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Mycorrhizal status of some plants of the Araucaria forest and the Atlantic rainforest in Santa Catarina, Brazil

Accepted: 27 August 2000

Abstract In Brazil, the Araucaria forest and the Atlantic rainforest are two threatened ecosystems, with 10% or less of their original areas presently existing. To assess the mycorrhizal status in these forests, roots of 29 native species, belonging to 19 families, were collected throughout the year from different regions of Santa Catarina, Brazil. Roots were washed, and then cut in a cryo-microtome to seek ectomycorrhizal colonization. Other roots were stained before being examined for vesicular-arbuscular mycorrhizas (VAM). Patterns of colonization were identified and photographed. All plants presented evidence of vesicular-arbuscular mycorrhizal colonization. No evidence of ectomycorrhizal colonization was found. Vesicular-arbuscular mycorrhizal colonization patterns varied from single intracellular aseptate hyphae, coils, and/or appressoria, to vesicles and/or arbuscules. Results confirmed that VAM hosts are predominant in South American forests while ectomycorrhizas are extremely rare even among genera known as ectomycorrhizal in other regions of the humid tropics.

Keywords Atlantic rainforest · Araucaria forest · Mycorrhizas · Brazil

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Introduction

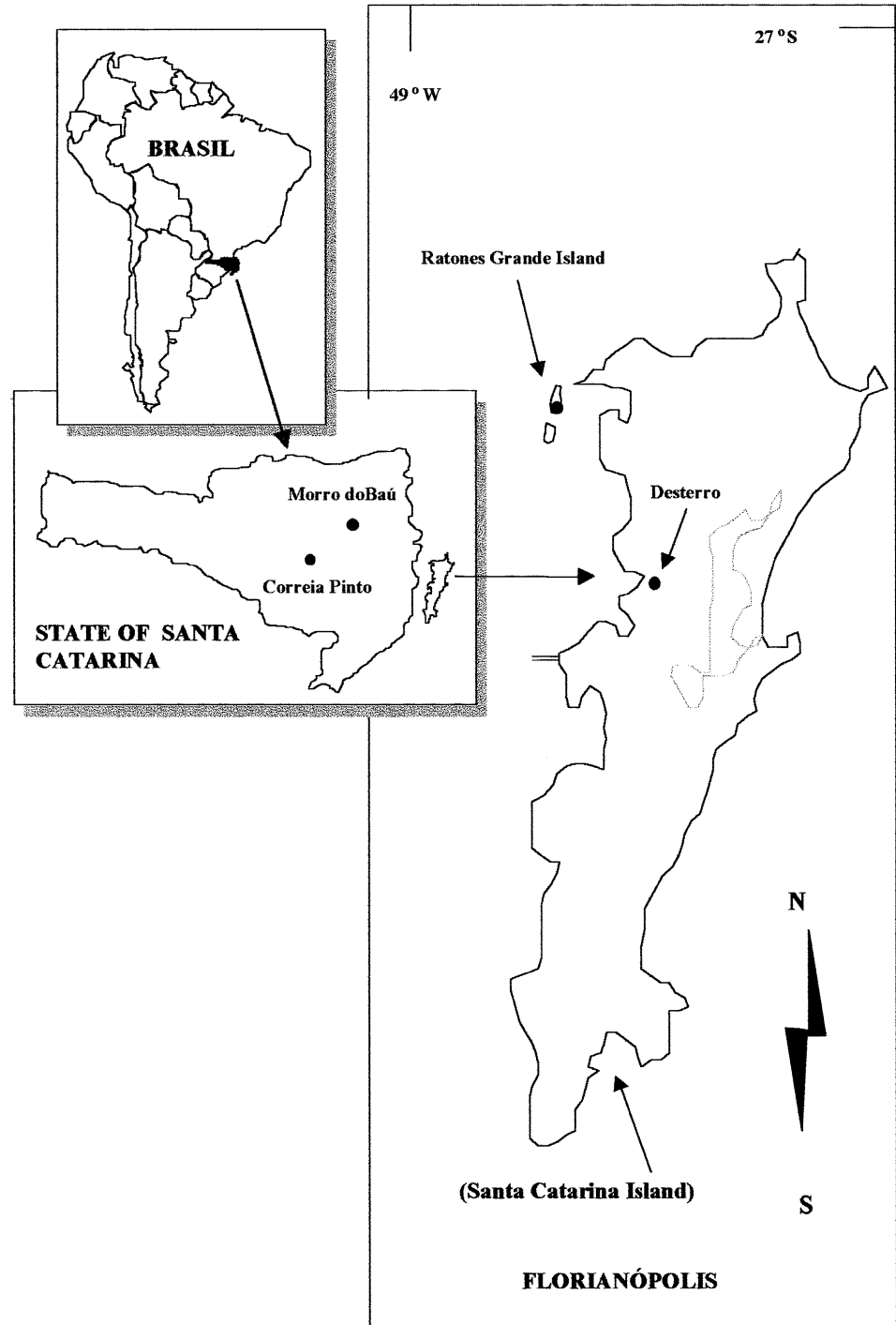
The Atlantic rainforest and the Araucaria forest in Brazil are among the ecosystems most affected by human activity, with 10% or less of their original area presently existing. The Atlantic rainforest presents a significant species richness, especially in terms of epiphytes and lianas, and contains an estimated 4,500 species of tracheophytes. The plant composition of the Araucaria forest is marked by the dominance of *Araucaria angustifolia* at the canopy level, and high-quality timber species of Lauraceae, Myrtaceae, Sapindaceae and Meliaceae. Until the 17th century this forest covered a great area of the state of Santa Catarina, Southern Brazil. Situated in a region of extensive agriculture, the forest was intensively exploited, mainly from the 1940s to the 1960s, and this still continues, although at a more limited level.

