983). The genera *Pinus* and *Pseudotsuga* typically form EM associations; arbuscular mycorrhizal (AM) associations have also been documented, although knowledge of their ecological significance and the interaction with ectomycorrhizae is lacking (Cázares and Trappe 1993; Cázares and Smith 1996; Smith et al. 1998). No information has been compiled on EM fungal species associated with either trees in its natural distribution; several papers identify EM fungal species associated with both trees in natural forests, but the information is scattered in survey reports (Trappe 1962; Melichar et al. 1985; Mathiasen and Albion 2001; Smith et al. 2002; Norvell and Exeter 2004), taxonomic studies (Gilbertson 1974; States 1984b), and ecological studies (Fogel 1976; Ammirati et al. 1987; States 1984a; Hunt and Trappe 1987; Luoma 1991; Luoma et al. 1991; O'Dell et al. 1992; States and Gaud 1997; Colgan et al. 1999; Stendell et al. 1999). Some studies list the EM fungal species of Douglas-fir planted in different parts of the world (Chu Chou and Grace 1981, 1983; Garrido 1986; Jansen 1991; Parladé et al. 1996a,b), and Barroetaña et al. (2005, 2006) reported the EM fungal species associated with ponderosa pine and Douglas-fir introduced in Patagonia.

Knowing the EM fungal species richness associated with a tree species over its natural distribution provides information important for ecological studies and management decisions in forest ecosystems. Such information is also necessary to understand the EM status of a tree species introduced in exotic afforested areas and to select appropriate EM fungal species for inoculation programs. The objectives of this review are (1) to list all EM fungal species associated with native ponderosa pine and Douglas-fir forests based on sporocarp surveys reported in the literature and data bases, (2) to compare the EM fungal species richness associated with ponderosa pine in native forests and in Patagonian plantations, and (3) to compare the EM fungal species richness associated with Douglas-fir

in native forests, Patagonian plantations, and other plantations around the world.

Methodology

The EM fungal species and their references are listed for native ponderosa pine and Douglas-fir forests and for exotic ponderosa pine and Douglas-fir plantations. The complete lists of taxa given below include infrageneric records: Varieties are included separately. Taxa obtained from herbarium surveys and personal communications with specialists who provided unpublished information are also included. All EM fungal species reported for ponderosa pine came from forests clearly dominated by this species, except for some records from the Oregon State University herbarium that refer to findings in mixed stands. The records for Douglas-fir came from studies in forests dominated by this species, where the usual situation along its distribution is the association with different EM tree species, such as red alder (*Alnus rubra* Bong.), western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), western larch (*Larix occidentalis* Nutt.), lodgepole pine (*Pinus contorta* Loud.), western white pine (*Pinus monticola* D. Don.), subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.), grand fir (*Abies grandis* Lindl.), and ponderosa pine, among others (Hermann and Lavender 1990). The EM status of all the taxa, at least at the genus level, was checked in Bougher and Castellano (1993), Brundrett et al. (1996), Castellano et al. (1989), Køljalg et al. (2000), and Molina et al. (1992), and those that are currently known to be saprophytic were excluded. Names and authors of each taxon follow the "Index Fungorum" data base, from CABI Bioscience and CBS, (<http://www.indexfungorum.org/Index.htm>). The sporocarp habit for each taxon was considered in four categories: epigeous (EP), hypogeous (HY), corticioid (C, fruitbodies resupinated), and subhypogeous (sub-HY).

Distribution of EM fungal species in native forests and exotic plantations

A total of 157 taxa (excluding infraspecies determinations and taxa determined only at the genus level) have been found reported for native ponderosa pine forests. Considering collections from mixed forests, the total number rises to 205. These taxa are listed in Table 1, along with references. In all, 514 taxa (excluding determinations below the species level and only at the genus level) have been reported for native Douglas-fir forests, as also listed in Table 1, along with references. This number rises to 608 when records below species level are considered, the latter belonging mainly to the genus *Inocybe*.

When the sporocarp habit for each EM fungal species reported by host tree in native forests is taken into

Table 1 Ectomycorrhizal fungal species registered from sporocarps in ponderosa pine and Douglas-fir native forests

Species	References ponderosa pine	References Douglas-fir	Habit	Comments
<i>Alpova trappei</i> Fogel	(1 ^a)	(16) (20)	HY	
<i>Amanita aprica</i> Tulloss & Lindgren nom. prov.		(21)	EP	IF-
<i>Amanita aspera</i> Fr.		(11) (20)	EP	
<i>Amanita caesarea</i> (Scop.) Pers.	(6) (10)		EP	
<i>Amanita chlorinosma</i> (Peck) Lloyd		(11)	EP	
<i>Amanita crocea</i> (Quél.) Singer	(10)		EP	
<i>Amanita franchetii</i> (Boud.) Fayod		(21)	EP	
<i>Amanita gemmata</i> (Fr.) Bertill.	(10)	(11) (21)	EP	
<i>Amanita muscaria</i> (L.) Lam.	(2) (6) (10)	(11) (20)	EP	
<i>Amanita pachycolea</i> D.E. Stuntz	(21)		EP	
<i>Amanita pantherina</i> Gonn. & Rabenh.	(2) (10)	(11) (20) (21)	EP	
<i>Amanita pantherina-gemmata</i> hybrid	(6)		EP	
<i>Amanita phalloides</i> (Vaill. Ex Fr.) Link	(1)		EP	
<i>Amanita porphyria</i> Alb. & Schwein.	(1)	(20)	EP	
<i>Amanita rubescens</i> Pers.	(6)		EP	
<i>Amanita silvicola</i> Kauffman		(11) (20) (21)	EP	
<i>Amanita smithiana</i> Bas.		(21)	EP	
<i>Amanita</i> sp.		(21)	EP	parasitized by <i>Sepedonium</i> sp.
<i>Amanita strobiliformis</i> (Paulet ex Vittad.) Bertill.		(11)	EP	
<i>Amanita vaginata</i> (Bull.) Lam.	(2) (10)	(11) (21)	EP	
<i>Amphinema byssoides</i> (Pers.) J. Erikss.	(3)		C	
<i>Balsamia magnata</i> Harkn.	(1) (8)	(20)	HY	
<i>Balsamia nigrens</i> Harkn.	(1)	(12)	HY	
<i>Balsamia platyspora</i> Berk.	(1)		HY	
<i>Balsamia</i> sp.		(18)	HY	
<i>Balsamia vulgaris</i> Vittad.	(1)		HY	
<i>Barssia oregonensis</i> Gilkey	(1)	(12) (14) (18) (20)	HY	
<i>Boletellus zelleri</i> (Murrill) Singer, Snell & E.A. Dick		(11)	EP	
<i>Boletinus amabilis</i> (Peck) Snell		(11)	EP	
<i>Boletus barrowsii</i> Thiers & A.H. Sm.	(6) (10)		EP	
<i>Boletus chrysenteron</i> gr. Bull.		(13) (20)		
<i>Boletus edulis</i> Bull.	(2) (6)	(11)		
<i>Boletus erythropus</i> Pers.		(11)		
<i>Boletus luridiformis</i> Rostk.		(21)		
<i>Boletus mirabilis</i> Murrill.		(20)		
<i>Boletus piperatus</i> Bull.		(20)		
<i>Boletus pulverulentus</i> Opat.		(11)		
<i>Boletus subtomentosus</i> L.		(11) (20)		
<i>Boletus zelleri</i> Murrill		(20) (21)		
<i>Brauniellula albipes</i> (Zeller) A.H. Sm. & Singer	(1) (8)		HY	
<i>Brauniellula nancyae</i> A.H. Sm. & Singer	(5)		HY	
<i>Camarophyllus borealis</i> (Peck) Murrill	(1)	(20)	EP	
<i>Camarophyllus</i> cf. <i>virginicus</i> (Wulfen) P. Kumm.	(1)		EP	
<i>Cantharellus formosus</i> Corner	(1)	(11) (17) (20)(21)	EP	
<i>Cantharellus subalbidus</i> A.H. Sm. & Morse	(1)	(11) (20) (21)	EP	
<i>Cenococcum geophilum</i> Fr.	(1) (2) (9)	(11)	HY	
<i>Chalciporus piperatoides</i> (A.H. Sm. & Thiers) T.J. Baroni & Both		(21)	EP	EM?
<i>Chalciporus piperatus</i> (Bull.) Bataille	(2)		EP	
<i>Choiromyces alveolatus</i> (Harkn.) Trappe	(1)		HY	
<i>Chroogomphus rutilus</i> (Schaeff.) O.K. Mill.	(1)		EP	
<i>Chroogomphus tomentosus</i> (Murrill) O.K. Mill.		(20)	EP	
<i>Chroogomphus vinicolor</i> (Peck) O. K. Mill.	(1) (6)		EP	
<i>Cortinarius</i> subg. <i>Bulbopodium</i>		(20)	EP	4 spp.

