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Positive relationship between wood size and basidiocarp production of polypore fungi in *Alnus acuminata* forest

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ABSTRACT

Polypores play a major role in wood decomposition. Based on presence/absence of basidiocarps, it has been shown that richness of polypores in forests is strongly affected by the size of logs. However, no study has addressed the relationship between the log size and basidiocarp production. Here, we examined the relationship between log diameter and number of basidiocarps and volume of the fructification (as surrogate of biomass) of the polypore community in Andean Alder forests from Northwest Argentina. We found a positive relationship between log diameter and basidiocarp production in the whole community analysis (fructifications of all species). This pattern was also followed by dominant species (*Bjerkandera adusta*, *Trametes cubensis* and *T. versicolor*) analyzed individually. The relationship was generally higher for volume of fructification than for number of basidiocarps. Through these effects on basidiocarp production, higher log diameter could promote higher sexual spore production and dispersal hence a higher genetic variability and viable populations of wood-decay species.

Introduction

The polypores (Aphyllophorales s.l., Basidiomycota) are very effective wood decayers (Oberwinkler 1994). Physical conditions of the wood, such as moisture content and microclimatic conditions, are known to influence the growth of the mycelium and the decay activity in the wood (Boddy 2001; Schwarze *et al.* 2000). Logs with larger diameter might favor decay activity and fruitbody production because they generally have more constant microclimatic conditions (Boddy 1983, 2001). In this regard, it has been shown that size of logs strongly affects the community structure of wood-decay fungi (Bader *et al.* 1995; Renvall 1995; Høiland & Bendiksen 1996; Lindblad 1998; Siitonen *et al.* 2001; Snäll & Jonsson 2001; Penttilä *et al.* 2004; Urcelay & Robledo 2004; Lonsdale *et al.* 2008). In particular, species richness is positively related to wood diameter (Renvall 1995; Lindblad 1998; Sippola & Renvall 1999; Penttilä *et al.* 2004). Moreover, the presence of logs with higher diameter allows the occurrence of basidiocarps of threatened and rare species (Bader *et al.* 1995; Sippola *et al.* 2001; Penttilä *et al.* 2004; Stokland & Kauserud 2004).

Because one of the main consequences of forest management is the structural simplification of stands and consequently the loss of diversity of saproxilic species (Siitonen 2001), polypores have been used as indicators of the conservation value of forest stands (Nordstedt *et al.* 2001; Snäll & Jonsson 2001). Nonetheless, the mere occurrence of species may not guarantee good dispersal and colonization of new substrata if it is not accompanied by sufficient production of reproductive structures. Therefore, not only the presence but also basidiocarp production should be important for fungal dispersion and population viability. Despite this obvious

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reasoning, to the best of our knowledge, the relationship between log size and basidiocarp production by wood-decay fungi in natural communities has not been previously examined.

Here we evaluate the relationship between wood diameter and basidiocarp production of the polypore community of Andean Alder (*Alnus acuminata*, Betulaceae) forest along a latitudinal gradient in Northwest Argentina. In particular, we examine the relationship between log diameter and basidiocarp production (number of basidiocarps and volume of fructification) of the whole polypore community and of each dominant species (i.e. most abundant). Because larger wood diameter implies greater resource availability for wood decayers and more stable microclimatic conditions, we hypothesize that there is a positive relationship between diameter and basidiocarp production.

Materials and methods

Study area

Three sampling sites were established to reflect the Andean Alder distribution in Argentina. The first site was located in Calilegua National Park, Ledesma Department, Jujuy Province (23°41′S; 64°53′W), at 1700 m (hereafter Jujuy). The second site was in Quebrada del Portugués, Tafí del Valle Department, Tucumán Province (27°00′S; 65°45′W), at 1900 m (hereafter Tucumán). The third site was at the southern distribution limit of Andean Alder, at Sierra de Narváez, (27°36′S; 65°55′W), Ambato Department, Catamarca Province, at 1800 m (hereafter Catamarca).

Sampling methods

Each study site was surveyed three times from the beginning to the end of one rainy season from spring to autumn (9–12 Nov. 1999, 14–17 Feb. 2000 and 3–6 Apr. 2000). In each study site, two plots of 50 × 50 m were established and the entire area of each plot was surveyed. We selected three survey dates and three sites along a latitudinal gradient covering temporal and spatial variability. All polypore fructifications found in the plots were recorded. Each record was the independent sampling unit. Fructifications consisted of one to several basidiocarps. The complete surface of each log was carefully examined and number of basidiocarps and volume of fructification of each polypore species were recorded together with the log diameter. To avoid recounting persistent basidiocarps, different sampling plots were surveyed on each sampling date. Details of polypore community structure in decaying Andean Alder are described elsewhere (Robledo *et al*. 2003; Urcelay & Robledo 2004).

