

Article

Biological Durability of Sapling-Wood Products Used for Gardening and Outdoor Decoration

Christian Brischke *, Lukas Emmerich, Dirk G.B. Nienaber and Susanne Bollmus

Wood Biology and Wood Products, University of Goettingen, D-37077 Goettingen, Germany; lukas.emmerich@uni-goettingen.de (L.E.); dirk.nienaber94@gmail.com (D.G.B.N.); susanne.bollmus@uni-goettingen.de (S.B.)

* Correspondence: christian.brischke@uni-goettingen.de

Received: 28 November 2019; Accepted: 13 December 2019; Published: 17 December 2019



Abstract: Sapling-wood products from different wood species such as willow (*Salix* spp. L.) and Common hazel (*Corylus avellana* L.) are frequently used for gardening and outdoor decoration purposes. Remaining bark is suggested to provide additional biological durability. Even for temporary outdoor use it seemed questionable that durability of juvenile sapwood can provide acceptably long service lives of horticultural products. Therefore, sapling-wood from seven European-grown wood species was submitted to laboratory and field durability tests. In field tests, specimens with and without bark were tested in comparison and submitted to differently severe exposure situations, i.e., in-ground contact, and above-ground situations with and without water trapping. All materials under test were classified ‘not durable’ independently from any potential protective effect of remaining bark, which contradicted their suitability for outdoor applications if multi-annual use is desired.

Keywords: basidiomycetes; fungal decay; horticulture; juvenile wood; resistance; sapwood

1. Introduction

The biological durability of most European-grown wood species is often insufficient for outdoor applications and wood needs protection either by design, wood modification, or wood preservation as pointed out in prEN 460 (Durability of wood and wood-based products—Natural durability of solid wood—Guide to the durability requirements for wood to be used in hazard classes [1]). Nevertheless, more recently, some wood species were advertised and customized for gardening and outdoor decoration purposes, although their durability is generally considered low, but had been rarely studied systematically. Among those, Common hazel (*Corylus avellana* L.) and different willow species (*Salix* spp. L.) are suggested for climb supports for clamberers [2,3], paling and woven fences [4], fascines, screens, flower bed edgings, raised beds, and other decoration items (Figure 1). Frequently, such products are manufactured from sapling-wood (here defined as roundwood from stems of less than 10 years of age) and bark is not removed since it is suggested to provide additional biological durability.

Goat willow (*Salix caprea*) is classified as ‘non-durable’ (DC 5, [5]), although some previous studies indicated slightly higher durability [6], i.e., DC 4. The durability of Common hazel is not classified within EN 350 (Durability of wood and wood-based products—Testing and classification of the durability to biological agents of wood and wood-based materials [5]). However, sapling-wood is juvenile wood. The latter has previously been reported to be less durable than adjacent mature wood for different wood species [7–11]. In addition, sapling-wood is exclusively sapwood, which is per definition ‘non-durable’ according to EN 350 [5], independent from the wood species. Consequently, it is hypothesized that sapling-wood is the least durable kind of xylem and manufacturing sapling-wood

products for outdoor use appears questionable, especially when ground contact is proposed such as for fences and fascines.



Figure 1. Examples of using Common hazel wood for gardening, outdoor decoration, and historical use for stabilization of soil. Left: climb support for roses; Center: miniature woven fence; Right: reproduction trench during World War I in Belgium.

Bark tissue of various wood species is known for containing substantial amounts of extractives which can have inhibitory effects on fungal growth and wood degradation. Bark extractives such as different organic acids, tannins, and alkaloids have, therefore, been used to improve the biological durability of wood and other lignocellulosic products as previously reported by different authors [12–15]. Bark itself has been used for application where biological durability is requested, that is, such as for roofing [16,17], boats [18,19], and mulch [20]. Recommendations to leave bark on sapling-wood products could therefore be meaningful, although it contains rather thin layers of bast and thick layers of secondary bark. The latter contains usually significantly more extractives than bast, but the ratio as well as the total amount of extractives is tree species specific [21]. Apart from potential biocidal or inhibitory effects of extractives, bark might serve as a chemo-mechanical barrier for moisture and can protect the wood tissue beneath from wetting for instance due to hydrophobic substances (e.g., suberin, resin acids) or the formation of thyloses. In contrary, re-drying of once wetted wood is inhibited by bark layers as well.