Table 1 (continued)

Species	References ponderosa pine	References Douglas-fir	Habit	Comments
<i>Cortinarius</i> subg. <i>Cortinarius</i>		(20)	EP	1 spp.
<i>Cortinarius limonius</i> (Fr.) Fr.		(21)	EP	
<i>C. violaceus</i> (L.) Gray		(21)	EP	
<i>Cortinarius</i> subg. <i>Dermocybe</i>		(20)	EP	5 spp.
<i>C. californicus</i> A.H. Sm.		(21)	EP	
<i>C. cascadiensis</i> Ammirat. & A.H. Sm		(21)	EP	
<i>C. cinnamomeus</i> (L.) Fr.	(1)	(11) (21)	EP	
<i>C. croceifolius</i> Peck	(2)		EP	
<i>C. croceus</i> (Schaeff.) Gray		(21)	EP	
<i>C. humboldtensis</i> Ammirati & A.H. Sm.	(1)		EP	
<i>C. malicorius</i> Fr.		(21)	EP	
<i>C. phoeniceus</i> var. <i>occidentalis</i> A.H. Sm.		(21)	EP	
<i>C. sanguineus</i> (Wulfen) Fr.		(21)	EP	
<i>C. semisanguineus</i> (Fr.) Guillet		(21)	EP	
<i>C. thiersii</i> Ammirati & A.H. Sm		(21)	EP	
<i>C. zakii</i> Ammirati & A.H. Sm.		(13) (21)	EP	
<i>Cortinarius</i> subg. <i>Leproclybe</i>		(20)	EP	9 spp.
<i>C. clandestinus</i> Kauffman		(21)	EP	
<i>C. cotoneus</i> Fr.		(21)	EP	
<i>C. gentilis</i> (Fr.) Fr.		(21)	EP	
<i>C. cf. rubicundulus</i> (Rea) A. Pearson		(21)	EP	
<i>Cortinarius</i> subg. <i>Myxaciium</i>		(20)	EP	4 spp.
<i>C. delibutus</i> Fr.		(21)	EP	
<i>C. emunctus</i> Fr.		(21)	EP	
<i>C. mucifluus</i> Fr.		(21)	EP	
<i>C. mucosus</i> (Bull.) Cooke		(21)	EP	
<i>C. pluvius</i> (Fr.) Fr.		(21)	EP	
<i>C. vanduzerensis</i> A.H. Sm. & Trappe		(21)	EP	
<i>C. vibratilis</i> (Fr.) Fr.		(21)	EP	
<i>C. sp.</i>		(21)	EP	
<i>Cortinarius</i> subg. <i>Phlegmacium</i>		(20)	EP	17 spp.
<i>C. allutus</i> Fr. sensu Moser		(21)	EP	
<i>C. bigelowii</i> Thiers & A.H. Sm.	(1)		Sub-HY	
<i>C. caesiostramineus</i> Rob. Henry		(21)	EP	
<i>C. calochrous</i> var. <i>coniferarum</i> (M.M. Moser) Nespiak		(21)	EP	
<i>C. cf. colymbadinus</i> Fr.		(21)	EP	
<i>C. elegantior</i> var. <i>americanus</i> M.M. Moser & McKnight		(21)	EP	
<i>C. glaucopus</i> (Schaeff.) Fr.	(10)	(21)	EP	
<i>C. infractus</i> Berk.	(1)	(21)	EP	
<i>C. magnivelatus</i> Morse ex Thiers & A.H. Sm.	(1)		Sub-HY	
<i>C. metarius</i> Kauffman	(10)			
<i>C. cf. miser</i> M.M. Moser sensu Moser		(21)	EP	
<i>C. multiformis</i> (Fr.) Fr.		(21)	EP	
<i>C. pallidifolius</i> A.H.Sm.		(21)	EP	
<i>C. papulosus</i> Fr.		(21)	EP	
<i>C. ponderosus</i> A.H. Sm.		(21)	EP	
<i>C. cf. purpurascens</i> (Fr.) Fr.		(21)	EP	
<i>C. cf. subtortus</i> (Pers.) Fr.		(21)	EP	
<i>C. superbus</i> A.H. Sm.		(21)	EP	
<i>C. turmalis</i> Fr.		(21)	EP	
<i>C. cf. variipes</i> Rob. Henry		(21)	EP	
<i>C. sp.</i>		(21)	EP	
<i>Cortinarius</i> subg. <i>Seriocybe</i>		(20)	EP	8 spp.
<i>C. cf. alboviolaceus</i> (Pers.) Fr.		(21)	EP	
<i>C. camphoratus</i> (Fr.) Fr.		(21)	EP	

Table 1 (continued)

Species	References ponderosa pine	References Douglas-fir	Habit	Comments
<i>C. cyanites</i> Fr.		(21)	EP	
<i>C. traganus</i> (Fr.) Fr.		(17)	EP	
<i>C. traganus</i> var. <i>ochraceus</i> M.M. Moser, Ammirati & M.T. Seidl		(21)	EP	
<i>Cortinarius</i> subg. <i>Telamonia</i>		(20)	EP	33 spp.
<i>C. acutus</i> (Pers.) Fr.		(21)	EP	
<i>C. albovariegatus</i> (Velen.) Melot		(21)	EP	
<i>C. angelesianus</i> A.H. Sm.		(21)	EP	
<i>C. aurantiomarginatus</i> Schaeff.		(21)	EP	
<i>C. aff. barlowensis</i> nom. prov.		(21)	EP	IF-
<i>C. aff. bibulus</i> Quél.		(21)	EP	
<i>C. biformis</i> Fr./ <i>subpurpureus</i> A.H. Sm.		(21)	EP	
<i>C. brunneus</i> (Pers.) Fr.		(21)	EP	
<i>C. brunneus</i> var. <i>glandicolor</i> (Fr.) H. Lindstr. & Melot		(21)	EP	
<i>C. cagei</i> Melot		(21)	EP	
<i>C. casimiri</i> (Velen.) Huijsman		(21)	EP	
<i>C. cedriolens</i> M.M. Moser		(21)	EP	
<i>C. cypriacus</i> Fr.		(21)	EP	
<i>C. damascenus</i> Fr.		(21)	EP	
<i>C. decipiens</i> (Pers.) Fr.		(21)	EP	
<i>C. depauperatus</i> (J.E. Lange) Rob. Henry		(21)	EP	
<i>C. detonsus</i> (Fr.) Fr.		(21)	EP	
<i>C. cf. dilutus</i> (Pers.) Fr.		(21)	EP	
<i>C. distans</i> var. <i>olympianus</i> A.H. Sm.		(21)	EP	
<i>C. dolabratus</i> Fr.		(21)	EP	
<i>C. duracinus</i> Fr.		(21)	EP	
<i>C. erubescens</i> M.M. Moser		(21)	EP	
<i>C. evernius</i> (Fr.) Fr.		(21)	EP	
<i>C. fasciatus</i> Fr.		(21)	EP	
<i>C. flexipes</i> (Pers.) Fr.		(21)	EP	
<i>C. illuminus</i> Fr.		(21)	EP	
<i>C. imbutus</i> Britzelm.		(21)	EP	
<i>C. ionophyllus</i> M.M. Moser		(21)	EP	
<i>C. jubarinus</i> Fr.		(21)	EP	
<i>C. laniger</i> Fr.		(21)	EP	
<i>C. leucopus</i> (Bull.) Fr.		(21)	EP	
<i>C. miniatopus</i> J.E. Lange		(21)	EP	
<i>C. obtusus</i> (Fr.) Fr. complex		(21)	EP	several spp.
<i>C. ochrophyllus</i> Fr.		(21)	EP	
<i>C. psammocephalus</i> (Bull.) Fr.		(21)	EP	
<i>C. aff. quarciticus</i> H. Lindstr.		(21)	EP	
<i>C. renidens</i> Fr.		(21)	EP	
<i>C. rigidus</i> (Scop.) Fr.		(21)	EP	
<i>C. cf. saturninus</i> (Fr.) Fr.		(21)	EP	
<i>C. scandens</i> Fr.	(1)	(cf. 21)	EP	
<i>C. scaurus</i> (Fr.) Fr.	(10)	(cf. 21)	EP	
<i>C. cf. stemmatus</i> Fr.		(21)	EP	
<i>C. umbilicatus</i> P. Karst.		(21)	EP	
<i>C. uraceus</i> Fr.		(21)	EP	
<i>C. aff. vernus</i> H. Lindstr. & Melot		(21)	EP	
<i>C. sp.</i>		(21)	EP	
<i>Cortinomyces sublilacinus</i>		(20)	HY	IF-. EM?
<i>Craterellus neotubaeformis</i> nom. prov.		(21)	EP	IF-
<i>Dentinum</i> sp.	(1)		EP	
<i>Destuntzia fusca</i> Fogel & Trappe	(1)		HY	

Table 1 (continued)