Data analysis

We calculated basidiocarp production based on number of basidiocarps and volume of fructification on each log. The fructification could invlove one to hundreds basidiocarps. When number of basidiocarps was above one hundred we annotated one hundred. Here, we considered a fructification of a certain species as the set of basidiocarps occurring together in the same log.

The volume of the fructification V_f was calculated as:

$$V_f = V_b \times N$$

where V_b is the volume of an average basidiocarp that corresponds to the value of an average size representative of the whole fructification and N is the number of basidiocarps.

For pileate basidiocarps V_b was calculated as follows:

$$V_b = \frac{\left(\frac{\pi \times r^2 \times h}{3}\right)}{2}$$

This is the formula to calculate the volume of a half cone, where r (radius of the cone) represents width of basidiocarp, and h (height of the cone) height of basidiocarp from the base. We consider the simplest reduction to a geometric form of the dimidiate to ungulate basidiocarp (Fig 1A). Most of the species included in the analysis fall into this category of basidiocarp (Robledo *et al*. 2003).

The basidiocarp volume of *Polyporus tricholoma*, the only stipitate species found here, was calculated as the sum of the volume of two cylinders: one that corresponds to the stipe and the other to the pileus (Fig 1B):

$$V_b = (\pi \times r^2 \times h)_{stipe} + (\pi \times r^2 \times h)_{pileus}$$

For resupinate basidiocarps V_b was calculated as:

$$V_b = w \times l \times h$$

where w, l, h, represent average width, length and height or thickness, respectively (Fig 1C).

Due to high variation, data were log transformed for the analysis, but analysis on non-transformed data yielded similar results (data not shown). Mean log diameter among sites and seasons were compared using ANOVA. We pooled all data on number and volume of basidiocarps to perform correlation analyses between log diameter and basidiocarp production using Spearman correlation rank. Statistical package Infostat was used for the analyses (Di Rienzo *et al*. 2008).

Results

We recorded 170 fructifications (more than 4000 basidiocarps) from 16 polypore species that were decaying Andean Alder wood in the three sampling dates. The mean log diameter in which the fungi were found was significantly different between sites ($F = 14.9443$, $P < 0.001$) but not between sampling dates (i.e. seasons) ($F = 0.0474$, $P = 0.9537$). Fruitbodies in Jujuy were found in logs that showed significantly lower mean diameter than Tucumán and Catamarca (Fig. 2). *Trametes versicolor* had the highest total relative frequency (number of occurrence of the species/number of occurrence of all species) followed by *Bjerkandera adusta* and *T. cubensis*, being the dominant species. These species were subjected to correlation analyses individually (Table 1). The other less abundant species were *Datronia mollis*, *Funalia gallica*, *Fuscoporia gilva*, *Ganoderma australe*, *Gloeoporus dichrous*, *Hexagonia papyracea*, *Junghuhnia carneola*, *Lenzites betulina*, *Perenniporia* sp., *Polyporus tricholoma*, *Pycnoporus sanguineus*, *Schizopora radula*

