DARWINIANA
www.ojs.darwin.edu.ar
NUEVA SERIE

DARWINIANA, nueva serie 1(1): 67-75. 2013
Versión final, efectivamente publicada el 31 de julio de 2013
ISSN 0011-6793 impresa - ISSN 1850-1699 en línea

BIODIVERSITY OF AGARICOMYCETES BASIDIOMES ASSOCIATED TO *SALIX* AND *POPULUS* (SALICACEAE) PLANTATIONS

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Abstract. Romano, G. M.; J. A. Calcagno & B. E. Lechner. 2013. Biodiversity of Agaricomycetes basidiomes associated to *Salix* and *Populus* (Salicaceae) plantations. *Darwiniana*, nueva serie 1(1): 67-75.

Although plantations have an artificial origin, they modify environmental conditions that can alter native fungi diversity. The effects of forest management practices on a plantation of willow (*Salix*) and poplar (*Populus*) over Agaricomycetes basidiomes biodiversity were studied for one year in an island located in Paraná Delta, Argentina. Dry weight and number of basidiomes were measured. We found 28 species belonging to Agaricomycetes: 26 species of Agaricales, one species of Polyporales and one species of Russulales. Our findings suggest that forest management practices on plantations of willow and poplar do not affect either the abundance or diversity of Agaricomycetes basidiomes.

Keywords. Agaricomycetes; Argentina; fungal diversity; plantation; woody debris.

Resumen. Romano, G. M.; J. A. Calcagno & B. E. Lechner. 2013. Biodiversidad de basidiomas de Agaricomycetes asociados a plantaciones de *Salix* y *Populus* (Salicaceae). *Darwiniana*, nueva serie 1(1): 67-75.

Aunque los cultivos forestales son comunidades artificiales, modifican condiciones ambientales que pueden alterar la diversidad fúngica nativa. Se estudiaron los efectos del manejo forestal de una plantación de sauces (*Salix*) y álamos (*Populus*) sobre la biodiversidad de Agaromycetes durante un año en una isla del Delta del Paraná, Argentina. Se midieron el peso seco y el número de basidiomas. Se identificaron 28 especies pertenecientes a los Agaricomycetes: 26 especies de Agaricales, una de Polyporales y una de Russulales. Nuestros resultados sugieren que el manejo forestal de dicha plantación no afecta la abundancia ni la diversidad de basidiomas de Agaricomycetes.

Palabras clave. Agaricomycetes; Argentina; detritos leñosos; diversidad fúngica; plantación forestal.

INTRODUCTION

Agaricomycetes, one of the largest clades of Basidiomycota, sensu Dowell Prosyllabus: LXXVII (2001) includes fungi forming hymenomycetous or gasteroid basidiomes, with basidia 2-8-spored, and parenthesomes perforate or imperforate. It is the least-inclusive clade containing Auriculariales, Sebacinales, Cantharellales, Phallomycetidae and Agaricomycetidae (Hibbett et al., 2007). This

Original recibido el 22 de febrero de 2013, aceptado el 3 de julio de 2013
Editor Asociado: Diego Salariato

group is approximately equivalent to Homobasidiomycetes sensu Hibbett & Thorn (2001) plus Auriculariales and Sebacinales (Hibbett et al., 2007). Agaricomycetes includes mycorrhyzal, saprobes and xylophagous fungi that play key roles as decomposers and mutualists, but they need specific conditions to form and ripen their basidiomes, giving this group a genuine ecological value to assess forests conservation. Plant communities produce microclimates that modify abiotic variables, like temperature and humidity, and add biotic ones, like substrate (e.g. decaying wood, leaves) and mutualist counterpart availability.