Species	References ponderosa pine	References Douglas-fir	Habit	Comments
<i>Elaphomyces anthracinus</i> Vittad.	(1)		HY	
<i>Elaphomyces granulatus</i> Fr.	(1) (8)	(12) (15) (16) (18) (19) (20)	HY	
<i>Elaphomyces muricatus</i> Fr.		(16) (19) (20)	HY	
<i>Endogone flammicorona</i> Trappe & Gerd.	(1)		HY	
<i>Endogone lactiflua</i> Berk.	(1) (8)	(16) (18) (19) (20)	HY	
<i>Gautieria caudata</i> (Harkn.) Zeller & C.W. Dodge	(1)	(20)	HY	
<i>Gautieria</i> cf. <i>crispa</i> E.L. Stewart & Trappe	(1) (6) (4) (5)		HY	
<i>Gautieria graveolens</i> Vittad.	(1 ^a)		HY	
<i>Gautieria mexicana</i> (E. Fisch.) Zeller & C.W. Dodge	(1 ^a)		HY	
<i>Gautieria monticola</i> Harkn.	(1)	(14) (15) (16) (19) (20)	HY	
<i>Gautieria morchelliformis</i> Vittad.	(1 ^a)		HY	
<i>Gautieria othii</i> Trog.	(1)		HY	
<i>Gautieria parksiana</i> Zeller & C.W. Dodge	(1 ^a)		HY	
<i>Gautieria</i> sp.		(12)	HY	
<i>Genabea cerebriformis</i> (Harkn.) Trappe	(1)	(12) (14) (18) (19) (20)	HY	
<i>Genea asperula</i> Trappe, Guzmán & Herrera	(1 ^a)		HY	
<i>Genea harknessii</i> Gilkey		(12) (19)	HY	
<i>Genea intermedia</i> Gilkey	(1)	(12) (14) (18) (19) (20)	HY	
<i>Geopora cooperi</i> f. <i>cooperi</i> Harkn.	(1) (6)	(12) (20)	HY	
<i>G. cooperi</i> f. <i>gilkeyae</i> Burds.	(1) (8)		HY	
<i>Gomphidius glutinosus</i> (Schaeff.) Fr.		(11) (20) (21)	EP	
<i>Gomphidius oregonensis</i> Peck		(11) (13)	EP	
<i>Gomphidius rutilus</i> (Schaeff.) S. Lundell	(2)		EP	
<i>Gomphidius smithii</i> Singer		(11)	EP	
<i>Gomphidius subroseus</i> Kauffman		(11) (13) (20) (21)	EP	
<i>Gomphidius tomentosus</i> Murrill.		(11)	EP	
<i>Gomphidius vinicolor</i> Peck	(2)		EP	
<i>Gomphus clavatus</i> (Pers.) Gray		(20) (21)	EP	
<i>Gomphus floccosus</i> (Schwein.) Singer		(20)	EP	
<i>Gymnomyces brunnescens</i> (Singer & A.H. Sm.) Trappe, T. Lebel & Castellano	(1 ^a)	(14) (18)	HY	
<i>Gymnomyces ellipsosporus</i> (Zeller) Trappe, T. Lebel & Castellano	(1) (5) (8)	(14) (20)	HY	
<i>Gymnomyces fulvisporus</i> (A.H. Sm.) Trappe, T. Lebel & Castellano	(1)		HY	
<i>Gymnomyces parksii</i> Singer & A.H. Sm.	(1 ^a)	(12)	HY	
<i>Gymnomyces</i> sp.	(9)	(12) (18)	HY	
<i>Gymnomyces subochraceus</i> (A.H. Sm.) Trappe, T. Lebel & Castellano	(1 ^a)	(20)	HY	
<i>Hebeloma crustuliniforme</i> (Bull.) Quél.	(1) (6)	(11) (20) (21)	EP	
<i>Hebeloma longicaudum</i> (Pers.) P. Kumm.		(21)	EP	
<i>Hebeloma mesophaeum</i> gr. (Pers.) Fr.		(13) (20) (21)	EP	
<i>Hebeloma perplexum</i> A.H. Sm., V.S. Evenson & Mitchel		(21)	EP	
<i>Hebeloma praeolidum</i> A.H. Sm., V.S. Evenson & Mitchel		(21)	EP	
<i>Hebeloma pumilum</i> J.E. Lange		(21)	EP	
<i>Hebeloma pusillum</i> J.E. Lange	(1)		EP	
<i>Hebeloma</i> cf. <i>sacchariolens</i> Quél.		(20) (21)	EP	
<i>Hebeloma</i> cf. <i>stenocystis</i> J. Favre		(21)	EP	
<i>Hebeloma</i> sp.		(21)	EP	
<i>Helvella crispa</i> (Scop.) Fr.	(10)		EP	
<i>Helvella lacunosa</i> Afzel.	(1)		EP	
<i>Helvella leucomeleana</i> (Pers.) Nannf.	(1)		EP	
<i>Hydnellum peckii</i> Banker	(1 ^a)		EP	
<i>Hydnoplicata gautierioides</i>		(20)	HY	IF-. EM?

Table 1 (continued)

Species	References ponderosa pine	References Douglas-fir	Habit	Comments
<i>Hydnotrya cerebriformis</i> (Tul. & C. Tul.) Harkn.	(1)		HY	
<i>Hydnotrya tulasnei</i> (Berk.) Berk. & Broome		(12)	HY	
<i>Hydnotrya variiformis</i> Gilkey	(1 ^a)	(19) (20)	HY	
<i>Hydnotryopsis setchellii</i> Gilkey	(1 ^a)		HY	
<i>Hydnum imbricatum</i> var. <i>monticola</i> Harrison	(1 ^a)		EP	var. IF-
<i>Hydnum repandum</i> L.		(11) (21)	EP	
<i>Hydnum umbilicatum</i> Peck		(20) (21)	EP	
<i>Hygrocybe flavescens</i> (Kauffman) Singer		(20)	EP	
<i>Hygrocybe laeta</i> (Pers.) P. Kumm.		(20)	EP	
<i>Hygrocybe miniata</i> (Fr.) P. Kumm.		(20)	EP	
<i>Hygrocybe virginea</i> (Wulfen) P.D. Orton & Wathing	(1 ^a)		EP	
<i>Hygrophorus agathosmus</i> (Fr.) Fr.		(20) (21)	EP	
<i>Hygrophorus atramentosus</i> Secr. ex H. Haas & R. Haller Aar		(21)	EP	
<i>Hygrophorus bakerensis</i> A.H. Sm. & Hesler		(20) (21)	EP	
<i>Hygrophorus</i> cf. <i>calyptryiformis</i> (Berk.) Berk.		(20)	EP	
<i>Hygrophorus</i> cf. <i>camarophyllus</i> (Alb. & Schwein.) Dumée, Grandjean & Maire		(20)	EP	
<i>Hygrophoruschryson</i> (Batsch) Fr.	(6) (10)	(11) (20)	EP	EM/S
<i>Hygrophorus eburneus</i> (Bull.) Fr.		(20) (21)	EP	
<i>Hygrophorus erubescens</i> (Fr.) Fr.	(6)		EP	
<i>Hygrophorus gliocyclus</i> Fr.	(1) (2)	(11)	EP	
<i>Hygrophorus karstenii</i> Sacc. & Cub.	(2)		EP	
<i>Hygrophorus odoratus</i> A.H. Sm. & Hesler		(21)	EP	
<i>Hygrophorus pusillus</i> Peck		(13)	EP	
<i>Hygrophorus speciosus</i> Peck	(6) (10)		EP	
<i>Hymenogaster brunnescens</i> A. H. Sm.	(5)		HY	
<i>Hymenogaster gilkeyae</i> Zeller & C.W. Dodge	(1 ^a)	(14)	HY	
<i>Hymenogaster hiemalis</i> sp. nov.	(1 ^a)		HY	IF-
<i>Hymenogaster macmurphyi</i> Zeller & C.W. Dodge	(1)		HY	
<i>Hymenogaster parksii</i> Zeller & C.W. Dodge		(12) (14)	HY	
<i>Hymenogaster subalpinus</i> A.H. Sm.	(5)		HY	
<i>Hymenogaster sublilacinus</i> A. H. Sm.	(1) (8)	(19)	HY	
<i>Hysterangium aureum</i> Zeller		(20)	HY	
<i>Hysterangium coriaceum</i> R. Hesse	(1) (6) (8)	(14) (15) (16) (18) (19) (20)	HY	
<i>Hysterangium crassirhachis</i> Zeller & C.W. Dodge	(1)	(14) (16) (19) (20)	HY	
<i>Hysterangium crassum</i> (Tul. & C. Tul.) E. Fisch.		(12) (14)	HY	
<i>Hysterangium fallax</i> Castellano sp. nov. (in herb.)	(1)		HY	IF-
<i>Hysterangium occidentale</i> Harkn.		(12)	HY	
<i>Hysterangium ochraceisporus</i> Castellano & States	(1)		HY	IF-
<i>Hysterangium separabile</i> Zeller	(1) (4) (5)	(12)	HY	
<i>Hysterangium setchellii</i> Fischer	(1)	(16) (19) (20)	HY	IF-
<i>Inocybe agglutinata</i> Peck		(21)	EP	
<i>Inocybe</i> cf. <i>amethystina</i> Kuyper		(21)	EP	
<i>Inocybe assimilata</i> Britzelm.		(21)	EP	
<i>Inocybe boltonii</i> R. Heim		(21)	EP	
<i>Inocybe</i> aff. <i>bresadolae</i> Masseur		(21)	EP	
<i>Inocybe brunnea</i> Quéf.		(13)	EP	
<i>Inocybe calamistrata</i> (Fr.) Gillet		(21)	EP	
<i>Inocybe castanea</i> Peck		(21)	EP	
<i>Inocybe catalaunica</i> Singer		(21)	EP	
<i>Inocybe</i> cf. <i>chrondroderma</i> Stuntz nom. prov.		(21)	EP	IF-
<i>Inocybe cincinnata</i> (Fr.) Quéf.		(21)	EP	
<i>I. cincinnata</i> var. <i>major</i> (S. Petersen) Kuyper		(21)	EP	

Table 1 (continued)