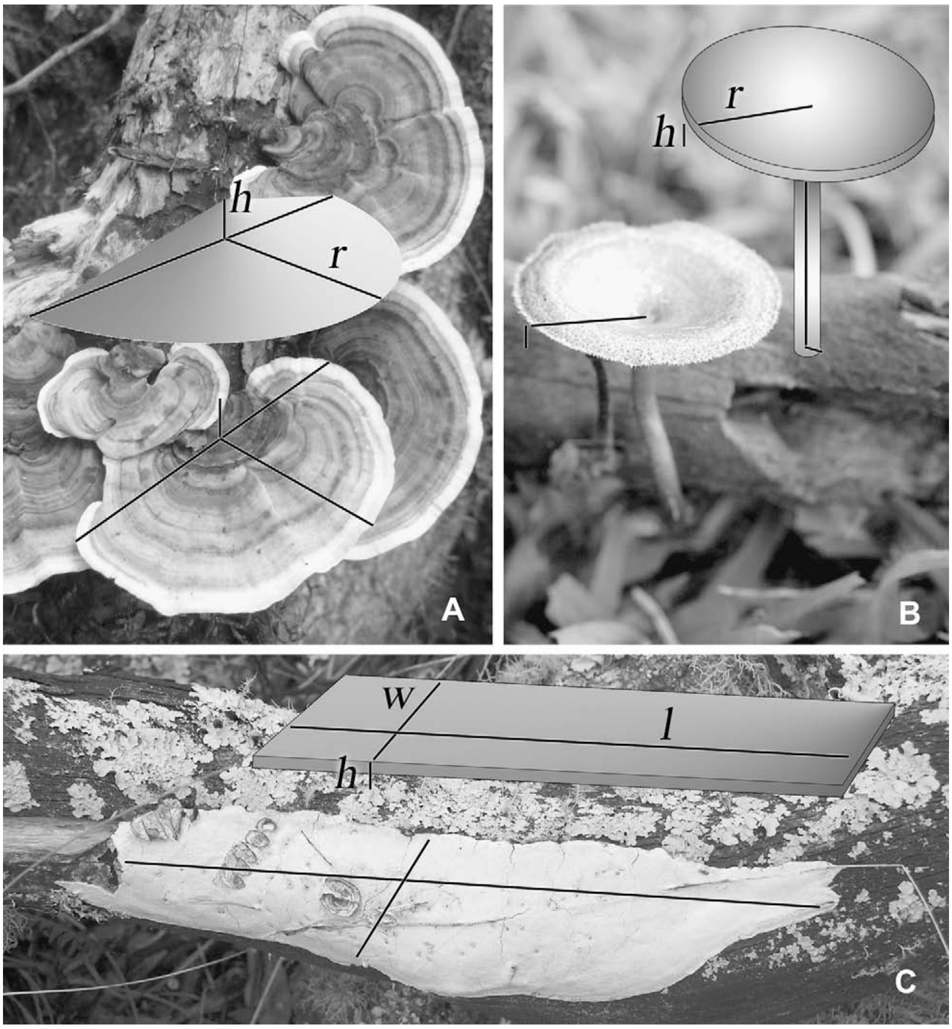

Fig 1 – Geometric representation of basidiocarps to calculate volume (see formulae in the text). (A) Demediate to ungulate; (B) stipitate; and (C) resupinate. Letters correspond to: *h*, height or thickness for resupinate; *r*, radius, *w*, width; and *l*, length.

and *T. villosa*. These species were included in the whole community analysis but were not analyzed for specific relationship due to insufficient data for correlation analysis.

The number of basidiocarps and volume of fructification of the whole polypore community positively correlated with log diameter albeit with different correlation coefficients (Table 1). The dominant species followed the same trends and the relationship was generally stronger for volume of fructification than for number of basidiocarps (Table 1). In particular, the positive relationship between volume of fructification and log diameter was highly significant for the whole community (Fig 3A), *B. adusta* (Fig 3B) and *T. cubensis* (Fig 3C) and marginally significant for *T. versicolor* (Fig 3D). These patterns were consistent across sites and sampling dates (data not shown).

Discussion

In the present study basidiocarp production was positively correlated with log diameter. To our knowledge this is the first report of this relationship in the field. Despite differences in mean log diameter between sites at different latitudes, the results followed the same trends within sites and for most variables, suggesting consistency of the observed general patterns.

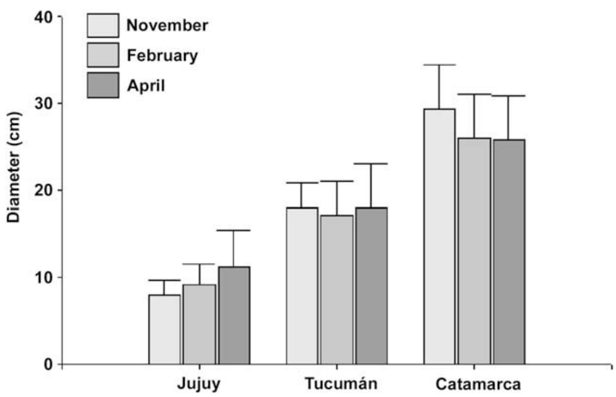

Fig 2 – Mean diameter of logs in which fructifications were found in three different sites across three sampling dates. Error bars indicate +1 SE.

Table 1 – Spearman correlation rank between log diameter (log_{10}) and number of basidiocarps (log_{10}) and volume of fructifications (log_{10}) of all polypore species, *Trametes cubensis*, *Bjerkandera adusta* and *Trametes versicolor* occurring in Andean Alder. *n* = number of fructifications

	All species ($n = 170$)	*T. cubensis* ($n = 31$)	*B. adusta* ($n = 34$)	*T. versicolor* ($n = 58$)
Number of basidiocarps	0.2649^d	0.3041^a	0.4963^c	0.2819^b
Volume of fructifications	0.5308^d	0.4677^b	0.4914^c	0.2210^a

$^a p < 0.1$, $^b p < 0.05$, $^c p < 0.01$, $^d p < 0.001$.