Several researchers studied the effects of different types of forestal management over fungal diversity: Lindner Czederpiltz et al. (1999) studied wood-inhabiting polyporoid and corticioid fungi in northern hardwood natural forests in the United States and concluded that management regimes that reduce the quantity or quality of woody debris could reduce the fungal diversity; Garibay-Orijel et al. (2009) studied the richness and species composition in pine-oak forests, and remarked the importance of developing forest management strategies with special focus on location and monitoring populations of different species that live in the woods; Oria-de-Rueda et al. (2010) studied the association of fungal biodiversity with reforestation of *Pinus* spp. (Pinaceae), *Populus nigra* L. (Salicaceae) and *Quercus* spp. (Fagaceae) and concluded that artificial reforestation could provide as much fungal production and diversity as those found in natural forest stands. Although in Argentina researches on fungal ecology have received little attention, in the past few years Robledo & Renison (2009) studied the diversity of Polyporales and its relation with the stage and altitude of native woods of *Polylepis* Ruiz & Pav. (Rosaceae). They observed that wood-polyporoid fungi are related to the structural complexity of the forest, measured by the number and volume of woody debris. According to Lindner Czederpiltz et al. (1999) and Garibay-Orijel et al. (2009) management of natural forests tends to diminish fungal diversity if it is not combined with clear policies that regulate their use. However, gilled Agaricomycetes have not been addressed in any of the papers mentioned above. Although plantations have an artificial origin, they present a configuration of ecosystem variables that can modify native fungi diversity. This is the reason why the study of the effect of plantations (and their management) on the local native mycobiota is an important issue for conservation.

The place selected to perform this research belongs to “Delta del Paraná”, a region of 1750000 ha located between 31° 5’ to 32° 29’ S and 58° 22’ to 59° 45’ W, in Buenos Aires province of Argentina. The climate is temperate with hot (19-35º C) summers and cool to cold (1-24º C) winters, average annual precipitations are 900 mm, more frequent in spring and autumn. This area is one of the most exploited in the province of Buenos Aires, so that native vegetation is reduced to meadows (Abeucci & Sarafian, 2006). The occurrence of south-eastern winds can increase Paraná water level a maximum of 2 meters, frequently causing floods in the region (Borus, 2010). For this reason, the plantations in this area are composed mainly of *Salix* (Salicaceae) and *Populus* (Salicaceae) which have the advantage of being resistant to partial and temporal floods. Plantations of these species of Salicaceae cover a total of 65000 ha in Delta del Paraná. This zone is the first provider of newsletter paper for Argentina (Borodowski & Suárez, 2013) due to the exploitation of its woody species.

The aim of the present work is to study the diversity of Agaricomycetes in these Salicaceae plantations and the effect of management over Agaricomycetes diversity, assessed by their basidiomes. Two hypotheses will be tested: Agaricomycetes basidiomes biodiversity is higher in Unmanaged zone than in Managed zone; and xylophagous Agaricomycetes basidiomes are more frequently found in Managed zone.

MATERIALS AND METHODS

The plantation consists mainly of *Populus nigra*, while *Salix humboldtiana* Willd. is left to grow in the perimeter. It is located in 34°1’27” S and 58°59’9” W and was divided into two zones, both of more than 10000 m^2 and more than 30 years old: one has never been managed (“Unmanaged zone”), and the other one was managed for the last time in 2006 (“Managed zone”). The management regime of these plantations consists of the removal of all branches except the youngest distal one of each tree, allowing faster branch regeneration. After every management procedure, the canopy is drastically reduced, and woody residues are left in situ in the ground.

Ten square sampling areas were arranged in a line of 200 m that was marked inside each zone. All sampling areas were divided into four quadrants of 10 x 12.5 m, and one was selected randomly. A total of 10 quadrants were selected in each area using this method. Mann-Whitney Tests (Daniel, 1978) were performed to compare the number and DBH (diameter at breast height) of trees present in every quadrant of both areas to evaluate if the chosen zones inside the plantation were comparable. Woody debris availability was not measured because floods limited field work.