Attention has been focused on the mycorrhizas of forests in the humid tropics (e.g. Singer and Araújo 1979; Janos 1980a, 1980b; St John 1980; Béreau and Garbaye 1994; Béreau et al. 1997; Siqueira et al. 1997; Moyersoen et al. 1998), but there is little information concerning these symbioses in a number of neotropical ecosystems such as the Atlantic and Araucaria forests in Southern Brazil, even though plant structure and dynamics have been extensively studied in these forests (Klein 1975, 1979/1980; Reitz et al. 1978). In this study our objective was to first characterize and describe the mycorrhizal status of native plants in the Atlantic rainforest and Araucaria forest in the state of Santa Catarina, Southern Brazil.

Materials and methods

This study was carried out at three sites located in the Atlantic rainforest and one in the Araucaria forest (Fig. 1). Sites in the Atlantic rainforest were: (1) Unidade de Conservação Ambiental do Desterro (Ilha de Santa Catarina), and (2) Ilha de Ratonés Grande, both in Florianópolis, and (3) Parque Botânico do Mor-

Fig. 1 Sites of sampling in the native Araucaria and Atlantic forests in Santa Catarina (southern Brazil)



ro do Baú, at Ilhota. The site in Araucaria forest was located at Correia Pinto, in a reserve belonging to a forest company (Celulose Catarinense).

The plant species selected represented frequent as well as rare species that included four different plant types (arboreal, short tree, shrub, and herbaceous) from all strata of the canopy (Table 1). Individual young plants of between 50 and 70 cm in height were sampled of 13 species in the Araucaria forest and 16 species in the Atlantic rainforest (Table 1). At least three plants from each species were uprooted, and entire shoots with the majority of the root systems were then placed in plastic bags and transported from the field to the laboratory.