Species	References ponderosa pine	References Douglas-fir	Habit	Comments
<i>Inocybe cinnamomea</i> A.H. Sm.		(21)	EP	
<i>Inocybe</i> cf. <i>curvipes</i> P. Karst.		(21)	EP	
<i>Inocybe</i> cf. <i>earleana</i> Kauffman		(21)	EP	
<i>Inocybe</i> cf. <i>eutheloides</i> Peck		(21)	EP	
<i>Inocybe fastigiata</i> (Schaeff.) Quél.	(6)		EP	
<i>Inocybe flavidolilacina</i> (Britzelm.) Lapl.		(21)	EP	
<i>Inocybe</i> aff. <i>flocculosa</i> (Berk.) sacc.		(21)	EP	
<i>I.</i> aff. <i>flocculosa</i> var. <i>crocifolia</i> (Herink) Kuyper		(21)	EP	
<i>Inocybe</i> cf. <i>furfurea</i> Kühner		(21)	EP	
<i>Inocybe</i> cf. <i>fuscidula</i> Velen.		(21)	EP	
<i>Inocybe fuscodisca</i> (Peck) Massee		(21)	EP	
<i>Inocybe geophylla</i> (Pers.) P. Kumm.		(13) (20#) (21)	EP	3 spp.
<i>I. geophylla</i> var. <i>lilacina</i> Gillet	(6)		EP	
<i>Inocybe glabrodisca</i> P.D. Orton		(21)	EP	
<i>Inocybe grammata</i> Quél. & Le Bret.		(21)	EP	
<i>Inocybe griseolilacina</i> J.E. Lange		(21)	EP	
<i>Inocybe griseoscabrosa</i> (Peck) Earle		(21)	EP	
<i>Inocybe hirsuta</i> var. <i>maxima</i> A.H. Sm.		(21)	EP	
<i>Inocybe hotsoniana</i> D.E. Stuntz		(21)	EP	
<i>Inocybe</i> aff. <i>inodora</i> Velen.		(21)	EP	
<i>Inocybe kauffmanii</i> A.H. Sm.		(21)	EP	
<i>Inocybe lacera</i> (Fr.) P. Kumm.	(1)	(21)	EP	
<i>Inocybe laetior</i> D.E. Stuntz		(21)	EP	
<i>Inocybe lanatodisca</i> Kauffman		(21)	EP	
<i>Inocybe langei</i> R. Heim and /or <i>hirtella</i> Bres.		(21)	EP	
<i>Inocybe</i> cf. <i>lanuginosa</i> (Bull.) P. Kumm.		(20#) (21)	EP	#7 spp.
<i>Inocybe</i> cf. <i>leptocystis</i> G.F. Atk.		(21)	EP	
<i>Inocybe leptophylla</i> G.F. Atk.		(21)	EP	
<i>Inocybe lilacina</i> (Peck) Kauffman		(13) (21)	EP	
<i>Inocybe maculata</i> Boud. complex		(20)	EP	1 sp.
<i>Inocybe</i> cf. <i>margaritispota</i> (Berk.) Sacc.		(21)	EP	
<i>Inocybe mixtilis</i> (Britzelm.) Sacc. complex		(13) (20#) (21)	EP	#3 spp.
<i>Inocybe nappies</i> J.E. Lange		(21)	EP	
<i>Inocybe nitidiuscula</i> (Britzelm.) Lapl.		(21)	EP	
<i>Inocybe obscura</i> (Pers.) Gillet		(13)	EP	
<i>Inocybe obscurobadia</i> (J. Favre) Grund. & D.E. Stuntz sensu Kuyper		(21)	EP	
<i>Inocybe olympiana</i> A.H. Sm.		(21)	EP	
<i>Inocybe praetervisa</i> Quél.		(13) (21)	EP	
<i>Inocybe pruinosa</i> R. Heim.		(21)	EP	
<i>Inocybe pudica</i> Kühner complex		(13) (20#)	EP	#33 spp.
<i>Inocybe pusio</i> P. Karst.		(21)	EP	
<i>Inocybe pyriodora</i> (Pers.) P. Kumm. complex		(20)	EP	1 sp.
<i>Inocybe</i> cf. <i>queletii</i> Konrad		(21)	EP	
<i>Inocybe</i> cf. <i>retipes</i> G.F. Atk.		(21)	EP	
<i>Inocybe rimosa</i> (Bull.) P. Kumm.		(21)	EP	
<i>Inocybe sindonia</i> (Fr.) P. Karst.		(21)	EP	
<i>Inocybe sororia</i> Kauffman complex		(20#) (21)	EP	#44 spp.
<i>Inocybe</i> cf. <i>splendens</i> R. Heim		(21)	EP	
<i>Inocybe</i> cf. <i>squarrosa</i> Rea		(21)	EP	
<i>Inocybe</i> sp.		(21)	EP	several spp.
<i>Inocybe suaveolens</i> D.E. Stuntz complex		(20#) (21)	EP	#1 sp.
<i>Inocybe subbrunnea</i> Kühner		(13)	EP	
<i>Inocybe subcarpta</i> Kühner & Boursier		(21)	EP	
<i>Inocybe substricta</i> Kauffman		(13) (21)	EP	

Table 1 (continued)

Species	References ponderosa pine	References Douglas-fir	Habit	Comments
<i>Inocybe</i> cf. <i>subochracea</i> (Peck) Earle		(21)	EP	
<i>Inocybe umboninota</i> Peck sensu Peck		(21)	EP	
<i>Inocybe xanthomelas</i> Boursier & Kühner		(21)	EP	
<i>Laccaria amethysteo-occidentalis</i> G. M. Muell.	(1) (9)	(20) (21)	EP	
<i>Laccaria bicolor</i> (Maire) P.D. Orton		(20) (21)	EP	
<i>Laccaria laccata</i> (Scop.) Fr.	(2) (6)	(11) (20)	EP	
<i>L. laccata</i> var. <i>pallidifolia</i> (Peck) Peck		(21)	EP	
<i>Lactarius alnicola</i> A.H. Sm.	(10)	(20)	EP	
<i>Lactarius aurantiacus</i> (Pers.) Gray		(11)	EP	
<i>Lactarius</i> cf. <i>alpinus</i> Peck		(21)	EP	
<i>Lactarius barrowsii</i> Hesler & A.H. Sm.	(6)		EP	
<i>Lactarius chelidonium</i> Peck	(6)		EP	
<i>Lactarius deliciosus</i> (L.) Gray	(1) (6) (10)	(11) (20) (21)	EP	
<i>Lactarius fallax</i> A.H. Sm. & Hesler		(20)	EP	
<i>L. fallax</i> var. <i>concolor</i> A.H. Sm. & Hesler		(21)	EP	
<i>Lactarius indigo</i> (Schwein.) Fr.	(6)		EP	
<i>Lactarius kauffmanii</i> Hesler & A.H. Sm.		(21)	EP	
<i>Lactarius luculentus</i> Burl.	(9)		EP	
<i>Lactarius pallescens</i> Hesler & A.H. Sm.		(20)	EP	
<i>Lactarius pseudodeceptivus</i> Hesler & A.H. Sm.		(20)	EP	
<i>Lactarius pseudomucidus</i> Hesler & A.H. Sm.		(20) (21)	EP	
<i>Lactarius rubidus</i> (Hesler & A.H. Sm.) Methven		(21)	EP	IF-
<i>Lactarius rubrilacteus</i> Hesler & A.H. Sm.	(1) (6)	(13) (20) (21)	EP	
<i>Lactarius rufus</i> (Scop.) Fr.		(11)	EP	
<i>Lactarius sanguifluus</i> (Paulet) Fr.		(11)	EP	
<i>Lactarius scrobiculatus</i> (Scop.) Fr.		(20)	EP	
<i>Lactarius subflammeus</i> Hesler & A.H. Sm.		(20) (21)	EP	
<i>Lactarius subviscidus</i> Hesler & A.H. Sm.	(1 ^a)		EP	
<i>Lactarius uvidus</i> (Fr.) Fr.	(10)		EP	
<i>Lactarius vinaceorufescens</i> A.H. Sm.		(20)	EP	
<i>Leucangium carthusianum</i> (Tul.) Paol.		(19)	HY	Sin. of <i>Picoa</i>
<i>Leucogaster candidus</i> (Harkn.) Fogel		(19)	HY	
<i>Leucogaster citrinus</i> (Harkn.) Zeller & C.W. Dodge		(19)	HY	
<i>Leucogaster gelatinosus</i> Fogel nom. Ined.		(19)	HY	IF-
<i>Leucogaster rubescens</i> Zeller & Dodge	(1) (5)	(15) (16) (18) (19) (20)	HY	
<i>Leucopaxillus amarus</i> (Alb. & Schwein.) Kühner	(1 ^a)		EP	
<i>Leucophleps magnata</i> Harkn.		(16) (19) (20)	HY	
<i>Leucophleps spinispora</i> Foguel	(1 ^a)	(16) (18) (19)	HY	
<i>Limacella glioderma</i> (Fr.) Maire		(21)	EP	
<i>Lycoperdon gemmatum</i> Batsch		(11)	EP	EM/S
<i>Macowanites</i> sp.	(1)		HY	
<i>Melanogaster ambiguus</i> (Vittad.) Tul. & C. Tul.		(12) (19)	HY	
<i>Melanogaster californicus</i> Wang, Castellano & Trappe	(1 ^a)		HY	IF-
<i>Melanogaster euryspermum</i> (Zeller & C.W. Dodge) Zeller	(1) (5) (8)	(19)	HY	IF-
<i>Melanogaster natsii</i> Wang, Trappe & Castellano nom. Ined.		(19)	HY	IF-
<i>Melanogaster thiersii</i> Wang, Trappe & Castellano nom. Ined.		(19)	HY	IF-
<i>Melanogaster trappei</i> I.P.S. Thind & B.M. Sharma	(1 ^a)	(19)	HY	
<i>Melanogaster tuberiformis</i> Corda	(1) (5) (8)	(18) (19) (20)	HY	
<i>Melanogaster variegatus</i> (Vittad.) Tul. & C. Tul.	(1)	(18) (19)	HY	
<i>Mycolevis siccigleba</i> A.H. Sm.	(1 ^a)		HY	
<i>Octaviania</i> sp.	(1)		HY	
<i>Pachyphloeus thysellii</i> W. Colgan & Trappe		(19)	HY	
<i>Paxillus involutus</i> (Batsch) Fr.	(1)	(11) (20)	EP	
<i>Phaeocollybia ammiratii</i> Norvell		(21)	EP	IF-, EM?
<i>Phaeocollybia attenuata</i> (A.H. Sm.) Singer		(21)	EP	

Table 1 (continued)