The polypores found in Andean Alder wood occurred in substrata ranging from trunks of living trees to dead fallen branches. *T. versicolor*, *B. adusta* and *T. cubensis* were the most abundant species in each functional group that occurs in different wood-decay stages and log diameters (Urcelay & Robledo 2004). The positive correlation between log diameter and basidiocarp production observed in the analysis of the whole community and for each dominant species individually, suggests that the relationship is consistent among species occupying different niches and successional stages. The relationship was less marked in *T. versicolor* known to occur in lower diameter classes (Urcelay & Robledo 2004). This suggests that the relationship between log diameter and basidiocarp production may be more important in higher diameter classes. In general, the relationship was stronger for volume of fructification than for number of basidiocarps, mainly when all species were included in the analyses. This pattern could be attributed to the fact that the analysis of the whole polypore community involved species that produce large imbricate clusters of basidiocarps (dominant species included here) and species with solitary or few basidiocarps (e.g. *G. australe*). In these last species, the relationship between log diameter and basidiocarp production was mainly reflected by volume but not by number. These findings suggest that volume, rather than number of basidiocarps, reflect potential reproductive success in response to substrate availability in polypores.

It is worth mentioning, that when the fructification was above one hundred basidiocarps, we considered them as 'one hundred' (see Materials and methods). These cases occurred only on the widest logs and contributed to underestimation of the positive relationship. Therefore, the *r* values for number and volume could be considered as conservative.

The lack of differences between sampling dates in mean diameter of logs in which fructifications were found, suggests that the substrate suitability for basidiocarp production is maintained from the beginning to the end of the rainy season.

Many studies have evaluated the relationship between log size and diversity of wood-decay fungi based on the occurrence of basidiocarps (Bader *et al.* 1995; Renvall 1995; Høiland & Bendiksen 1996; Lindblad 1998; Siitonen *et al.* 2001; Snäll & Jonsson 2001; Heilmann-Clausen & Christensen 2004; Penttilä *et al.* 2004; Urcelay & Robledo 2004), however, less attention has been paid to quantity of basidiocarps. The observed positive relationship between log diameter and basidiocarp

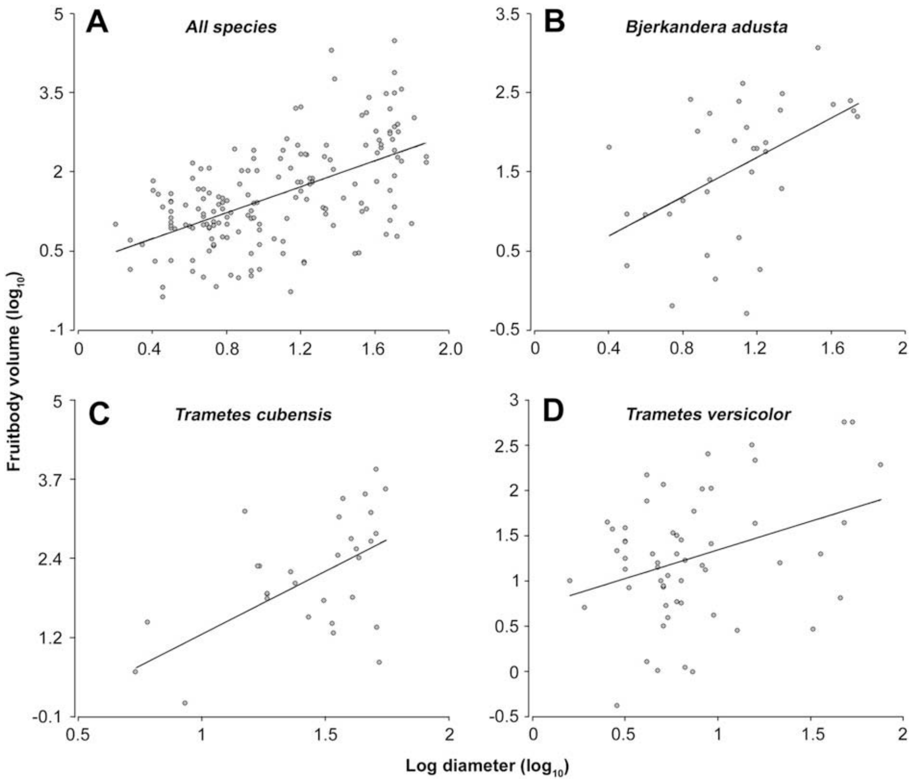

Fig 3 – Relationships between log diameter (log_{10}) and volume of fructification (log_{10}) of: (A) whole polypore community; (B) *Bjerkandera adusta*; (C) *Trametes cubensis*; and (D) *Trametes versicolor* occurring in Andean Alder forests.

production support our hypothesis and suggests that log diameter may be important for the sexual reproductive structures of wood-inhabiting fungi.

Previous studies have shown a positive relationship between size of log and spore dispersion–dikariotisation (Edman *et al.* 2004a, b) and in turn gene flow (Högberg & Stenlid 1999; Stenlid & Gustafsson 2001). Our results suggest that these relationships could not be solely accounted by the mere presence or absence of the polypore species as has been suggested, but also by the basidiocarp production. This hypothesis certainly deserves further study to understand the mechanisms behind the effects of forest management on population dynamics and community structure of polypores.

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