Root systems were freed of substrate, washed in running tap water and divided into two parts. One part, consisting of 50–100 cm root length, was stained to observe the presence of vesicular-arbuscular mycorrhizas (VAM) according to the technique described by Koske and Gemma (1989). For *Araucaria angustifolia* and *Ilex paraguaiensis*, roots were more efficiently stained following the technique of Vierheilig and Piché (1998). For each individual system, at least 25 root segments, ca. 2 cm length, were mounted on glass slides for microscopic examination. The other part of the intact root system was observed under a dissecting microscope for the presence of ectomycorrhizas (ECM). When potential ectomycorrhizal roots were seen, root tips were cut in a

Table 1 Natives species of Araucaria (AR) and Atlantic (AT) forests in Santa Catarina (Brazil) and their vesicular-arbuscular mycorrhizal patterns of colonization. A Arboreal, T short tree, S shrub, H herbaceous, SS secondary stages, ap appressoria, ar ar-

buscules, h intracellular aseptate hyphae, v vesicles, c coils, cc septate hyphae bearing clamp connections on the surface of the roots, ND not determined

Family	Species	Plant type/ Canopy strata	Ecological type	Patterns of colonization	Site/forest
Aquifoliaceae	<i>Ilex paraguariensis</i> J. St.-Hil.	T/Middle	Frequent	ap, h, ar, v, c	Correia Pinto/AR
Araliaceae	<i>Didymopanax angustissimum</i> Marchal	A/Upper	Insular frequent	h, ar, v	Ratones Grande/AT
Araucariaceae	<i>Araucaria angustifolia</i> (Bertol.) Kuntze	A/Upper	Dominant	ap, h, ar, v, c	Correia Pinto/AR
Caesalpinoideae	<i>Bauhinia</i> sp.	A/Middle	Rare	h, v	Desterro/AT
	<i>Cassia</i> sp.	A/Middle	Rare	h	Correia Pinto/AR
Elaeocarpaceae	<i>Sloanea guianensis</i> (Aubl.) Benth.	A/Upper	Co-dominant	h	Morro do Baú/AT
Euphorbiaceae	<i>Hieronyma alchorneoides</i> Allemão	A/Upper	Frequent-SS	h, v	Morro do Baú/AT
Flacourtiaceae	<i>Casearia sylvestris</i> Sw.	T/Middle	Frequent	h, v, c	Desterro/AT
Lauraceae	<i>Nectandra rigida</i> Nees	A/Upper	Very frequent	h, v	Ratones Grande/AT
Marantaceae	<i>Calathea</i> sp.	H/Understorey	Frequent	h, v	Desterro/AT
Melastomataceae	<i>Leandra dasytricha</i> (A. Gray) Cogn.	S/Understorey	Frequent	h	Desterro/AT
Meliaceae	<i>Cabralea canjerana</i> (Vell.) Mart.	A/Middle	Frequent	h, v, c	Desterro/AT
Mimosoideae	<i>Inga marginata</i> Willd.	A/Upper	Frequent-SS	h, v	Desterro/AT
	<i>Mimosa scabrella</i> Benth.	A/Middle	Dominant	h, v	Correia Pinto/AR
Moraceae	<i>Brosimum lactescens</i> (S. Moore) C.C. Berg	A/Upper	Very rare	h, v, cc	Correia Pinto/AR
Myrsinaceae	<i>Rapanea ferruginea</i> (Ruiz and Pav.) Mez	T/Upper	Dominant-SS	h	Desterro/AT
Myrtaceae	<i>Acca sellowiana</i> (Berg) Burret	T/Middle	Rare	ap, h, v	Correia Pinto/AR
	<i>Campomanesia</i> sp.	A/Middle	ND	h, v, cc	Correia Pinto/AR
	<i>Eugenia</i> sp.	A/Middle	ND	h, v	Correia Pinto/AR
	<i>Eugenia</i> sp.	A/Middle	ND	h, v	Correia Pinto/AR
	<i>Eugenia</i> sp.	A/Middle	ND	h, v	Correia Pinto/AR
	<i>Eugenia</i> sp.	A/Middle	ND	h, ar, v	Correia Pinto/AR
	<i>Gomidesia spectabilis</i> (DC.) Berg	A/Middle	Frequent	ap, h, v	Morro do Baú/AT
	<i>Psidium guajava</i> L. ^a	A/Middle	Introduced-SS	h	Correia Pinto/AR
	<i>Psidium</i> sp.	A/Middle	ND	h, v	Correia Pinto/AR
Piperaceae	<i>Piper</i> sp.	H/Understorey	Frequent	ap, v	Desterro/AT
Polygonaceae	<i>Coccoloba warmingii</i> Meisn.	A/Upper	Rare	h, v, cc	Desterro/AT
Sapindaceae	<i>Matayba guianensis</i> Aubl.	A/Upper	Frequent-SS	h, v	Desterro/AT
Schizaeaceae	<i>Anemia phyllitidis</i> (L.) Sw.	H/Understorey	Frequent	h, v, c	Desterro/AT