This study aimed at examining the natural biological durability of sapling-wood comprehensively. Therefore, sapling-wood from seven European-grown wood species was submitted to laboratory and field durability tests. In field tests, specimens with and without bark were tested in comparison and submitted to differently severe exposure situations, i.e., in-ground contact and above-ground situations with and without water trapping, to fully reflect the anticipated in-use conditions of gardening products available in specialized trade.

2. Materials and Methods

2.1. Wood Specimens

For laboratory decay resistance tests, sapling-wood was sampled from young trees (less than 10 years old) of English oak (*Quercus robur*, Oak), Common hazel (*Corylus avellana*, Hazel), Black cherry (*Prunus serotina*), White willow (*Salix alba*, Willow), European beech (*Fagus sylvatica*, Beech), Silver birch (*Betula pendula*, Birch), Rowan (*Sorbus aucuparia*), and Scots pine (*Pinus sylvestris*) at different stands in Lower Saxony, Germany. For laboratory decay tests, specimens with a length of 50 ± 1 mm and an average diameter (without bark) between 17.3 and 20.9 mm. The target diameter of the sapling-wood specimens at a given length of 50 mm was $d_{\text{target}} = 21.9$ mm according to Equation (1). However, the diameter of the collected samples varied around the target value as shown in Table 1.

$$d_{target} = \sqrt{\frac{A_{CEN\ TS\ 15083-1}}{\pi}} \cdot 2 \text{ (mm)} \quad (1)$$

where, d_{target} is the target diameter of the sapling-wood specimens, in mm; $A_{CEN\ TS\ 15083-1}$ is the cross-sectional specimen area acc. to CEN/TS 15083-1 (2005) = 375 mm².

The bark was peeled off immediately after cutting the trees. In addition, sapwood specimens of 15 × 25 × 50 mm³ were cut from Beech, Hazel, Willow, Birch, and Scots pine according to CEN/TS 15083-1 (Durability of wood and wood-based products—Determination of the natural durability of solid wood against wood-destroying fungi, test methods—Part 1: Basidiomycetes [22]). For each test fungus, 16 replicate specimens were used. Further detailed information about the specimens is summarized in Table 1. For the different field tests, sapling-wood was sampled from the same species as listed above, but separate sets of specimens were prepared with and without bark. The length of the field test specimens was 500 mm, the mid-length diameter varied between 15 and 50 mm (Table 1). For each test set-up, 10 replicates with and without bark were exposed, resulting in 60 specimens per each wood species.

Table 1. Wood species and specimen mid-length diameter used in laboratory decay tests ($n = 16$), in-ground field tests ($n = 10$), above-ground tests ($n = 10$), and above-ground sponge tests ($n = 10$).

Wood Species	Botanical Name	Diameter (mm)						
		Lab Decay Test	In-Ground Field Test		Above-Ground Field Test		Above-Ground Sponge Field Test	
		Without Bark	With Bark	Without Bark	With Bark	Without Bark	With Bark	Without Bark
English oak	<i>Quercus robur</i>	17–22	20–38	20–29	18–36	12–32	18–33	15–37
European beech	<i>Fagus sylvatica</i>	16–18	20–37	23–38	18–35	11–36	20–40	18–39
Common hazel	<i>Corylus avellana</i>	17–21	21–33	17–35	17–37	18–36	15–39	18–37
Black cherry	<i>Prunus serotina</i>	17–22	17–33	17–34	14–37	14–37	14–28	15–40
Rowan	<i>Sorbus aucuparia</i>	16–25	22–31	18–33	20–33	14–34	22–33	17–30
White willow	<i>Salix alba</i>	18–22	15–50	21–44	14–45	13–42	12–34	13–36
Silver birch	<i>Betula pendula</i>	16–20	20–50	22–39	22–43	21–33	17–35	19–37
Scots pine	<i>Pinus sylvestris</i>	18–22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

