Potential for Using Borates to Mitigate the Risk of *Phytophthora ramorum* Spread on Douglas-Fir Logs

Jed Cappellazzi
Jeffrey J. Morrell

Abstract

Phytophthora ramorum is an increasingly important tree pathogen in northern California and southern Oregon. While it has the greatest effect on tanoak, it can infect a wide range of tree species, including Douglas-fir. Oregon has instituted a quarantine area to slow the spread of this pathogen, and there are concerns that further restrictions may be imposed on log movement, including those of Douglas-fir. The potential for using boron as a log treatment to limit *P. ramorum* was evaluated. While boron either alone or in a glycol solution was capable of moving into the bark, there was no evidence that it could move further into the sapwood. The results suggest that bark removal would be necessary for the use of boron as a mitigation agent for the spread of *P. ramorum*.

The global movement of plant materials carries with it the risk of unintended transportation of potential plant pathogens (Morrell 1995; Pimentel et al. 2000; Food and Agriculture Organization of the United Nations 2009, 2010). Ever-increasing volumes of international trade in wood products make developing methods for reducing this risk increasingly important. One potential pest of concern in many countries is *Phytophthora ramorum* (Hansen et al. 2005, Kliejunas 2010). This fungus attacks a wide range of trees and shrubs, although it is especially destructive to tanoak (*Lithocarpus densiflorus*). *P. ramorum* is a major concern in northern California and southwestern Oregon, and the State of Oregon has instituted a quarantine area to minimize further pathogen spread. There is the potential for other regions to institute limits on the movement of materials from the quarantine area. While tanoak has relatively few uses, other species growing in this region may also be affected by regulatory actions. Among the most important would be Douglas-fir (*Pseudotsuga menziesii*), which is often exported outside the region in log and lumber form (Morgan et al. 2012). While mature Douglas-fir trees are not killed by *P. ramorum*, they are possible hosts and might be subjected to quarantine procedures (Hansen et al. 2005, Brown and Brasier 2007, McKeever 2010, US Department of Agriculture Animal and Plant Health Inspection Service 2013). Phytosanitary processes that might be applied to this material could include debarking, thermal treatments, and fumigation.

Debarking is a generally accepted method for reducing the risk of insect infestation of logs (Morrell 1995, International Plant Protection Convention [IPPC] 2009). *P. ramorum* tends to be on or in the bark, so removing this portion of the log would markedly reduce the risk of spread. However, *P. ramorum* has been shown to infect the xylem of a number of hardwood species (Brown and Brasier 2007), and there is some evidence that *P. ramorum* can penetrate Douglas-fir sapwood (McKeever 2010). Thus, debarking might not be completely effective and, regardless, would be difficult to accomplish on harvest sites located within quarantine areas. Thermal treatments are commonly used for wood in global transport, including logs, pallets, and other solid wood packaging (Harnik et al. 2004, IPPC 2009). Wood is an excellent insulator and heats very slowly (MacLean 1952). As a result, thermal treatment of logs would be slow and costly. It might also be difficult to implement in a quarantine area without considerable capital cost. Fumigation with methyl bromide is also a commonly used mitigation method for lumber and logs, but it can be difficult to apply, is a potent ozone degrader, and has been slated for eventual removal from the market (Morrell 1995).

While Douglas-fir is not currently affected by *P. ramorum* quarantines, it will be important to identify suitable methods for mitigating the risk of spread on logs

The authors are, respectively, Faculty Research Assistant and Professor, Dept. of Wood Sci. and Engineering, Oregon State Univ., Corvallis (Jed.Cappellazzi@oregonstate.edu, Jeff.Morrell@oregonstate.edu [corresponding author]).This paper was received for publication in June 2017. Article no. 17-00037.

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of this and other species in the region. Ideally, the method could be applied in the field prior to debarking, allowing logs to be moved off harvest sites with minimal restrictions. One possible mitigation method is dip treatment with a water-diffusible biocide, such as borate. Boron has activity against a range of fungi and insects, it has relatively low toxicity against nontarget organisms, and, most important, it is capable of diffusing into wet wood (McQuire and Goudie 1972, Ra et al. 2001, Caldeira 2010). Boron has been shown to limit the activity of *P. ramorum* in culture at concentrations equal to or greater than 0.5 percent boric acid equivalent (Hulburt 2014). Boron has also been shown to diffuse well through wet Douglas-fir sapwood and heartwood (Lebow and Morrell 1989, Morrell and Lebow 1992, Morrell and Freitag 1995, Gezer et al. 1999, Freitag and Morrell 2002). Boron has been used in a variety of applications, but it is currently not allowed in any mitigation processes for global wood movement. The use of boron as a mitigation tool will require the development of data demonstrating the ability of the boron to move into the wood through the bark at levels that are effective against *P. ramorum*. Preliminary tests suggested that boron could penetrate the bark of Douglas-fir and move into the sapwood (Hulburt 2014); however, there were questions about potential bark damage prior to testing. For this reason, the tests were repeated to assess the ability of boron to diffuse through non-debarked Douglas-fir bolts at levels necessary to kill *P. ramorum*. This report describes the results of those follow-up tests.