Species	References ponderosa pine	References Douglas-fir	Habit	Comments
<i>Phaeocollybia benzokauffmanii</i> Norvell		(21)	EP	
<i>Phaeocollybia dissiliens</i> A.H. Sm. & Trappe		(21)	EP	
<i>Phaeocollybia fallax</i> A.H. Sm.		(21)	EP	
<i>Phaeocollybia gregaria</i> A.H. Sm. & Trappe		(21)	EP	
<i>Phaeocollybia kauffmanii</i> (A.H. Sm.) Singer		(21)	EP	
<i>Phaeocollybia</i> aff. <i>luteosquamulosa</i> Norvell		(21)	EP	
<i>Phaeocollybia olivacea</i> A.H. Sm.		(21)	EP	
<i>Phaeocollybia piceae</i> A.H. Sm. & Trappe		(21)	EP	
<i>Phaeocollybia pleurocystidiata</i> Norvell & Redhead		(21)	EP	
<i>Phaeocollybia riffliipes</i> Norvell		(21)	EP	
<i>Phaeocollybia sipei</i> A.H. Sm.		(21)	EP	
<i>Phaeocollybia</i> sp.		(20)	EP	
<i>Phaeocollybia spadicea</i> A.H. Sm.		(21)	EP	
<i>Phaeocollybia tibiikauffmanii</i> Norvell		(21)	EP	
<i>Phellodon tomentosus</i> (L.) Banker		(21)	EP	
<i>Phylloporus rhodoxanthus</i> (Schwein.) Bres.	(1)	(20) (21)	EP	
<i>Pisolithus tinctorius</i> (Pers.) Coker & Couch	(1)	(11)	EP	
<i>Pyrenogaster atrogleba</i> (Zeller) L.S. Dominguez & Castellano	(1 ^a)	(20)	HY	
<i>Pyrenogaster pityophilus</i> Malençon & Rioussset	(1)		HY	
<i>Radiigera fuscogleba</i> Zeller		(19) (20)	HY	
<i>Radiigera taylorii</i> (Lloyd) Zeller	(1 ^a)	(20)	HY	
<i>Ramaria acrisiccescens</i> Marr & D.E. Stuntz		(20) (21)	EP	
<i>Ramaria araiospora</i> Marr & D.E. Stuntz		(21)	EP	
<i>Ramaria aurantiisiccescens</i> Marr & D.E. Stuntz		(21)	EP	
<i>Ramaria celerivirescens</i> Marr & D.E. Stuntz		(20) (21)	EP	
<i>Ramaria cystidiophora</i> var. <i>fabiolens</i> Marr & D.E. Stuntz		(20)	EP	
<i>Ramaria fenica</i> (P. Karst.) Ricken		(20)	EP	
<i>Ramaria flavigelatinosa</i> var. <i>aromatica</i> Marr & D.E. Stuntz		(21)	EP	IF-
<i>Ramaria flavigelatinosa</i> var. <i>carnisalmonea</i> Marr & D.E. Stuntz		(21)	EP	
<i>Ramaria formosa</i> (Pers.) Quél.		(20) (21)	EP	
<i>Ramaria</i> cf. <i>fumosiavellanea</i> Marr & D.E. Stuntz		(21)	EP	
<i>Ramaria gelatiniaurantia</i> Marr & D.E. Stuntz		(21)	EP	
<i>Ramaria gelatinosa</i> var. <i>oregonensis</i> Marr & D.E. Stuntz		(21)	EP	
<i>Ramaria leptiformosa</i> Marr. & D.E. Stuntz		(21)	EP	
<i>Ramaria longispora</i> Marr & D.E. Stuntz		(21)	EP	
<i>Ramaria myceliosa</i> (Peck) Corner	(1)		EP	
<i>Ramaria rubricarnata</i> Marr & D.E. Stuntz		(21)	EP	
<i>Ramaria sandaracina</i> var. <i>euosma</i> Marr & D.E. Stuntz		(21)	EP	
<i>Ramaria sandaracina</i> var. <i>sandaracina</i> Marr & D.E. Stuntz		(20)	EP	
<i>Ramaria</i> sp.		(17) (21)	EP	
<i>Ramaria stuntzii</i> Marr		(20) (21)	EP	
<i>Ramaria subbotrytis</i> (Coker) Corner		(20)	EP	
<i>Rhizopogon abietis</i> A.H. Sm.	(1)		HY	
<i>Rhizopogon</i> cf. <i>arctostaphyli</i> A.H. Sm.	(1 ^a)		HY	
<i>Rhizopogon ater</i> Trappe & Grubisha		(11)	HY	
<i>Rhizopogon atroviolaceus</i> A.H. Sm.	(1)		HY	
<i>Rhizopogon brunnescens</i> Zeller	(1 ^a)		HY	
<i>Rhizopogon cinerascens</i> A.H. Sm.	(1 ^a)		HY	
<i>Rhizopogon clavitisporus</i> A.H. Sm.	(1 ^a)		HY	
<i>Rhizopogon cusickiensis</i> A.H. Sm.	(1 ^a)		HY	
<i>Rhizopogon ellenae</i> A.H. Sm.	(1)		HY	
<i>Rhizopogon ellipsosporus</i> Trappe, Castellano & Amar.	(1 ^a)		HY	
<i>Rhizopogon evadens</i> A.H. Sm.	(1) (4) (5) (6) (8)		HY	

Table 1 (continued)

Species	References ponderosa pine	References Douglas-fir	Habit	Comments
<i>Rhizopogon</i> cf. <i>exiguus</i> Zeller		(20)	HY	
<i>Rhizopogon flavofibrillosus</i> A.H. Sm.	(1 ^a)		HY	
<i>Rhizopogon fuscorubens</i> A.H. Sm.	(1)		HY	
<i>Rhizopogon gilkeyae</i> A.H. Sm.		(20)	HY	
<i>Rhizopogon hawkeriae</i> A.H. Sm.		(18) (19) (20)	HY	
<i>Rhizopogon idahoensis</i> A.H. Sm.	(1 ^a)		HY	
<i>Rhizopogon luteolus</i> Fr.	(1 ^a)		HY	
<i>Rhizopogon occidentalis</i> Zeller & C.W. Dodge	(1)		HY	
<i>Rhizopogon ochraceorubens</i> A.H. Sm.	(1) (4) (5) (6) (8)		HY	
<i>Rhizopogon parksii</i> A.H. Sm.		(12) (14) (15) (16) (18) (20)	HY	
<i>Rhizopogon pedicellus</i> A.H. Sm.	(1 ^a)		HY	
<i>Rhizopogon rogersii</i> A.H. Sm.	(1 ^a)	(19)	HY	
<i>Rhizopogon rubescens</i> (Tul. & C. Tul.) Tul. & C. Tul.	(1)	(11)	HY	
<i>Rhizopogon</i> cf. <i>rudus</i> A.H. Sm	(1 ^a)		HY	
<i>Rhizopogon salebrosus</i> A.H. Sm.	(1 ^a)		HY	
<i>Rhizopogon semireticulatus</i> A.H. Sm.	(1)		HY	
<i>Rhizopogon smithii</i> Hosford	(1)		HY	
<i>Rhizopogon</i> sp. nov.		(20)	HY	
<i>Rhizopogon subareolatus</i> A.H. Sm.		(19)	HY	
<i>Rhizopogon subcaerulescens</i> A.H. Sm.	(1) (4) (5) (6) (8) (9)	(16) (18) (20)	HY	
<i>Rhizopogon subclavitisporus</i> A.H. Sm.		(20)	HY	
<i>Rhizopogon subgelatinosus</i> A.H. Sm.	(1)		HY	
<i>Rhizopogon sublateritius</i> A.H. Sm.	(1)		HY	
<i>Rhizopogon subradicatus</i> A.H. Sm.	(1)		HY	
<i>Rhizopogon subsalmonius</i> A.H. Sm.	(1)		HY	
<i>Rhizopogon tephrogleba</i> K.A. Harrison & A.H. Sm.	(1)		HY	
<i>Rhizopogon truncatus</i> Linder	(1)		HY	
<i>Rhizopogon variabilisporus</i> A.H. Sm.	(1 ^a)		HY	
<i>Rhizopogon versisporus</i> Hosford nom. rev	(1 ^a)		HY	IF-
<i>Rhizopogon villescens</i> A.H. Sm.		(20)	HY	
<i>Rhizopogon villosulus</i> Zeller		(12) (14) (19) (20)	HY	
<i>Rhizopogon vinicolor</i> A.H. Sm.		(12) (14) (16) (18) (19) (20)	HY	
<i>Rhizopogon vulgaris</i> (Vittad.) M. Lange		(19)	HY	
<i>Russula abietina</i> Peck		(21)	EP	confused concept
<i>Russula</i> aff. <i>adulterina</i> Secr.		(21)	EP	
<i>Russula aeruginea</i> Fr.		(20) (21)	EP	
<i>Russula albidula</i> Peck		(20) (21)	EP	
<i>Russula albonigra</i> (Krombh.) Fr.		(17) (20)	EP	
<i>Russula alcalinicola</i> Burl.		(21)	EP	
<i>Russula alutacea</i> (Fr.) Fr.	(6) (10)	(20) (21)	EP	
<i>Russula amoenolens</i> Romagn.		(20)	EP	
<i>Russula atroviolacea</i> Burl.		(21)	EP	
<i>Russula aurantiolutea</i> Kauffman		(21)	EP	
<i>Russula</i> cf. <i>azurea</i> Bres.		(21)	EP	
<i>Russula bicolor</i> Burl.		(21)	EP	
<i>Russula brevipes</i> Peck	(6) (10)	(17) (20) (21)	EP	
<i>Russula brunneoviolacea</i> Crawshay		(21)	EP	
<i>Russula cascadenis</i> Shaffer		(20)	EP	
<i>Russula cerolens</i> Z. Schaef. complex		(20)	EP	
<i>Russula</i> cf. <i>caerulea</i> (Pers.) Fr.		(21)	EP	and/or <i>R. lilacea</i> Quéf.
<i>Russula cessans</i> gr. A. Pearson		(20) (21)	EP	

Table 1 (continued)

