British Mycological Society promoting fungal science
journal homepage: www.elsevier.com/locate/funbio

Increased heat resistance in mycelia from wood fungi prevalent in forests characterized by fire: a possible adaptation to forest fire

*Fredrik CARLSSON**, *Mattias EDMAN*, *Svante HOLM*, *Anna-Maria ERIKSSON*, *Bengt Gunnar JONSSON*

Department of Natural Sciences, Engineering and Mathematics, Mid Sweden University, Holmgatan 10, 851 70 Sundsvall, Sweden

ARTICLE INFO

Article history:
Received 6 May 2011
Received in revised form
5 July 2012
Accepted 9 July 2012
Available online 15 August 2012
Corresponding Editor:
Anna Rosling

Keywords:
Adaptation
Basidiomycetes
Competition
Dead wood
Ecology
Forest fire
Mycelia
Resistance to heat
Restoration fires
Saprotrophic

ABSTRACT

Forest fires have been the major stand-replacing/modifying disturbance in boreal forests. To adapt to fire disturbance, different strategies have evolved. This study focuses on wood fungi, and a specific adaptation to forest fire: increased heat resistance in their mycelia. Fifteen species of wood fungi were selected and a priori sorted in two groups according to their prevalence in fire-affected environments. The fungi were cultivated on fresh wood and exposed to 100, 140, 180, 220 °C for 5, 10, 15, 20 and 25 min. under laboratory conditions. A clear difference was found among the two groups. Species prevalent in fire-affected habitats had a much higher survival rate over all combinations of time and temperature compared to species associated with other environments. Thus, the results indicate that fire adaptation in terms of increased heat resistance in mycelia occurs in some species of wood fungi. Such adaptation will influence the ecology and population dynamics of wood fungi, as well as having implications for best practices during restoration fires.

Introduction

Wood fungi are the primary decomposers of dead wood in boreal forests. They are ecologically important in a number of ways. As decomposers, they contribute to the turnover of nutrients and organic matter. Over time, the breakdown of fallen and standing trees will result in logs with different chemical and structural composition and hence provide a broad diversity of substrates on the forest floor and in the soil. From a biodiversity perspective, the presence of these fungal species contributes to the variability of dead wood, which is a prerequisite for many other saproxylic species (Renvall 1995; Jonsson *et al.* 2005). Many threatened and red-listed species are found among the wood fungi (Larsson 1997; Gärdenfors 2010). Knowledge of their habitat requirements and how they respond to environmental

* *Corresponding author*. Tel.: +46 60148557; fax: +46 60148802.
E-mail address: fredrik.carlsson@miun.se (F. Carlsson)
1878-6146/$ – see front matter
http://dx.doi.org/10.1016/j.funbio.2012.07.005

factors is needed to correctly analyze possible causes for their decline.

Forest fire is the main disturbance factor in boreal forests (Zackrisson 1977; Wein & McLean 1983; Pyne et al. 1996; Linder et al. 1997; Östlund et al. 1997; Ryan 2002). Over the course of time, many boreal forest species including wood fungi have adapted to repeated fires. Today, forest fires are suppressed in Fennoscandia (Zackrisson 1977; Niklasson & Granström 2000) and many species favoured by or adapted to fire are declining and several are considered threatened or near threatened (Berg et al. 2002; Gärdenfors 2010; Rassi et al. 2010). Restoration fires are increasingly being used as a management tool and species richness of wood fungi is high in areas subjected to restoration burning (Penttilä 2004; Olsson & Jonsson 2010).

Fire suppression in Fennoscandia is a part of forest management and has excluded fires also in fire prone habitats such as dry pine forests (Niklasson & Granström 2000). For fungal species confined to pine, the loss of fire from the ecosystem poses a serious threat. Fire regimes in spruce forests are generally different as these forests burn with a lower frequency. The fire severity is however much greater with a greater consumption of substrates (Penttilä 2004), suggesting a lower selection pressure on spruce inhabiting species. It has been shown that rare wood fungi associated with spruce suffer to a greater extent if there is stand replacing disturbance (modern forestry), when compared to pine-confined species (Penttilä et al. 2006). One theory is that forest fire has promoted evolution of a more potent spore dispersal mechanism in pine species (Edman et al. 2004; Penttilä 2004) which would theoretically ensure re-colonization after disturbances.