Materials and Methods

Samples were prepared from two freshly felled trees cut into 23 log sections measuring 27 to 31 cm long and 17.2 to 24.2 cm in diameter. Bark thickness ranged from 1 to 4 mm.

Boron treatment solution was delivered to a small spot on each log following a technique developed by Hulburt (2014). A 17.5-mm-long section of 25-mm-diameter polyvinyl chloride (PVC) pipe was attached to the bark at three locations along each log using a boron-free caulking compound around the base. The process created a well in which the boron solution could be placed without running down and off the bark. Ten milliliters of a 15 percent boric acid equivalent (BAE) solution of disodium octaborate tetrahydrate (DOT; RioTinto Minerals, Valencia, California) or a DOT–polyethylene glycol formulation (Bora-Care, Nisus Corp., Knoxville, Tennessee) was placed into each well, allowed to stand for 1 hour, and poured off. The logs were incubated at 4°C for 31 days to minimize the potential for microbial contamination before boron movement was assessed. Each log was cut in half longitudinally and then cut into three sections, each containing a single PVC well. Each section was cut into zones corresponding to the bark (with cambium and phloem), the outer sapwood ($\sim$10 mm inward from the bark), and the inner sapwood (10 to 20 mm farther inward from the bark). All cuts were made from the pith outward to minimize the risk of inadvertently carrying boron from the surface inward.

Samples from each zone were ground to pass a 20-mesh screen prior to being hot water extracted. The extract was analyzed for boron using the azomethine H–carminic acid method according to American Wood Protection Association Standard A65-16 (American Wood Protection Association 2012). The boron diffusion data were subjected to the Welch two-sample t test ($\alpha = 0.05$).

Results and Discussion

Douglas-fir is not considered a primary host for *P. ramorum*, but there is some suggestion that sapwood colonization is possible (McKeever 2010). Any use of boron for mitigating the risk of *P. ramorum* spread must ensure that this chemical is capable of penetrating through bark and into the sapwood. Bark is characterized by the presence of various water-repellent compounds and is typically considered a barrier to liquid movement (Chang 1954, Panshin and de Zeeuw 1980).

Background levels of boron in bark and sapwood of log sections not receiving boron averaged 0.015 and 0.007 percent BAE, respectively, far below the levels that would affect *P. ramorum* (Table 1). Boron levels in bark beneath wells receiving 15 percent DOT averaged 0.240 percent BAE. While this level was below that found to be fungistatic to *P. ramorum*, it indicated that a considerable amount of boron could be delivered into the bark where it might be available to affect the organism. Increasing the boron level in the treatment solution is possible; however, levels above 20 percent would require special handling procedures, including heating, that would probably not be feasible in the field. Boron levels in the outer 10 mm of sapwood fell off sharply and were similar to the background levels found for the controls. These results are similar to those found previously (Hulburt 2014). Similarly, low boron levels were found further inward from the surface, indicating that boron did not move beyond the cambium and into the sapwood.

The use of the boron-glycol resulted in much higher levels of boron in the bark zone (0.445% BAE) that approached the reported fungistatic level against *P. ramorum*, although there was considerable variation in levels found among the 23 test pieces, and there were no significant differences between the two boron treatments. Glycol is reported to enhance boron movement, especially in drier wood, and appeared to markedly improve uptake (Freitag and Morrell 2002). Boron levels in the outer sapwood were similar to those found in wood receiving DOT alone. Boron levels were also low further inward. The results suggest that the glycol improved uptake but could not overcome the barrier between the bark–cambium and the sapwood. As with the DOT alone, it is possible to increase the concentration of boron to increase bark loading above the threshold; however, it is not clear if higher external boron loadings would be able to move further inward.

One month was chosen as the incubation period with the thought that logs could be treated on-site and stored for that

Table 1.—Mean boron acid equivalent content (%BAE) in sections cut from the bark and sapwood of Douglas-fir log sections treated with disodium octaborate tetrahydrate (DOT) alone or DOT with glycol.

Treatment	Boron level (%BAE)[a]		
	Bark zone	Outer sapwood	10–20 mm sapwood
Control	0.015 (0.010)	0.007 (0.007)	0.009 (0.010)
DOT	0.240 (0.113)	0.009 (0.007)	0.007 (0.007)
DOT-glycol	0.445 (0.287)	0.008 (0.010)	0.009 (0.019)

[a] Values represent means of 28 samples per treatment. Figures in parentheses represent one standard deviation.

period before being moved to either a mill or an export facility. While longer storage periods are possible, this increases processing time, adding costs. It also exposes the logs to additional rainfall that could encourage boron loss. One of the advantages of boron is that it can diffuse into the wood with moisture; however, it can also leach out with rainfall. While all of the boron is not immediately lost, the longer it is exposed to wetting, the greater the risk that chemical loadings will fall below a fungistatic level. The loss of boron on-site also creates a risk to surrounding vegetation because boron is phytotoxic at higher levels (Nable et al. 1997). The results suggest that bark presents a formidable barrier to boron movement and may have to be removed prior to application.

