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Review

Fungal decay of western redcedar wood products– a review

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ABSTRACT

Western redcedar (WRC; *Thuja plicata* Donn) is widely used in outdoor building applications where the natural decay resistance of its heartwood is highly valued. However, as demonstrated in laboratory and field tests, the durability of WRC can be compromised under a variety of circumstances and conditions. The dynamics of the wood decay process are not well-understood. Several fungi, including more than 30 wood decay fungi, have been isolated from WRC wood products in service. However, little is known about the frequency with which these species occur, their succession patterns, the mechanisms involved, or their responses to fungicidal extractives. To ensure the accurate selection of WRC planting stock for heartwood resistance to fungal decay it is crucial that research be initiated to understand the relationship between WRC's natural durability and the suite of extractive-detoxifying and decay fungi that grow on WRC wood products. Moreover, improved knowledge of the fungi that biodegrade WRC wood products is essential for developing new approaches to improve the service life of this valuable species.

Contents

1. Introduction

Western redcedar (*Thuja plicata* Donn) is a naturally decay resistant softwood native to the Pacific Northwest of North America (Sowder, 1929). It grows along the coast from Alaska to California and inland in British Columbia, Washington, Idaho, and Montana,

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though the bulk of the resource is located in British Columbia. Western redcedar (WRC) has long been used by the indigenous peoples of the Pacific Northwest for a wide range of applications (Hebda and Mathewes, 1984). European settlers began using WRC in the mid-1800s and industrial production in the Pacific Northwest soon followed. Plantations of WRC have since been established in Europe and New Zealand. WRC is widely used in applications where it is valued for its dimensional stability, unique colour and pleasing appearance, and natural decay resistance (Gonzalez, 2004). WRC is widely used in North America and is exported to Europe, Australia, China, and Japan. Major end uses include shakes and shingles, siding, decking, and fence boards (Gonzalez, 2004). Canadian exports typically range from 1.0 to 1.5 billion board feet annually (Gonzalez, 2004). WRC is also used for utility poles, with approximately 155,000 produced annually in Canada and the United States (Freeman and Stirling, 2014).

The natural decay resistance of WRC, and its associated heartwood extractives, began to attract research interest in the early 20th century (Sowder, 1929) and it has since become one of the world's most intensively studied naturally durable woods. Laboratory and field test performance data led to WRC being included in European and Australian natural durability standards (e.g., CEN, 1994; Standards Australia, 2005). Using a five-class system based on the results of laboratory decay tests, the European standard lists wood from North American-grown WRC as durability class 2 (durable). Using a four-class system based on extensive, multi-site field tests, the Australian standard lists WRC as class 3 in ground contact and class 2 in above-ground applications. North American classification of naturally durable woods has been documented (Clausen, 2010), but not standardized due to lack of North American performance data and the absence of well-defined quality assurance methods (Morris et al., 2011b). Early research on WRC extractives led to the conclusion that the thujaplicins are primarily responsible for the decay resistance of WRC with a lesser or negligible role for the lignans and terpenes (Nault, 1988). More recent work suggests a much more important role for the lignans as discussed below.

The WRC resource used in the manufacture of wood products was originally dominated by trees sourced from old-growth forests. On the coast of British Columbia, old-growth forests are those older than 250 years, while in the interior old-growth forests are those older than 120–140 years (BC Ministry of Forests, 2003). Whatever their exact age, WRC trees from old-growth forests tend to have a high heartwood to sapwood ratio, fewer knots, and a high incidence of heart rot (Buckland, 1946). Wood in the outer heartwood of old-growth WRC trees also has high concentrations of extractives (Nault, 1988; Daniels and Russell, 2007). Although some young second growth has much lower thujaplicin content than old growth, the decay resistance of wood from old-growth and second-growth WRC sourced from managed forests has been found to be similar (Freitag and Morrell, 2001; Morris et al., 2016). Old-growth WRC is still harvested in the Pacific Northwest in significant quantities, but second-growth material is making up a slowly increasing amount of the fibre supply. The decay resistance of wood from WRC grown in Europe and New Zealand is reported to be similar or slightly less than that of North American-grown old-growth (Cartwright, 1941; Flæte et al., 2011).

In use, WRC wood products may be exposed to a variety of biodeterioration hazards. Classification systems for these hazards have been developed by groups in several countries, including the American Wood Protection Association (AWPA, 2016c) in the USA. All systems define decay hazards based on whether wood is used in exposed, above-ground applications or in ground-contact applications. The hazard of decay to wood used in ground-contact applications is generally higher than that to wood used in above-ground applications. This is due to the conditions found in soil but not above ground, i.e., a continuous moisture supply, macro-and micronutrients, compounds that bind extractives, soft-rot fungi, and mycelium or strands of wood-rotting basidiomycetes (Wakeling and Morris, 2014) as well as reduced temperature fluctuations. As a result, WRC is often treated with a wood preservative when used in ground contact (Freeman and Stirling, 2014).

Above-ground exposure of wood is generally less conducive to decay. Decay initiation is most often by spores rather than growing mycelia. Climate also has a strong influence on above-ground decay hazards, with warm and wet conditions generally most conducive to decay. Global climate change is impacting the above-ground decay hazard in many locations (Morris and Wang, 2008; Lebow and Carll, 2010), so past durability performance in a given location may not be predictive of future performance. Areas now experiencing warmer temperatures and higher concurrent rainfall can anticipate more rapid above-ground decay than in the past.

The natural decay resistance of wood like that occurring in WRC has taken on greater significance in the 21st century as the use of wood in service is increasingly acknowledged as a tool critical to combatting climate change (Eriksson et al., 2007). The longer wood resists decay, the greater its value as a carbon sink. Like all wood products, those made from WRC will be more prone to decay when exposed to environmental conditions that are favourable for fungal growth. The present work provides and overview of current knowledge about the organisms that occur on WRC wood products and affect product performance, the laboratory and field tests that assess the durability of WRC heartwood, and management options for maximizing decay resistance in WRC wood products. This work is intended to complement a recent publication about decay in living WRC (Sturrock et al., 2017), where there is an in-depth review of western redcedar extractives and of approaches to managing decay in western redcedar trees and products, including the potential for using tree breeding to enhance durability. Examples of decay in WRC wood products are shown in Figs. 1–4.

2. Colonization of WRC wood products

2.1. Fungi

Several authors report fungi isolated from a wide range of WRC wood products in service, including shingles, fence posts, and utility poles (Tables 1 and 2). The list includes mostly fungi belonging to the Basidiomycota (17 white rots and 16 brown rots), as well as several fungi from the Ascomycota that cause soft rot or

Fig. 1. Evidence of decay on the in-ground portion of a WRC fence post after 6 years in Maple Ridge, British Columbia.