2.2. Durability Test with Basidiomycete Monocultures

Laboratory decay resistance tests were conducted according to a modified CEN/TS 15083-1 [22] protocol as follows: all specimens were oven-dried at 103 ± 2 °C for 48 h, weighed to the nearest 0.001 g, and afterwards conditioned at 20 °C/65% relative humidity (RH) until constant mass. After sterilization in an autoclave at 121 °C and 2.4 bar for 20 min, two specimens of the same species were placed on fungal mycelium in a Kolle flask. To avoid direct contact between wood and overgrown malt agar (4%) stainless steel washers were used. The incubation time was 16 weeks. The following test fungi were used: *Coniophora puteana* = (Schum.:Fr.) P. Karsten BAM Ebw. 15 and *Trametes versicolor* = (L.:Fr.) Pilat CTB 863A. After incubation, the specimens were cleaned from adhering mycelium, weighed to the nearest 0.001 g, and mass loss (ML) calculated according to Equation (2).

$$ML_f = \frac{m_{0,i} - m_{0,f}}{m_{0,i}} \cdot 100 (\%) \quad (2)$$

where, $m_{0,i}$ is the oven-dry mass before incubation, in g; $m_{0,f}$ is the oven-dry mass after incubation, in g.

2.3. Field Durability Tests

Specimens with and without bark, each of 500 mm length, were exposed outdoors in three different settings. Firstly, specimens were buried to half of their length in the loamy soil on the in-ground field test site at the University of Goettingen (51°33'34.6"N 9°57'19.1"E) in September 2017. At the Goettingen test site brown, white, and soft rot decay occur. To avoid the growth of grass and other plants a horticultural water permeable textile sheet was placed on the soil. Secondly, specimens were placed horizontally on aluminum L-profiles (4 × 30 × 60 mm) with a distance of 10 mm to each other. In a third test setting specimens were wrapped with cellulose sponges (thickness: 5 mm, width: 100 mm), which were fixed with two cable strips at the center of the specimens and served for water trapping (Figure 2).



Figure 2. Field tests with sapling wood specimens. (a): in-ground exposure. (b): specimens with and without bark, partly wrapped with a cotton sponge.

Decay was assessed every 6 months (results during first 1.5 years of exposure are reported). Therefore, the specimens were evaluated according to EN 252 (Field test method for determining the relative protective effectiveness of a wood preservative in ground contact [23]) using a pick-test where a pointed knife was pricked into the specimens and backed out again. The fracture characteristics of the splinters as well as depth and appearance of decay were assessed visually, and referred to the evaluation scheme according to EN 252 [23] (Table 2). Due to varying cross-sectional areas of the specimens and their circular shape, the rating system had to be adjusted. Therefore, based on the depth of decay the minimum intact cross-sectional area was determined according to Equation (3). The latter was assigned to the five different rating steps according to EN 252 [23], based on the percentage minimum remaining intact cross-sectional area A_{intact} as shown in Table 2. A_{intact} and the corresponding adapted decay rating according to EN 252 [23] were determined for each specimen separately, considering the individual mid-length diameters of the specimens.

$$A_{intact} = \frac{\left(\frac{d_i}{2} - s_{decay}\right)^2 \cdot \pi}{\left(\frac{d_i}{2}\right)^2 \cdot \pi} (\%) \quad (3)$$

where, A_{intact} is the minimum remaining intact cross-sectional area, in %; d_i is the initial diameter of specimen, in mm; s_{decay} is the maximum depth of decay in mm.

Table 2. Decay rating scheme according to EN 252 [23], corresponding maximum depth of decay s_{decay} , and remaining minimum intact cross-sectional area A_{intact} .