The study took place from April to December of 2010, with sampling once every 15 days. All basidiomes were sampled according to Garibay-Orijel et al. (2009), including basidiomes found growing on soil, trees, stumps and woody debris, photographed "in situ" and dried later. All samples were studied both macro- and microscopically. The identification of species was based on cultures and herbarium specimens. Microscopic samples were mounted in 5% KOH and 1% aqueous phloxine. The fungal productivity was measured by dry weight of basidiomes (Pilz et al., 1998) and the number of basidiomes per square meter in each quadrant was also determined. Substrate and specific location of the collected fungi were observed for later comparison. T-tests and ANOVA (Sokal & Rohlf, 1995) were performed for dry weight and number of basidiomes found where treatments of the main factor "forest management" were "Managed" and "Unmanaged". In order to achieve homogeneity of variances and normality, variables were transformed according to y': $1/(y+1)$ and y': $\log10(y+1)$ respectively. For both variables the sample size was $n = 204$.

Species diversity was evaluated with Shannon diversity index (Shannon & Weaver, 1949). In order to calculate species richness, the number of species present in each and both areas was considered. Levelling off in rarefaction curve was performed to decide the minimum sampling size and the area of the quadrants to be used. Abundance of each species was obtained by the sum of basidiomes found in each quadrant of each area in all the sampling dates.

RESULTS

Comparison between zones

No significant differences were found between the number of trees present in both zones ($p > 0.05$). The mean was 24.7 ± 3.2 per quadrant for the Unmanaged versus 48.7 ± 15.7 for the Managed zone, although the Managed zone was more variable. On the contrary, significant differences were found between DBH of trees present in both zones, with a mean of 24.9 ± 1.2 cm for the Unmanaged while the Managed zone had a mean of 6.6 ± 0.3 cm ($p < 0.05$).

No significant differences were found ($p > 0.05$) for dry weight and number of basidiomes of all sampled material between Unmanaged and Managed zones (Fig. 1).

Diversity, richness and species evenness

We found a total of 28 species (Table 1) belonging to Agaricomycetes: 26 species of Agaricales, one species of Polyporales and one species of Russulales. Species more frequently found according to dry weight and number of basidiomes, are shown in Figs. 2 and 3, respectively.

We observed similar trends for number of basidiomes and dry weight, with higher diversity and

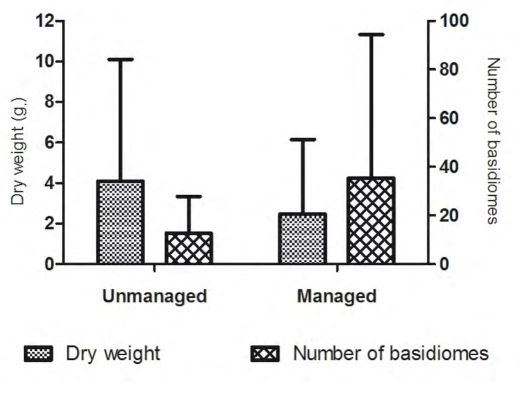

Fig. 1. Dry weight and number of basidiomes found in Unmanaged and Managed zones.

Table 1. Agaromycetes of Salicaceae plantations from Paraná Delta, detailing substrate, zone (U, Unmanaged zone; M, Managed zone), dry weight and number of basidiomes sampled.