^a *Psidium guajava* L. occurring naturally in secondary forests close to areas subjected to human activity

cryo-microtome (30 µm width) and at least ten sections were mounted on glass slides and observed under a light microscope. The type of mycorrhiza and the fungal structures were noted and photographed.

Results

Vesicular-arbuscular mycorrhizal colonization was evident in all plant roots collected (Table 1). No evidence of ECM was found, although septate hyphae bearing clamp connections on the surface of the roots were detected on three species: *Coccoloba warmingii* Meisn. (Polygonaceae), *Brosimum lactescens* (S. Moore) C.C. Berg (Moraceae) and *Campomanesia* sp. (Myrtaceae). However, microscopic examination of microtomed sections of these roots showed no evidence of mantle nor Hartig net, this being indicative of ECM colonization.

Although the pattern of colonization varied among the species, coarse intracellular aseptate hyphae and vesicles were the most frequent VAM structures present in the species studied (Table 1). Vesicles were present in the roots of 24 species such as in one *Eugenia* sp.

(Fig. 2a) and *Acca sellowiana* (Berg) Burret (Fig. 2b), whereas arbuscules were observed only in *Ilex paraguariensis* J. St.-Hil., *Didymopanax angustissimum* Marchal (Fig. 2c), *Araucaria angustifolia* (Bertol.) Kuntze (Fig. 2d), and one *Eugenia* sp. Three species presented aseptate intracellular hyphae, vesicles and appressoria: *A. sellowiana*, *Gomidesia spectabilis* (DC.) Berg (Fig. 2e) and *Cabralea canjerana* (Vell.) Mart. (Fig. 2f). *Piper* sp. showed no intracellular hyphae, but appressoria and vesicles were discerned in many root segments. In some species the pattern of VAM colonization was limited to coarse aseptate intracellular hyphae such as in *Cassia* sp. (Fig. 2g), *Leandra dasytricha* (A. Gray) Cogn., *Sloanea guianensis* (Aubl.) Benth., *Psidium guajava* L. and *Rapanea ferruginea* (Ruiz and Pav.) Mez. In other cases, however, we also observed vesicles, such as in *Matayba guianensis* Aubl., *Bauhinia* sp., *Hieronyma alchorneoides* Allemão, *Nectandra rigida* Nees, *Calathea* sp., *Inga marginata* Willd., *Mimosa scabrella* Benth., *B. lactescens*, *Campomanesia* sp., *Psidium* sp. and three *Eugenia* spp.

Besides arbuscules, roots of *A. angustifolia* and *I. paraguariensis* presented vesicles and intracellular coils