Rating	Description	s_{decay} (mm)	A_{intact} (mm ²)	A_{intact} (%)
0	No attack	0	1250	100
1	Slight attack	1	1104	88
2	Moderate attack	3	836	67
3	Severe attack	5	600	48
4	Failure	50	0	0

3. Results and Discussion

3.1. Durability against Basidiomycetes

The average mass loss (ML_f) caused by *C. puteana* was between 32% and 50%, and between 24% and 48% after incubation with *T. versicolor* (Figure 3). The median ML_f caused by *C. puteana* was well above 30% corresponding to durability class 5 (DC 5, ‘not durable’) according to CEN/TS 15083-1 [21] and EN 350 [5]. Sapwood of any wood species is ‘not durable’ as defined in EN 350 [5], although several studies showed that sapwood of different wood species showed less than 5% median ML_f in laboratory decay tests according to CEN/TS 15083-1 [22] or similar test protocols such as Atlas cedar (*Cedrus atlantica* (Endl.) Manetti, [24]), Red maple (*Acer rubrum* L., [25]), Douglas fir (*Pseudotsuga menziesii* Franco., [26]) and different other American conifers [27]. However, in most cases where durability was assigned better than DC 5 might be related (1) to its within-species variation and (2) to varying virulence of the respective test fungus with respect to discrete ML_f boundaries for the different DC according to CEN/TS 15083-1 [22].

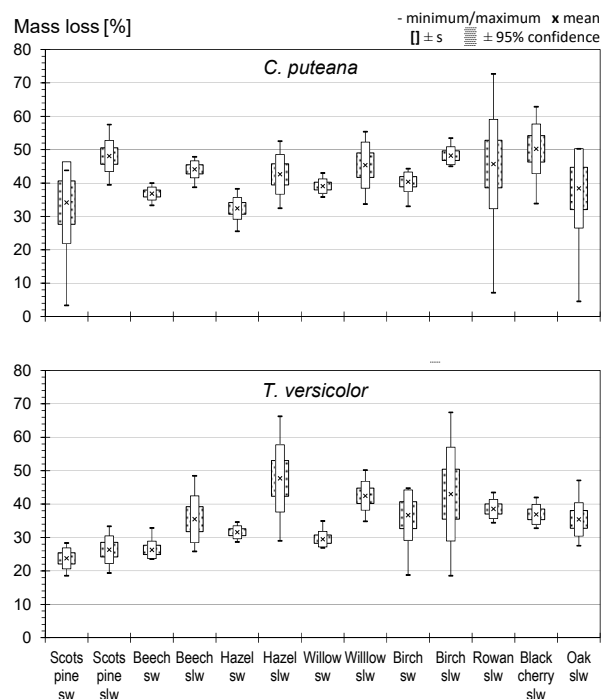


Figure 3. Mass loss (ML_f) of sapwood (sw) and sapling-wood (slw) specimens after 16 weeks of incubation with *Coniophora puteana* and *Trametes versicolor*.

In most cases, ML_f of sapling-wood was significantly higher compared to sapwood of the same wood species, which underpins the hypothesis that juvenile wood, which has still not undergone any heartwood formation, can be considered less durable than regular sapwood.

3.2. Durability against Fungal Decay in Field Tests

All in-ground specimens failed after only 1 year of exposure (Figure 4), which coincides with decay rates determined for beech wood in a test field in Hannover, Germany, where the average service life of standard graveyard test specimens was between 0.6 and 0.9 years [28]. In-ground decay was initiated generally faster in specimens without bark, but different decay rates between sets with and without bark were equalized during the second half-year of exposure.