Order	Family	Species	Substrate	Zone	Dry weight (g)	Number of basidiomes
Agaricales	Bolbitiaceae	*Conocybe* sp.	Wood	U	0.150	9
Agaricales	Inocybaceae	*Inocybe* aff. *lanuginosa* (Bull.) P. Kumm.	Wood	M	0.042	1
Agaricales	Inocybaceae	*Tubaria* sp.	Wood	M	0.234	5
Agaricales	Mycenaceae	*Mycena* aff. *olida* Bres.	Wood	M/U	0.010	22
Agaricales	Mycenaceae	*Mycena* sp. 1	Wood	M	0.125	30
Agaricales	Mycenaceae	*Mycena* sp. 2	Wood	M	0.005	2
Agaricales	Physalacriaceae	*Oudemansiella canarii* (Jungh.) Höhn.	Wood	M/U	38.423	36
Agaricales	Pleurotaceae	*Hohenbuehelia approximans* (Peck) Singer	Wood	U	0.836	23
Agaricales	Pleurotaceae	*Hohenbuehelia nigra* (Schwein.) Singer	Wood	M/U	0.403	18
Agaricales	Pleurotaceae	*Pleurotus albidus* (Berk.) Pegler	Wood	M/U	22.904	5
Agaricales	Pleurotaceae	*Pleurotus ostreatus* (Jacq.) P. Kumm.	Wood	M/U	34.166	30
Agaricales	Pleurotaceae	*Pleurotus pulmonarius* (Fr.) Quél.	Wood	M/U	1.078	2
Agaricales	Pluteaceae	*Pluteus* aff. *cervinus* (Schaeff.) P. Kumm.	Wood	M	21.172	27
Agaricales	Pluteaceae	*Pluteus* aff. *plautus* Quél.	Wood	U	0.214	2
Agaricales	Pluteaceae	*Pluteus* sp.	Wood	M	0.049	1
Agaricales	Psathyrellaceae	*Coprinellus disseminatus* (Pers.) J.E. Lange	Wood	M	0.002	3
Agaricales	Psathyrellaceae	*Coprinellus domesticus* (Bolton) Vilgalys, Hopple & Jacq. Johnson	Wood	M	0.940	10
Agaricales	Psathyrellaceae	*Coprinellus truncorum* (Scop.) Redhead, Vilgalys & Moncalvo	Wood	M	0.179	2
Agaricales	Psathyrellaceae	*Coprinopsis sp.*	Soil	M	0.029	7
Agaricales	Psathyrellaceae	*Psathyrella candolleana* (Fr.) Maire	Wood	M	1.435	24
Agaricales	Schizophyllaceae	*Schizophyllum commune* Fr.	Wood	M/U	8.221	105
Agaricales	Strophariaceae	*Hebeloma crustuliniforme* (Bull.) Quél.	Soil	U	3.996	9
Agaricales	Strophariaceae	*Hebeloma* sp.	Soil	M/U	6.235	3
Agaricales	Strophariaceae	*Hypholoma* sp.	Wood	M/U	1.640	57
Agaricales	Strophariaceae	*Pholiota* sp.	Wood	U	0.978	6
Agaricales	Tricholomataceae	*Resupinatus applicatus* (Batsch) Gray	Wood	U	0.015	56
Polyporales	Polyporaceae	*Lentinus tigrinus* (Bull.) Fr.	Wood	M/U	13.490	40
Russulales	Auriscalpiaceae	*Lentinellus* aff. *ursinus* (Fr.) Kühner	Wood	U	13.146	146

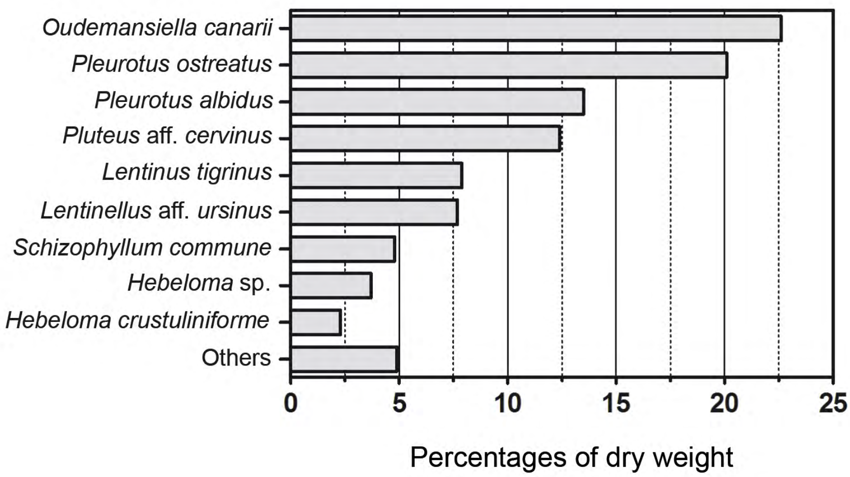

Fig. 2. Percentages of dry weight of basidiomes sampled per species.

richness in the Managed zone, where 21 species of Agaricomycetes were found (16 in Unmanaged). In the Unmanaged zone *Pleurotus ostreatus* (Jacq.) P. Kumm. was dominant (43% of dry weight), while in the Managed zone was *Pluteus* aff. *cervinus* (Schaeff.) P. Kumm., with 51%. According to the number of basidiomes, *Resupinatus applicatus* (Batsch) Gray was the most frequent species found in the Unmanaged zone (26%), and *Lentinus tigrinus* (Bull.) Fr. in the Managed zone (17%).