An organism can however adapt in several different ways to a disturbance. For a wood fungus to avoid extinction in a forest system subjected to fire, two possible survival strategies exist; (1) by having a short generation time and good dispersal ability, thus increasing the probability of re-colonizing dead trees and reproducing before consumed by the fire or (2) by surviving fire inside a dead tree or in the soil.

Previous studies on wood fungi and temperature have mainly focused on optimum temperature and growth range of these fungi, including relatively high temperatures, but have not addressed maximum heat tolerance. Some studies have explored lethal temperatures, but the focus of these studies has mainly been on control and protection against wood fungi (Humphrey & Siggers 1933; Cartwright & Finlay 1958; Ammer 1964; Cockroft 1981; Miric & Willeitner 1984; Törnqvist et al. 1987; Viitanen & Ritshkoff 1991; Schmidt & Huckfeldt 2005). Schmidt (2006) merged these data, showing that optimum growth temperature varies across a range of species, and strains among the same species between 20 °C and 37 °C. Mawaka & Magan (1999) showed similar results but also added the total growth range for both boreal and tropical species which ranges from 0 °C (minimum for all species) to 56 °C (maximum for any species). Moreover, some species can survive up to 95 °C for 4 h if studied in its natural substrate and some species can survive up to 2 weeks with highly elevated temperatures in comparison to their normal growth range (among them *Gloeophyllum sepiarium*; Schmidt 2006). In another study, maximum heat tolerance in a range of wood inhabiting fungi was tested (Ramsfield et al. 2010). The majority of the species tested could tolerate a maximum temperature of between 56 °C and 66 °C for 1 min. However, the cited studies do not provide data that will allow for comparison of a larger set of species, in relation to forest fire.

This study focuses on heat tolerance in mycelia from wood decaying basidiomycetes. It is an important step towards a broader understanding of the adaptation possibilities in this species group. We aim to evaluate the survival ability of mycelia from a range of pine- and spruce-associated species, subjected to different temperatures for different lengths of time. Species were sorted a priori in two groups: species occurring in forest stands subjected to fire or with dry sun-exposed conditions, and species occurring in closed forest conditions.

Materials and methods

Studied species

Twelve different species with a preference for colonizing Scots pine (*Pinus sylvestris* L.) and three species confined to Norway spruce (*Picea abies* (L.) Karst) were selected for the study. All species are saprotrophic except for *Phellinus pini*, which is strictly parasitic. Based on a growing body of empirical observations these species were divided into two groups: fire-associated and nonfire-associated species (Table 1).

The species classified as fire-associated are mainly found in natural forests with a history of fire influence with most

Table 1 – Wood decaying basidiomycete species (and adherent GenBank and CBS accession nr.) Grouped according to association with forest fire. Dominating natural substrates are shown in brackets and substrate used in the heat tolerance experiment is underlined.

Fire-associated species	GenBank	CBS	Nonfire-associated species	GenBank	CBS
Dichomitus squalens (<u>pine</u> and spruce)	JQ518275	–	*Fomitopsis pinicola* (<u>pine</u> and spruce)[a]	JQ518283	–
Phlebiopsis gigantea (<u>pine</u> and spruce)	JQ518278	–	*Ischnoderma benzoinum* (<u>pine</u> and spruce)	JQ518274	–
Gloeophyllum sepiarium (<u>pine</u> and spruce)	JQ518282	–	*Phellinus pini* (<u>pine</u>)	JQ437410	–
G. protractum (<u>pine</u>)	JQ518280	CBS132523	*Skeletocutis amorpha* (<u>pine</u> and spruce)	JQ518277	–
Junghuhnia luteoalba (<u>pine</u> and spruce)	JQ518279	CBS132524	*Antrodia serialis* (<u>spruce</u>)	JQ518284	CBS132521
Oligoporus sericeomollis (<u>pine</u> and spruce)	JQ518276	CBS132842	*Phlebia centrifuga* (<u>spruce</u>)	JQ518272	–
A. infirma (<u>pine</u>)	JQ518281	–	*Phellinus ferrugineofuscus* (<u>spruce</u>)	JQ518285	CBS132519
A. sinuosa (<u>pine</u> and spruce)	JQ518273	CBS132522			

a Fomitopsis pinicola are common on many conifer and deciduous species.