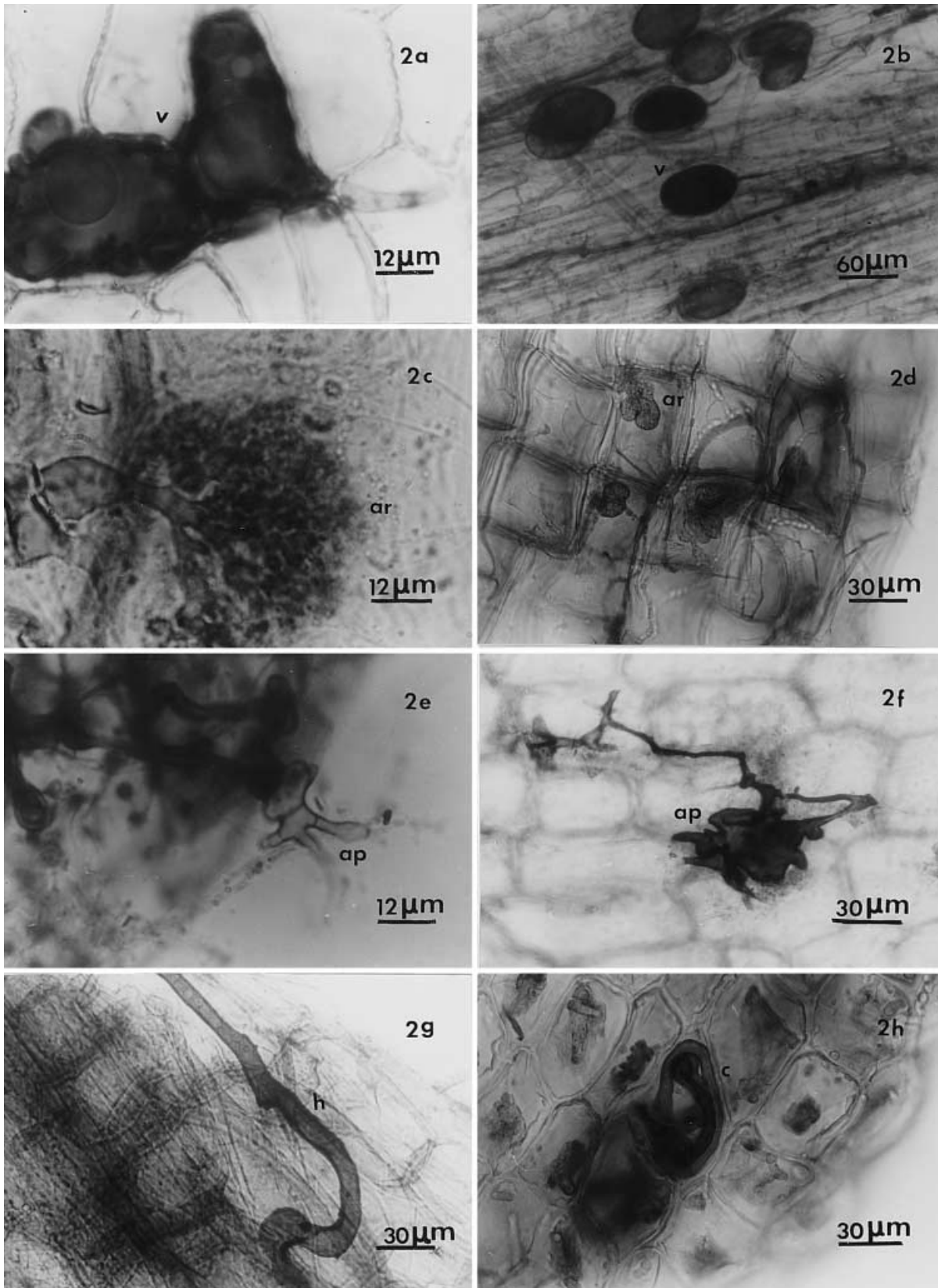


Fig. 2a-h Patterns of VAM colonization in roots of native plants of Araucaria and Atlantic forests in southern Brazil. Vesicles: *Eugenia* sp. (a) and *Acca sellowiana* (b). Arbuscules: *Didymopanax*

angustissimum (c) and *Araucaria angustifolia* (d). Appressoria: *Gomidesia spectabilis* (e) and *Cabralea canjerana* (f). Hyphae: *Cassia* sp. (g); Coils: *Ilex paraguariensis* (h)

(Fig. 2h). Roots of *Anemia phyllitidis* (L.) Sw., *Casearia sylvestris* Sw. and *Cabralea canjerana* were colonized by aseptate hyphae, vesicles and intracellular coils.