We also compared diversity and richness of collected species according to their substrate. Soil mushrooms were rarely found in both zones (Table 1). When dry weight was compared, the Managed zone registered higher values of diversity and evenness than the Unmanaged, for both wood and soil inhabitants. However, when number of basidiomes was used, both zones had a similar diversity and evenness for xylophagous fungi, while diversity, richness and evenness of soil fungi were higher in the Managed zone (Table 2).

DISCUSSION

Comparison between zones

The lack of differences found between the numbers of trees present in both zones sustains the homogeneity of the plantation forest. Differences found between diameters of trees are probably a consequence of the type of forest management practiced in the region, with trees in the Managed zone having a minor value of DBH than those in the Unmanaged zone.

Surprisingly, the management of *Salix* (Salicaceae) and *Populus* (Salicaceae) did not affect the fruiting of Agaricomycetes in the studied plantation, this finding can be attributed to the type of management used in the region of Delta del Paraná, as there is always substrate available for xylophagous fungi colonization (Torres & González, 2005; Rajala et al., 2010). This could be the reason of the lack of differences found between zones. Moreo-

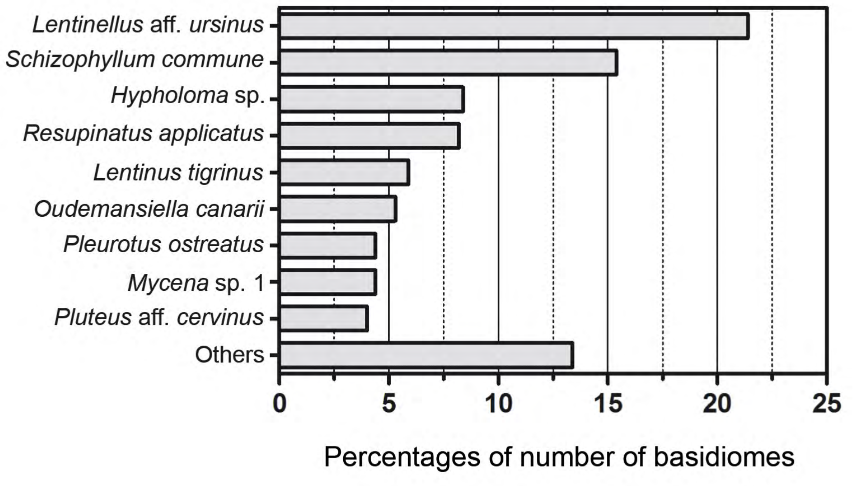

Fig. 3. Percentages of number of basidiomes sampled per species.

ver, the periodicity of crops in Managed zone is from four to seven years, and since the last one took place in 2006, *Populus* (Salicaceae) and *Salix* (Salicaceae) had up to 10 branches per tree in Managed zone, probably minimizing the effect of management at the moment of sampling.

Although dry weight is more commonly used, not only for fungi (Pilz et al., 1998) but also for all organisms in general, the estimation of number of basidiomes is a complementary result of the first in mycological researches (Oria-de-Rueda et al., 2010). Despite there were no significant differences in dry weight and number of basidiomes between zones, we observed a tendency in variables measurements for all species found: a low value in number of basidiomes was associated with a high value in dry weight. This was generally observed for most samples obtained: *Pluteus* aff. *cervinus* (Schaeff.) P. Kumm. produces only a few basidiomes but with a high weight, this is the reason why although it represents the 12.4% of dry weight only represents the 4.0% of number of basidiomes; *Psathyrella candolleana* (Fr.) Maire produces a large number of low weighted basidiomes. However, there were some species that disrupted this trend, like *Mycena* aff. *olida* Bres. which produces little groups of low weighted basidiomes, as reported in similar environments (Maas Geesteranus, 1992).