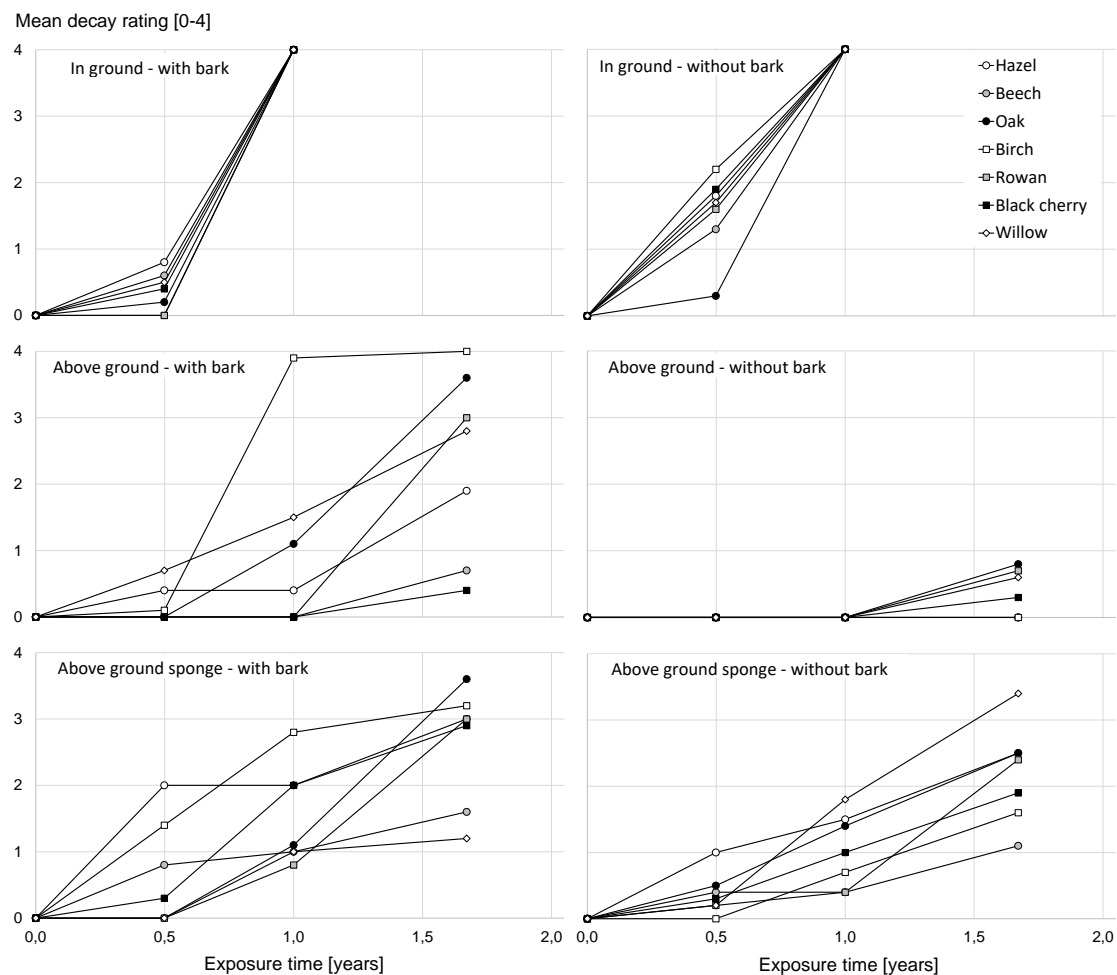


Figure 4. Mean decay rating of field test sapling-wood specimens with and without bark in-ground and above-ground exposed as single specimens with and without sponge wrapping for moisture trapping.

Specimens exposed 1 m above ground showed first signs of decay at least after 1.7 years of exposure, and earlier in most cases. Specimens with bark decayed slightly faster than those where bark had been removed before exposure. Wrapping a sponge around the center of the specimens led to higher decay rates only in specimens without bark. Similar acceleration measures were previously applied to L-joint specimens by Van Acker and Stevens [29] and led to increased decay rates compared to specimens without water capturing. In contrast, within this study permanent moistening of the bark might have improved the performance of the bark envelope around the cylindrical specimens. Especially on Beech, severe flaking of bark was observed, as shown in Figure 5, which then led to an increased formation of cracks. Consequently, the expected negative effect of wetting on the durability of the specimens was superposed by positively affecting the integrity of the protective bark layer. In specimens without bark, decay was significantly accelerated by wrapping sponges.



Figure 5. Visual appearance of above-ground specimens after 6 months of exposure. (a): severe flake off of bark on Beech specimens with sponge wrapping. (b): formation of cracks in Hazel specimens without bark.

After 2 years of exposure, all above-ground specimens showed at least moderate decay, most specimens were severely decayed or had failed. Provided that mechanical strength is not an issue for the respective application, the service life of all sapling-wood specimens was less than 1 year when exposed in ground, and less than 2 years when exposed above ground. The serviceability of fences or load-bearing items such as climbing supports would have been lost earlier. Differences in decay rate between wood species were statistically insignificant, which can also be related to their general low durability and thus to short service lives of all tested materials.