Species	References ponderosa pine	References Douglas-fir	Habit	Comments
<i>Russula claroflava</i> Grove	(10)	(21)	EP	
<i>Russula consobrina</i> (Fr.) Fr.		(21)	EP	
<i>Russula cremoricolor</i> Earle		(20) (21)	EP	
<i>Russula crenulata</i> Burl.		(20)	EP	
<i>Russula cristata</i> Romagn.		(21)	EP	
<i>Russula</i> cf. <i>cyanoxantha</i> (Schaeff.) Fr.		(20)	EP	
<i>Russula decipiens</i> (Singer) Kühner & Romagn.		(21)	EP	
<i>Russula decolorans</i> (Fr.) Fr.		(20) (21)	EP	
<i>Russula delica</i> Fr.	(2)	(11)	EP	
<i>Russula densifolia</i> Secr. ex Gillet	(10)	(20)	EP	
<i>Russula dissimulans</i> Shaffer		(20) (21)	EP	
<i>Russula ellenae</i> Thiers		(20)	EP	
<i>Russula emetica</i> (Schaeff.) Pers.	(10)	(11)	EP	
<i>Russula flaviceps</i> Peck		(21)	EP	
<i>Russula foetens</i> (Pers.) Pers.		(11)	EP	
<i>Russula fragrantissima</i> Romagn.		(17) (20)	EP	IF-
<i>Russula fragilis</i> (Pers.) Fr.		(20) (21)	EP	
<i>Russula gracilis</i> Burl.		(20)	EP	
<i>Russula graveolens</i> Romell.		(21)	EP	
<i>Russula grisea</i> (Batch.) Fr.		(21)	EP	
<i>Russula integra</i> gr. (L.) Fr.		(20)	EP	
<i>Russula laurocerasi</i> Melzer		(20) (21)	EP	
<i>Russula maculata</i> Quél. & Roze	(6)	(21)	EP	
<i>Russula murrillii</i> Burl.	(9)	(11) (21)	EP	
<i>Russula nigricans</i> (Bull.) Fr.		(11)	EP	
<i>Russula olivacea</i> (Schaeff.) Fr.		(21)	EP	
<i>Russula</i> cf. <i>parazurea</i> Jul. Schäff.		(21)	EP	
<i>Russula pectinata</i> (Bull.) Fr.		(21)	EP	
<i>Russula pectinatoides</i> Peck		(20)	EP	
<i>Russula</i> cf. <i>pelargonica</i> Niolle		(21)	EP	
<i>Russula placita</i> Burl.		(11) (20) (21)	EP	
<i>Russula puellaris</i> Fr.		(21)	EP	
<i>Russula raoultii</i> Quél.		(21)	EP	
<i>Russula</i> aff. <i>rhodopoda</i> Zvára		(21)	EP	
<i>Russula risigallina</i> f. <i>chamaeleontina</i> (Lasch) Bon		(21)	EP	
<i>Russula rosacea</i> (Pers.) Gray	(6) (10)		EP	
<i>Russula rosea</i> Pers.		(21)	EP	
<i>Russula sanguinea</i> (Bull.) Fr.	(1 ^a)	(20) (21)	EP	
<i>Russula semirubra</i> Singer		(21)	EP	IF-
<i>Russula sororia</i> Fr.	(1 ^a)		EP	
<i>Russula</i> sp.		(13) (21)	EP	
<i>Russula</i> sp. nov. B		(20)	EP	
<i>Russula sphagnophila</i> Kauffman		(21)	EP	
<i>Russula</i> cf. <i>stuntzii</i> Grund		(21)	EP	
<i>Russula subnigricans</i> Hongo	(10)		EP	
<i>Russula turci</i> Bres.		(21)	EP	
<i>Russula</i> cf. <i>versicolor</i> Jul. Schäff.		(21)	EP	
<i>Russula vesca</i> Fr.		(21)	EP	
<i>Russula veteriosa</i> Fr.		(21)	EP	
<i>Russula vinosobrunnea</i> (Bres.) Romagn.		(21)	EP	
<i>Russula viscida</i> Kudrna		(21)	EP	
<i>Russula xeramphelina</i> (Schaeff.) Fr.	(10)	(11) (21)	EP	
<i>Sarcosphaera coronaria</i> (Jacq.) J. Schröt.	(1 ^a)		EP	
<i>Sarcosphaera eximia</i> (Durieu & Lév.) Maire	(1 ^a)		EP	
<i>Scleroderma bovista</i> Fr	(1 ^a)	(11)	Sub-HY	

Table 1 (continued)

Species	References ponderosa pine	References Douglas-fir	Habit	Comments
<i>Scleroderma fuscum</i> (Corda) E. Fisch.	(1)	(20)	Sub-HY	
<i>Scleroderma hypogaeum</i> Zeller	(1)		Sub-HY	
<i>Sclerogaster columellatus</i> (Zeller) Fogel	(1 ^a)		HY	
<i>Sclerogaster pacificus</i> Zeller & C.W. Dodge	(1 ^a)		HY	
<i>Sclerogaster xerophilus</i> Fogel	(1) (4) (5) (6) (8)		HY	
<i>Sedecula pulvinata</i> Zeller	(1) (5)		Sub-HY	
<i>Suillus abidipes</i> (Peck) Singer	(1)		EP	
<i>Suillus borealis</i> A.H. Sm., Thiers & O.K. Mill.	(1)		EP	
<i>Suillus brevipes</i> (Peck) Kuntze	(1 ^a) (10)		EP	
<i>Suillus caeruleus</i> A.H. Sm. & Thiers		(21)	EP	
<i>Suillus glandulosipes</i> Thiers & A.H. Sm.	(1)		EP	
<i>Suillus granulatus</i> (L.) Rousell	(1) (2) (6) (10)	(11)	EP	
<i>Suillus kaibabensis</i> Thiers	(6)		EP	
<i>Suillus lakei</i> (Murrill) A.H. Sm. & Thiers		(11) (13) (20) (21)	EP	
• <i>Suillus luteus</i> (L.) Rousell	(1) (2)	(11)	EP	
<i>Suillus piperatus</i> (Bull.) Kuntze		(11)	EP	
<i>Suillus ponderosus</i> A.H. Sm. & Thiers		(20)	EP	
<i>Suillus pseudobrevipes</i> A.H. Sm. & Thiers	(1) (10)		EP	
<i>Suillus tomentosus</i> (Kauffman) Singer	(1) (2)		EP	
<i>Suillus volcanolis</i> Thiers	(1)		EP	
<i>Thelephora americana</i> Lloyd	(1)		C	on seedlings
<i>Thelephora</i> cf. <i>palmata</i> (Scop.) Fr.		(21)	C	
<i>Thelephora terrestris</i> Ehrn. complex		(20) (21)	C	
<i>Tomentella sublacina</i> (Ellis & Holw.) Wakef.	(9)		C	
<i>Trappea darkeri</i> (Zeller) Castellano	(1 ^a) (8)		HY	
<i>Trappea phillipsii</i> (Harkness) Castellano	(1 ^a)		HY	
<i>Tricholoma</i> cf. <i>aestuans</i> (Fr.) Gillet		(20)	EP	
<i>Tricholoma atroviolaceum</i> A.H. Sm.		(21)	EP	
<i>Tricholoma</i> cf. <i>aurantium</i> (Schaeff.) Ricken		(21)	EP	
<i>Tricholoma flavovirens</i> (Pers.) S. Lundell	(1)	(20)	EP	
<i>Tricholoma inamoenum</i> (Fr.) Gillet		(21)	EP	
<i>Tricholoma</i> cf. <i>myomyces</i> (Pers.) J.E. Lange		(21)	EP	
<i>Tricholoma orirubens</i> Quél.		(21)	EP	
<i>Tricholoma pardinum</i> Quél.	(1)	(20) (21)	EP	
<i>Tricholoma portentosum</i> (Fr.) Quél.		(21)	EP	
<i>Tricholoma saponaceum</i> (Fr.) P. Kumm.		(20) (21)	EP	
<i>Tricholoma sejunctum</i> (Sowerby) Quél.		(21)	EP	
<i>Tricholoma</i> sp.		(21)	EP	
<i>Tricholoma sulphureum</i> (Bull.) P. Kumm.		(20) (21)	EP	
<i>Tricholoma terreum</i> gr. (Schaeff.) Quél.		(20) (21)	EP	
<i>Tricholoma virgatum</i> gr. (Fr.) P. Kumm.		(20) (21)	EP	
<i>Tricholoma zelleri</i> (D.E. Stuntz & A.H. Sm.) Ovrebo & Tylutki	(6)		EP	
<i>Truncocolumella citrina</i> Zeller		(11) (12) (14) (16) (18) (19) (20)	HY	
<i>Tuber anniae</i> W. Colgan & Trappe		(19)	HY	
<i>Tuber asa</i> Lesp.	(1)		HY	
<i>Tuber californicum</i> Harkn.	(1)	(20)	HY	
<i>Tuber gibbosum</i> Harkn.		(12) (14) (19) (20)	HY	
<i>Tuber levissimum</i> Gilkey	(8)	(14)	HY	
<i>Tuber monticola</i> Harkn.		(19) (20)	HY	
<i>Tuber murinum</i> R. Hesse		(12) (14)	HY	
<i>Tuber rufum</i> Picco	(1)	(12) (14)	HY	
<i>Tuber shearii</i> Harkn.		(20)	HY	
<i>Tuber</i> sp.	(2)	(18)	HY	

Table 1 (continued)

Species	References ponderosa pine	References Douglas-fir	Habit	Comments
<i>Tuber</i> sp. nov.		(20)	HY	
<i>Tuber sphaerosporum</i> Gilkey	(1 ^a)	(20)	HY	
<i>Zelleromyces gilkeyae</i> Singer & A.H. Sm.		(12) (20)	HY	
<i>Zelleromyces</i> sp. nov. in herb.	(1 ^a)		HY	

EP Epigeous habit; HY hypogeous habit; Sub-HY subhypogeous habit; C corticioid habit; IF– not included in the data base “Index Fungorum” from CABI Bioscience and CBS, available in the Internet (<http://www.indexfungorum.org/Index.htm>); EM ectomycorrhizae; EM? genus not registered as EM; EM/S genus mainly saprophytic with some EM species. References: (1) Herbarium data base, Department of Forest Science, Oregon State University, Corvallis, Oregon, USA (OSC); (2) Trappe 1962; (3) Gilbertson 1974; (4) States 1984a; (5) States 1984b; (6) States, personal communication; (7) Melichar et al. 1985; (8) States and Gaud 1997; (9) Stendell et al. 1999; (10) Mathiasen and Albion 2001; (11) Trappe 1962; (12) Fogel 1976; (13) Ammirati et al. 1987; (14) Hunt and Trappe 1987; (15) Luoma 1991; (16) Luoma et al. 1991; (17) O’Dell et al. 1992; (18) Amaranthus et al. 1994; (19) Colgan et al. 1999; (20) Smith et al. 2002; (21) Norvell and Exeter 2004

^a Species found only in mixed forests

consideration (Table 2), it can be observed that EP species richness is clearly dominant in Douglas-fir (84% EP–15% HY), whereas a better balance between EP and HY EM fungal species is observed for ponderosa pine (52% EP–43.5% HY for dominant ponderosa pine).