Discussion

Bearing in mind that our results do not exclude the possibility of the occurrence of other kind of mycorrhizal associations in the species examined, the absolute dominance of VAM in these plants was in agreement with Janos (1987) and the observations of other authors on the mycorrhizal status of neotropical forests (St John 1980; Béreau and Garbaye 1994). On the other hand, they seem to contradict the observations of Thomazini (1973) and Singer and Araújo (1979) concerning the occurrence of ECM in native Brazilian trees, especially species of Caesalpinioideae as *Cassia* spp. and *Bauhinia* spp.. However, in the former paper no explanation of the pattern of colonization on the basis of the fungal structures was given. Singer and Araújo (1979) reported the occurrence of fruiting bodies of putative ectomycorrhizal fungi in the Amazonian forest, but no evidence of root colonization by ectomycorrhizal fungi was shown.

There were five species which contained intracellular coils (*Ilex paraguariensis*, *Araucaria angustifolia*, *Casearia sylvestris*, *Cabralea canjerana* and *Anemia phyllitidis*) (Table 1), indicating that these species form the Paris-type VAM (Smith and Smith 1997). In the case of *A. angustifolia*, a gymnosperm, and *A. phyllitidis*, a pteridophyte, the presence of Paris-type VAM is in accordance with the general view that these primitive plant classes present a predominance of this type of VAM (Smith and Smith 1997). In *Didymopanax angustissimum* (Araliaceae), the arbuscules formed were terminal structures from a trunk hypha (Fig. 2c) which indicated the Arum-type of VAM. Among the other species surveyed, due to the absence of arbuscules or coils, the type of VAM could not be confirmed.

Absence of ECM colonization in the plants examined was particularly interesting for many species belong to families which have been proposed in the literature as ectomycorrhizal hosts, for example Caesalpinioideae (Leguminosae) (Frioni et al. 1999), Myrtaceae (Oliveira et al. 1997), Polygonaceae, and Euphorbiaceae (Redhead 1982). In particular, the presence of VAM in roots of *Coccoloba warmingii* (Polygonaceae) was unexpected because this genus has been consistently described as an ECM host (Béreau et al. 1997; Smith and Read 1997).

The lack of ectomycorrhizal inocula in the region cannot explain the absence of ECM because the sites of study, particularly the one in the Araucaria forest, are located in areas where introduced species of ectomycorrhizal hosts (*Eucalyptus* spp. and *Pinus* spp.) are extensively planted and ectomycorrhizal fruiting bodies are abundant. A similar situation was studied by Béreau and Garbaye (1994) in French Guyana, where the

neotropical rain forest is located close to exotic plantations of ECM hosts, but the native plants nevertheless are predominantly colonized by VAM fungi. We cannot exclude the possibility of a VAM-ECM succession related to plant age in these species, however, as is the case in many *Eucalyptus* spp. (Bellei et al. 1992; Oliveira et al. 1997).

Recognising that these results cover only a small proportion of the plant diversity in these forests, and that the observations were of young plants, they must be considered preliminary. Nevertheless, for some species examined (*C. canjerana*, *R. ferruginea* and *A. sellowiana*) this is the first report of their mycorrhizal status that has been published. Considering the predominance of VAM associations in these forests and that mycorrhizas likely affect plant growth, survival and competitive ability, VAM should receive special attention in management/conservation programmes for these forests.

Acknowledgements The authors gratefully acknowledge CAPES-Programa Especial de Treinamento (PET) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for fellowships; UFSC-Unidade de Conservação Ambiental do Desterro, and Celulose Catarinense S.A. (CELUCAT), for facilities; Dr E. Cázares, Oregon State University, USA, Dr R. S. Pavovsky, ESALQ-USP and Dr S. L. Stürmer, UFSC, Brazil, for reviewing this manuscript.

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