4. Conclusions

Sapling-wood from seven different tree species turned out to be not durable, both in laboratory and different field tests. Against advertisement promises and as expected from studies on the durability of sapwood and juvenile heartwood of various wood species, the durability of sapling-wood, which is considered juvenile sapwood, was even lower than common sapwood. Protective effects of remaining bark were not observed. It is therefore expected that service lives of gardening and outdoor decoration accessories made from sapling-wood are generally low. In particular, under Central European climatic conditions the service life is barely 2 years in above-ground and 1 year in in-ground contact. The effect of additional water capturing seemed to be negligibly small due to the very low durability of the material itself.

Author Contributions: C.B. was mainly responsible for the conceptualization, methodology used, data evaluation, data validation, and formal analysis. Investigations and data curation were conducted by D.G.B.N. and L.E. The original draft of this article was prepared by C.B., S.B. and L.E. who was also responsible for the review and editing process of this article. C.B. and L.E. did care for the visualization.

Funding: This research received no external funding.

Acknowledgments: Martin Rosengren, Mirko Küppers, and Rainer Henke are acknowledged for providing sapling-wood test material and corresponding sapwood portions.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. prEN 460. *Durability of Wood and Wood-Based Products—Natural Durability of Solid Wood—Guide to the Durability Requirements for Wood to Be Used in Hazard Classes*; European Committee for Standardization: Brussels, Belgium, 2018.
2. Uglow, J. *A Little History of British Gardening*; Random House: Munich, Germany, 2012.
3. Larkcom, J. *Creative Vegetable Gardening*; Hachette UK: London, UK, 2017.