Eighteen taxa have been reported for introduced ponderosa pine and 15 for Douglas-fir in Patagonia, Argentina, as listed in Table 3 (Barroetaveña et al. 2005, 2006). For Douglas-fir plantations around the world, 65 taxa have been detected at the species level (Table 3), including records from Argentina (Barroetaveña et al. 2006), New Zealand (Chu Chou and Grace 1981, 1983), Chile (Garrido 1986), Spain (Parladé et al. 1996a,b), and The Netherlands (Jansen 1991). The same trend of a higher proportion of EP species in Douglas-fir was found (71% EP–20% HY), and again a better balance between EP and HY species was found for ponderosa pine (44% EP–28% HY).

Comparison of species richness

When EM fungal taxa between native ponderosa pine and Douglas-fir are compared, it is found that 52 genera are recorded for the former and 58 for the latter. From these records, the six larger genera for Douglas-fir accounted for 75% of the registered species (*Cortinarius*, 168 spp.; *Inocybe*, 105 spp.; *Russula*, 66 spp.; *Ramaria*, 17 spp.; *Lactarius*, 16

spp.; and *Phaeocollybia*, 15 spp.). In ponderosa pine, they accounted for 44.6% of the registered species (*Rhizopogon*, 20 spp.; *Amanita*, 11 spp.; *Russula*, 11 spp.; *Cortinarius*, 10 spp.; *Suillus*, 10 spp.; and *Lactarius*, 8 spp.). There are 39 common genera for both tree hosts, with different numbers of shared species (5 out of 173 spp. of *Cortinarius*, 1 out of 107 spp. of *Inocybe*, 9 out of 68 spp. of *Russula*, 3 out of 21 spp. of *Lactarius*, 2 out of 32 spp. of *Rhizopogon*, 2 out of 14 spp. of *Suillus*, 5 out of 17 spp. of *Amanita*, and none of *Ramaria*, *Chroogomphus*, *Gomphidius*, nor *Hydnotrya*). There are, on the other hand, 13 genera registered only for ponderosa pine (*Amphinema*, *Brauniellula*, *Camarophyllus*, *Choiromyces*, *Dentinum*, *Destuntzia*, *Helvella*, *Macowanites*, *Octaviania*, *Sclerogaster*, *Sedecula*, *Tomentella*, and *Trappea*) and 18 genera registered only for Douglas-fir (*Alpova*, *Boletellus*, *Boletinus*, *Cortinomyces*, *Craterellus*, *Gomphus*, *Hydnoplicata*, *Hydnum*, *Hygrocybe*, *Leucangium*, *Limacella*, *Lycoperdon*, *Pachyphloeus*, *Phaeocollybia*, *Phellodon*, *Radiigera*, *Thelephora*, and *Truncocolumella*).

Significantly fewer taxa were found in plantations of introduced ponderosa pine in Patagonia (18 taxa, Table 3) than reported for native forests (ratio of introduced to native 1:8.7), and only five species (i.e., *Rhizopogon ellenae*, *R. roseolus*, *Amphinema byssoides*, *Scleroderma fuscum*, and *Suillus luteus*), representing 28% from the total, have been recorded from native ponderosa pine forests. A more pronounced,

Table 2 Number and percentage of EM fungal species from native forests ordered by their habit, and by host tree species

Habit	Pure Pp		Pure + mixed Pp		Douglas-fir	
	N	Percent	N	Percent	N	Percent
Epigeous	81	52	91	44.5	434	84
Hypogeous	68	43.5	105	51.5	75	15
Corticioid	2	1.5	2	1	2	0.5
Subhypogeous	5	3	6	3	2	0.5

Excluding records at infraspecies level and generic determination of genus already reported.

Pp Ponderosa pine; N number of taxa

Table 3 Ectomycorrhizal fungal species detected from sporocarps in ponderosa pine and Douglas-fir plantations from Patagonia (Argentina) and around the world

Species	Reference ponderosa pine (PP)	Reference Douglas-fir (DF)	Habit	Comments
<i>Amanita fulva</i> (Schaeff.) Fr.		(4)	EP	DF: R–
<i>Amanita gemmata</i> (Fr.) Bertill.		(3) (4)	EP	DF: R+
<i>Amanita muscaria</i> (L.) Lam.		(1) (4)	EP	DF: R+
<i>Amanita rubescens</i> Pers.		(4)	EP	DF: R– (R+ for ponderosa pine)
<i>Amanita rubescens</i> var. <i>annulosulfurea</i> Gillet		(4)	EP	DF: R–
<i>Amanita</i> sp.	(8)		EP	PP: (genus R+)
<i>Amphinema byssoides</i>(Pers.) J. Erikss.	(8)	(7)	C	PP: R+; DF: R–
<i>Boletus badius</i> (Fr.) Fr.		(4)	EP	DF: R–; sub <i>Xerocomus badius</i> (Fr.) Kühner
<i>Boletus chrysenteron</i> Bull.		(4) (5)	EP	DF: R+; sub <i>Xerocomus chrysenteron</i> (Bull.) Quél.
<i>Boletus pulverulentus</i> Opat.		(5)	EP	DF: R+
<i>Boletus subtomentosus</i> L.		(4)	EP	DF: R+; sub <i>Xerocomus subtomentosus</i> (L.) Fr.
<i>Clitopilus</i> sp.		(1)	EP	DF: genus R–
<i>Cortinarius</i> subg. <i>Telamonia</i>			EP	
<i>C. scaurus</i> (Fr.) Fr.		(4)	EP	DF: R+
<i>Cortinarius</i> sp.	(8)		EP	PP: (subgenus R+)
<i>Cortinarius</i> subg. <i>Dermocybe</i>			EP	
<i>C. croceoconus</i> Fr.		(4)	EP	DF: R–; sub <i>Dermocybe croceoconus</i> (Fr.) M.M. Moser
<i>C. semisanguineus</i> (Fr.) Guillet		(4)	EP	DF: R+; sub <i>Dermocybe semisanguinea</i> (Fr.) M.M. Moser
<i>Endogone flammicorona</i> Trappe & Gerd.		(2)	HY	DF: R– (R+ for ponderosa pine)
<i>Endogone lactiflua</i> Berk.		(7)	HY	DF: R+
<i>Hebeloma crustuliniforme</i> (Bull.) Quél.		(1) (3)	EP	DF: R+
<i>Hebeloma hiemale</i> Bres.	(8)	(7)	EP	PP: R–; DF: R–
<i>Hebeloma mesophaeum</i>(Pers.) Fr.	(8)	(7)	EP	PP: R–; DF: R+
<i>Hymenogaster subalpinus</i>A.H. Sm.		(7)	HY	DF: R– (R+ for ponderosa pine)
<i>Hysterangium coriaceum</i>R. Hesse		(7)	HY	DF: R+
<i>Inocybe assimilata</i> Britzelm.		(4)	EP	DF: R+; sub <i>I. umbrina</i> Bres
<i>Inocybe kauffmanii</i> A.H. Sm.	(8)	(7)	EP	PP: R–; DF: R+
<i>Inocybe lacera</i> (Fr.) P. Kumm.		(4)	EP	DF: R+
<i>Inocybe lanuginosa</i> var. <i>lanuginosa</i> (Bull.) P. Kumm.		(4)	EP	DF: R–; sub <i>I. longicystis</i> G.F. Atk.
<i>I. lanuginosa</i> var. <i>ovatocystis</i> (Boursier & Kühner) Stangl.		(4)	EP	DF: R–; sub <i>I. ovatocystis</i> Kühner
<i>Inocybe mixtilioides</i> Krieglst.		(4)	EP	DF: R–; sub <i>I. mixtilioides</i> Kuyper
<i>Inocybe nappies</i> J.E. Lange		(4)	EP	DF: R+
<i>Inocybe</i> cf. <i>pseudoumbrina</i> Stangl.		(4)	EP	DF: R–
<i>Inocybe soluta</i> Velen		(4)	EP	DF: R–
<i>Inocybe</i> sp.		(3)	EP	DF: (genus R+)
<i>Inocybe subcarpta</i> Küner & Bousier		(4)	EP	DF: R+
<i>Laccaria amethystina</i> Cooke		(1)	EP	DF: R–
<i>Laccaria bicolor</i> (Maire) P.D. Orton		(4)	EP	DF: R+
<i>Laccaria laccata</i> (Scop.) Fr.		(1) (4)	EP	DF: R+
<i>Laccaria proxima</i> (Boud.) Pat.		(4)	EP	DF: R–
<i>Laccaria tortilis</i> (Bolton) Cooke	(8)	(7)	EP	PP: R–; DF: R–
<i>Lactarius chrysorrheus</i> Fr.		(4)	EP	DF: R–; sub <i>L. theiogalus</i> (Bull.) Fr
<i>Lactarius deliciosus</i> (L.) Gray		(3)	EP	DF: R+
<i>Lactarius helvius</i> (Fr.) Fr.		(4)	EP	DF: R–
<i>Lactarius hepaticus</i> Plowr.		(4)	EP	DF: R–
<i>Lactarius necator</i> (Bull.) Pers.		(4)	EP	DF: R–
<i>Lactarius rufus</i> (Scop.) Fr.		(4)	EP	DF: R+
<i>Lycoperdon gemmatum</i> Batsch.		(1)	EP	DF: R+. Genus mainly saprophytic
<i>Melanogaster ambiguus</i> (Vittad.) Tul. & C. Tul.		(5) (6)	HY	DF: R+
<i>Paxillus involutus</i> (Batsch) Fr.		(4)	EP	DF: R+