Diversity, richness and species evenness

Independently of the values obtained for each zone, species more frequently found have a high plasticity in substrates. *Oudemansiella canarii* (Jungh.) Höhn. is able to grow in a variety of substrates, such as *Piptadenia* Benth. (Fabaceae) (Singer & Digilio, 1951), *Erythrina crista-galli* L. (Fabaceae) (Singer & Digilio, 1951; Sede & Lopez, 1999), mango branches (Anacardiaceae) (Pegler, 1977), *Salix* (Salicaceae) (Wright & Albertó, 2002), and *Canarium commune* L. (Burseraceae) (Petersen et al., 2008). Moreover, it has a wide distribution as it has been found in Africa (Pegler, 1977), Brazil (Lima et al., 2008), oriental Asia (Petersen et al., 2008) and Argentina; particularly in Tucumán (Singer & Digilio, 1951), Buenos Aires (Singer & Digilio, 1951; Sede & Lopez, 1999) and Misiones (Wright et al., 2008). The produc-

Table 2. Diversity, richness and evenness index for dry weight and number of basidiomes for Managed and Unmanaged zones.

Variable	Zone	Substrate	Index of		
			Diversity	Richness	Evenness
Dry weight	Unmanaged	Soil	0.085	1.000	0.085
		Wood	1.791	3.700	0.484
	Managed	Soil	0.891	1.585	0.562
		Wood	1.940	3.700	0.524
Number of basidiomes	Unmanaged	Soil	0.544	1.000	0.544
		Wood	3.106	3.700	0.839
	Managed	Soil	1.296	1.585	0.818
		Wood	3.082	3.700	0.833

tion of *Pleurotus ostreatus* (Jacq.) P. Kumm. has increased in Argentina, particularly in the surroundings of Paraná River, because of the availability of wooden subtrates. *Pleurotus ostreatus* (Jacq.) P. Kumm. is not specific of any substrate and since its initial description for Argentina in 1993 (Lechner et al., 2002), it is extending its distribution in the region. *Pluteus* aff. c*ervinus* (Schaeff.) P. Kumm. was not frequently found, but the magnitude of dry weight of its basidiomes was over the mean, allowing *P.* aff. *cervinus* (Schaeff.) P. Kumm. to stand out with 12.4%. *Lentinus tigrinus* (Bull.) Fr. is a gilled species that belongs to Polyporales, and it is only cited growing on *Salix* (Salicaceae) (Lechner & Albertó, 2007), one of the two predominant trees in the studied region.

The commercial management of the plantation forest leaves a large number of different woody debris available to xylophagous fungi (Torres & González, 2005; Rajala et al., 2010). Some of these fungi could be compromising the quality of *Salix* (Salicaceae) and *Populus* (Salicaceae) wood, threatening the use of the entire plantation forest (Bava & López Bernal, 2006). Since some xylophagous Agaricomycetes could be involved, studying their biodiversity is an important concern for forest plantations. Soil fungi also exhibited higher values of diversity, richness and evenness in the Managed zone; although it may be for a different reason: in spite of floods affected both zones, the drainage was not equally effective. In this way, the presence of residual water in the Unmanaged zone could have acted reducing the fruiting (Ritz & Young, 2004; Egli et al., 2006; Boddy et al., 2008).

Finally, we recommend studies for longer periods, as we cannot assure that our results are not subjected to annual fluctuations. We also point out the importance of performing studies focused on the effects of forest management over Agaricomycetes in plantations with less than five years of management.

ACKNOWLEDGEMENTS

The authors thank University of Buenos Aires and CONICET (Argentina) for financial assistance. Also family Brobjerg for permitting this study in the island of Paraná Delta.

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