4. Buch, C.; Kasielke, T.; Mörtl, B. *Corylus avellana*—Gewöhnliche Hasel, Haselstrauch (Betulaceae). *Jahrb. Boch. Bot. Ver.* **2016**, *7*, 197–211.
5. EN 350. *Durability of Wood and Wood-Based Products—Testing and Classification of the Durability to Biological Agents of Wood and Wood-Based Materials*; European Committee for Standardization: Brussels, Belgium, 2016.
6. Meyer-Veltrup, L.; Brischke, C.; Alfredsen, G.; Humar, M.; Flæte, P.O.; Isaksson, T.; Larsson Brelid, P.; Westin, M.; Jermer, J. The combined effect of wetting ability and durability on outdoor performance of wood: Development and verification of a new prediction approach. *Wood Sci. Technol.* **2017**, *51*, 615–637. [[CrossRef](#)]
7. Gierlinger, N.; Jacques, D.; Grabner, M.; Wimmer, R.; Schwanninger, M.; Pâques, L.E. Colour of larch heartwood and relationships to extractives and brown-rot decay resistance. *Trees* **2004**, *18*, 102–108. [[CrossRef](#)]
8. Bhat, K.M.; Thulasidas, P.K.; Florence, E.M.; Jayaraman, K. Wood durability of home-garden teak against brown-rot and white-rot fungi. *Trees* **2005**, *19*, 654–660. [[CrossRef](#)]
9. Dünisch, O.; Richter, H.G.; Koch, G. Wood properties of juvenile and mature heartwood in *Robinia pseudoacacia* L. *Wood Sci. Technol.* **2010**, *44*, 301–313. [[CrossRef](#)]
10. Latorraca, J.V.; Dünisch, O.; Koch, G. Chemical composition and natural durability of juvenile and mature heartwood of *Robinia pseudoacacia* L. *An. Acad. Bras. Cienc.* **2011**, *83*, 1059–1068. [[CrossRef](#)] [[PubMed](#)]
11. Blohm, J.H. Holzqualität und Eigenschaften des juvenilen und adulten Holzes der Douglasie (*Pseudotsuga menziesii* (Mirb.) Franco) aus Süddeutschen Anbaugebieten. Ph.D. Thesis, University of Hamburg, Hamburg, Germany, 2015.
12. Doi, S.; Kurimoto, Y. Durability of sugi (*Cryptomeria japonica* D. Don) bark against wood decay fungi and a subterranean termite. *Eur. J. Wood Wood Prod.* **1998**, *56*, 178. [[CrossRef](#)]
13. Nemli, G.; Gezer, E.D.; Yıldız, S.; Temiz, A.; Aydın, A. Evaluation of the mechanical, physical properties and decay resistance of particleboard made from particles impregnated with *Pinus brutia* bark extractives. *Bioresour. Technol.* **2006**, *97*, 2059–2064. [[CrossRef](#)] [[PubMed](#)]
14. Harun, J.; Labosky, P. Antitermitic and antifungal properties of selected bark extractives. *Wood Fiber Sci.* **2007**, *17*, 327–335.
15. Tascioglu, C.; Yalcin, M.; de Troya, T.; Sivrikaya, H. Termiticidal properties of some wood and bark extracts used as wood preservatives. *BioResources* **2012**, *7*, 2960–2969.
16. Lines, R. Man's use of birch—Past and present. *Proc. R. Soc. Edinb. Sect. B Biol. Sci.* **1984**, *85*, 203–213. [[CrossRef](#)]
17. Gottesfeld, L.M.J. The importance of bark products in the aboriginal economies of northwestern British Columbia, Canada. *Econ. Bot.* **1992**, *46*, 148–157. [[CrossRef](#)]
18. Gidmark, D. *The Birchbark Canoe Makers of Lac Barriere*; Algonquian Papers-Archive; 19th Algonquian Conference: Maniwaki, Quebec, 1988; Volume 19.
19. Raffan, J.; Franks, C.E.S. Bark, skin & cedar: Exploring the canoe in Canadian experience. *Am. Rev. Can. Stud.* **2000**, *30*, 393.
20. Skroch, W.A.; Powell, M.A.; Bilderback, T.E.; Henry, P.H. Mulches: Durability, aesthetic value, weed control, and temperature. *J. Environ. Hortic.* **1992**, *10*, 43–45.
21. Herrick, F.W. Chemistry and utilization of western hemlock bark extractives. *J. Agric. Food Chem.* **1980**, *28*, 228–237. [[CrossRef](#)]
22. CEN/TS 15083-1. *Durability of Wood and Wood-Based Products—Determination of the Natural Durability of Solid Wood against Wood-Destroying Fungi, Test Methods—Part 1: Basidiomycetes*; European Committee for Standardization: Brussels, Belgium, 2005.
23. EN 252. *Field Test Method for Determining the Relative Protective Effectiveness of a Wood Preservative in Ground Contact*; European Committee for Standardization: Brussels, Belgium, 2015.
24. Brunetti, M.; De Capua, E.L.; Macchioni, N.; Monachello, S. Natural durability, physical and mechanical properties of Atlas cedar (*Cedrus atlantica* Manetti) wood from Southern Italy. *Ann. For. Sci.* **2001**, *58*, 607–613. [[CrossRef](#)]
25. Anagnost, S.E.; Smith, W.B. Comparative decay of heartwood and sapwood of Red maple. *Wood Fiber Sci.* **1997**, *29*, 189–194.
26. Brischke, C.; Gellerich, A.; Homann, P. Impact of sapwood portions on the durability of adjacent heartwood of *Pinus sylvestris*, *Pseudotsuga menziesii* and *Quercus robur*: Part 1: Laboratory studies. In Proceedings of the IRG Annual Meeting, IRG/WP 18-10922, Johannesburg, South Africa, 29 April–3 May 2018; p. 15.

27. Humphrey, C.J. Laboratory tests on the durability of American woods: I. Flask tests on conifers. *Mycologia* **1916**, *8*, 80–92. [[CrossRef](#)]
28. Stirling, R.; Alfredsen, G.; Brischke, C.; De Windt, I.; Francis, L.P.; Frühwald Hansson, E.; Humar, M.; Jermer, J.; Klamer, M.; Kutnik, M.; et al. Global survey on durability variation—On the effect of the reference species. In Proceedings of the IRG Annual Meeting, IRG/WP 16-20573, Lisbon, Portugal, 15–19 May 2016; p. 26.
29. Van Acker, J.; Stevens, M. Biological durability of wood in relation to end-use—Part 2: The use of an accelerated outdoor L-joint performance test. *Holz Roh Werkst.* **2003**, *61*, 125–132. [[CrossRef](#)]



© 2019 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).