Table 3 (continued)

Species	Reference ponderosa pine (PP)	Reference Douglas-fir (DF)	Habit	Comments
Radiigera sp.	(8)		HY	PP: (genus R+)
Radiigera taylorii (Lloyd) Zeller		(7)	HY	DF: R+
Rhizopogon ellena e A.H. Sm.	(8)		HY	PP: R+
<i>Rhizopogon parksii</i> A.H. Sm.		(2)	HY	DF: R+
Rhizopogon roseolus (Corda) Th. Fr.	(8)		HY	PP: R+; sub <i>R. rubescens</i> ^a
<i>Rhizopogon subareolatus</i> A.H. Sm.		(5) (6)	HY	DF: R+
Rhizopogon subolivascens A.H. Sm.	(8)		HY	PP: R–
Rhizopogon villosulus Zeller		(7)	HY	DF: R+
<i>Rhizopogon vinicolor</i> A.H. Sm.		(1) (2)	HY	DF: R+
<i>Russula emetica</i> (Schaeff.) Pers.		(4)	EP	DF: R+
<i>Russula nitida</i> (Pers.) Fr.		(4)	EP	DF: R–
<i>Russula ochroleuca</i> (Pers.) Fr.		(4)	EP	DF: R–
<i>Russula parazurea</i> Jul. Schäff.		(4)	EP	DF: R+
<i>Russula</i> sp.		(1)	EP	DF: (genus R+)
Scleroderma areolatum Ehrenb.	(8)		Sub-HY	PP: R–
<i>Scleroderma bovista</i> Fr.		(1) (2)	Sub-HY	DF: R+
<i>Scleroderma citrinum</i> Pers.		(4)	Sub-HY	DF: R–
Scleroderma fuscum (Corda) E. Fisch.	(8)		Sub-HY	PP: R+
<i>Scleroderma verrucosum</i> (Bull.) Pers.		(1) (2)	Sub-HY	DF: R–
Suillus lakei (Murrill) A.H. Sm. & Thiers		(1) (7)	EP	DF: R+
Suillus luteus (L.) Roussel	(8)	(2)	EP	PP: R+; DF: R+
Thelephora terrestris Ehrh.	(8)	(4) (7)	C	PP: R–; DF: R+
Tomentella atramentaria Rostr.	(8)	(7)	C	PP: R–; DF: R–
Tricholoma muricatum Shanks	(8)		EP	PP: R–
<i>Tricholoma saponaceum</i> (Fr.) P. Kumm.		(5)	EP	DF: R+
<i>Tricholoma</i> sp.		(1)	EP	DF: (genus R+)
Tuber borchii Vittad.		(7)	HY	DF: R–
Tuber californium Harkn.		(7)	HY	DF: R+
<i>Tuber maculatum</i> Vittad.		(6)	HY	DF: R–
<i>Tuber</i> sp. 1		(2)	HY	DF: (genus R+)
Tuber sp. 2	(8)		HY	PP: (genus R+)

Records from Patagonia (Argentina) are highlighted in bold.

EP Epigeous habit; HY hypogeous habit; Sub-HY subhypogeous habit; C corticioid habit; R– species not reported from native forests; R+ species reported from native forests. References: (1) Chu Chou and Grace 1981; (2) Chu Chou and Grace 1983; (3) Garrido 1986; (4) Jansen 1991; (5) Parladé et al. 1996a; (6) Parladé et al. 1996b; (7) Barroetaveña et al. 2006; (8) Barroetaveña et al. 2005.

^a Following Martín 1996, *R. roseolus* includes *R. rubescens*.

similar trend was found for Douglas-fir, with only 15 species (Table 3) being reported for Patagonia (ratio of introduced to native 1:34.3); nine of them (i.e., *Endogone lactiflua*, *Hebeloma mesophaeum*, *Inocybe kauffmanii*, *Hysterangium coriaceum*, *Radiigera taylorii*, *Rhizopogon villosulus*, *Suillus lakei*, *Thelephora terrestris*, and *Tuber californicum*), representing 60% of the total, have been recorded from native Douglas-fir forests, whereas the genera *Amphinema* and *Tomentella* have not been recorded from native forests at all.

None of the EM species recorded for Douglas-fir in Patagonia match those reported from plantations in other parts of the world (Table 3), excepting *S. lakei* and *T. terrestris*, with no records of *Amphinema*, *Hymenogaster*, *Hysterangium*, *Radiigera*, and *Tomentella*.

Discussion

This review is based exclusively on sporocarp surveys recorded in the literature and data bases; thus, the lists of taxa obtained represent an underestimate of EM fungal species, as many species produce sporocarps only under certain conditions or they fruit occasionally, so the occurrence of their fruit bodies in a certain area may represent only a limited fraction of the EM community (Dahlberg 2001). Furthermore, tree ages were not taken in consideration in the analysis, as the aim of the review has been to provide an overall idea of EM species richness for each tree host.

A much higher number of EM fungal taxa has been found for native Douglas-fir forests compared to native

ponderosa pine (514 vs 157). Trappe (1977) estimated that more than 2,000 EM fungi could associate with Douglas-fir over its natural range. This could be correlated with (1) a larger geographical distribution of Douglas-fir as compared with ponderosa pine, associated with a wide variety of EM trees and different soils and/or (2) more humid conditions required for Douglas-fir (Hermann and Lavender 1990; Long 1995), this possibly supporting a higher fungal species richness. In this sense, we point out that the higher proportion of HY EM species in ponderosa pine (ratio EP to HY 1.2:1 for PP and 5.6:1 for DF) could be explained by the drier site conditions where this tree species grows, the HY habit guaranteeing a more stable and humid environment for fungal persistence (Moore-Landecker 1996).

A small group of genera was found to comprise a high proportion of the species richness for native Douglas-fir (i.e., *Cortinarius*, *Inocybe*, and *Russula*), whereas for native ponderosa pine, the species richness was found more evenly distributed among several genera, the latter being represented moderately (i.e., *Russula* with 11 spp. and *Cortinarius* with 10 spp.) to scantily (i.e., *Inocybe* with three spp.), the richest genus being *Rhizopogon* with 20 spp. A very different situation was found in Patagonia, with no records of *Inocybe* or *Russula* and only one record of *Cortinarius* for ponderosa pine, although *Rhizopogon*, a genus with a very high ecological amplitude, dominant in exotic *Pinus* plantations (Molina et al. 1999), was well represented.

Although 56% of the genera are common to both host trees in their natural range distribution; the coincidence is lower at the species level, with only 11% of shared species, showing that each host has a different associated mycobiota. The same low coincidence was found in Patagonia, with only 27% of shared species. This high specificity between EM species and these hosts should be an important consideration when planning inoculation programs.

When EM species richness of each tree species in natural forests is compared with that of Patagonian plantations, the much lower number of species found in the latter is outstanding. This could be explained in part by the fact that most forested lands in Patagonia, especially those assigned to ponderosa pine, are grasslands with AM associations that lack EM fungi compatible with pines (Godoy et al. 1994; Fontenla et al. 1998); consequently, trees will have only those EM fungal species gained in nurseries. This supports results observed in *Pinus radiata* D. Don. plantations in grasslands in Chile (Garrido 1986), Ecuador (Chapela et al. 2001), Australia (Lamb 1979), and New Zealand (Chu Chou 1979; Chu Chou and Grace 1990) and for *Pinus* spp. and *Eucalyptus* spp. in Brazil (Giachini et al. 2000). Although Douglas-fir has also been planted in areas dominated by EM *Nothofagus* species, only non-native EM fungal species have been reported to occur in these plantations (Barroetaveña et al.

2006), possibly because of the big taxonomic distance between these two species that evolved in very distant geographical areas.

A high proportion of EM fungal species native to the natural range of Douglas-fir has been reported in Patagonia, but in the case of ponderosa pine, only 28% of the species reported from Patagonian plantations (i.e., 5 out of 18) have been recorded in native forests of the species. This could be due to the fact that many other species of *Pinus* have been introduced in the region, probably bringing different EM fungal associates compatible also with ponderosa pine. In contrast, *P. menziesii* is the only species of the genus used in forestry, and it is known to have many highly specific EM fungi, e.g., *Rhizopogon* section “*Villosuli*”, such as *R. villosulus* (Molina and Trappe 1994; Massicotte et al. 1994; Grubisha et al. 2002), and *S. lakei* (Molina and Trappe 1982). These are probably more effective and competitive for Douglas-fir than taxa associated with *Pinus* spp. in the region (Barroetaveña et al. 2006).

The EM fungal species reported for native Douglas-fir forests do not coincide much with plantations of that species elsewhere. From the 64 EM fungal species reported from plantations around the world, 28 of them (44%) have not been registered from native forests. Furthermore, most EM fungi in Patagonian plantations have not been recorded in plantations elsewhere, except *S. lakei* and *T. terrestris*. In *Eucalyptus*, another tree genus planted outside its natural range, new EM fungal taxa not yet recorded from native forests have been recently registered from Brazil (Giachini et al. 2000). These findings could be due to different inoculum sources that have favored the dissemination of other EM fungal species. Exotic plantations, as an artificial environment, could also enhance the formation of novel host+EM fungi associations that are neglected or dismissed under natural conditions. Local environmental conditions different from those existing in native forests should be stressed as key factors in the establishment and persistence of the new symbiosis, possibly offering better adaptability through absence or low level of EM inoculum, soil features, and climate.

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