Conclusions

While boron was capable of moving into the bark–cambium zone following short exposures to either DOT or DOT plus glycol, it was not capable of moving further into the sapwood in a time frame that would be compatible with log processing on a harvest site. Results indicate that bark would have to be removed prior to treatment if boron were to be used for limiting *P. ramorum* spread in Douglas-fir logs.

Literature Cited

American Wood Protection Association. 2012. Standard method to determine the amount of boron in treated wood using azomethine-H or carminic acid. Standard A65-16. *In:* Book of Standards. AWPA, Birmingham, Alabama.

Brown, A. V. and C. M. Brasier. 2007. Colonization of tree xylem by *Phytophthora ramorum, P. kernoviae* and other *Phytophthora* species. *Plant Pathol*. 56(2):227–241.

Caldeira, F. 2010. Boron in wood preservation: A review in its physico-chemical aspects. *Silva Lusit*. 18(2):179–196.

Chang, Y. P. 1954. Bark of North American conifers. USDA Technical Bulletin 1095. USDA, Washington, D.C.

Food and Agriculture Organization of the United Nations (FAO). 2009. Global review of forest pests and diseases. FAO, Rome.

Food and Agriculture Organization of the United Nations (FAO). 2010. Guide to implementation of phytosanitary standards in forestry. FAO, Rome.

Freitag, C. M. and J. J. Morrell. 2002. Effect of glycol on movement of borate from fused borate rods. *Forest Prod. J*. 52(6): 68–74.

Gezer, E., J. Michaels, and J. Morrell. 1999. Effects of glycol on leachability and efficacy of boron wood preservatives. *Wood Fiber Sci*. 31(2):136–142.

Hansen, E. M., J. L. Parke, and W. Sutton. 2005. Susceptibility of Oregon forest trees and shrubs to *Phytophthora ramorum*: A comparison of artificial inoculation and natural infection. *Plant Dis*. 89(4):63–70.

Harnik, T. Y., M. Mejia-Chang, J. Lewis, and M. Garbelotto. 2004. Efficacy of heat-based treatments in eliminating the recovery of the sudden oak death pathogen (*Phytophthora ramorum*) from infected California bay laurel leaves. *HortScience* 39(7):1677–1680.

Hulburt, J. M. 2014. Phytosanitation of Douglas-fir (*Pseudotsuga menziesii*) logs to litigate the risk of artificially disseminating *Phytophthora ramorum* within the global trade of timber. MS thesis. Oregon State University, Corvallis.

International Plant Protection Convention (IPPC). 2009. ISPM15: Regulation of wood packaging material in international trade. Food and Agriculture Organization of the United Nations, Rome.

Kliejunas, J. T. 2010. Sudden oak death and *Phytophthora ramorum*: A summary of the literature, 2010 edition. General Technical Report PSW-GTR-234. USDA Forest Service, Pacific Southwest Research Station, Albany, California. 181 pp.

Lebow, S. T. and J. J. Morrell. 1989. Penetration of boron in Douglas-fir and western hemlock lumber. *Forest Prod. J*. 39(1):67–70.

MacLean, J. D. 1952. Preservative treatment of wood by pressure methods. US Department of Agriculture Handbook No. 40. USDA, Washington, D.C.

McKeever, K. M. 2010. Characterizing Douglas-fir tissue colonization the ''sudden oak death'' pathogen, *Phytophthora ramorum*. MS thesis. Washington State University, Pullman.

McQuire, A. J. and K. A. Goudie. 1972. Accelerated boron diffusion treatment of timber. *N. Z. J. Forest Sci*. 2(2):165–187.

Morgan, T. A., J. P. Brandt, K. E. Songster, C. E. Keegan III, and G. A. Christensen. 2012. California's forest products industry and timber harvest, 2006. General Technical Report PNW-GTR-866. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. 48 pp.

Morrell, J. J. 1995. Importation of unprocessed logs into North America: A review of pest mitigation procedures and their efficacy. *Forest Prod. J*. 45(9):41–50.

Morrell, J. J. and C. M. Freitag. 1995. Effect of wood moisture content on diffusion of boron-based biocides through Douglas-fir and western hemlock lumber. *Forest Prod. J*. 45(3):51–55.

Morrell, J. J. and S. T. Lebow. 1992. Borate treatment of seasoned western hemlock and Douglas-fir lumber. *Forest Prod. J*. 41(1): 27–29.

Nable, R. O., G. S. Banuelos, and J. G. Paull. 1997. Boron toxicity. *Plant Soil* 193:181–198.

Panshin, A. J. and C. de Zeeuw. 1980. Textbook of Wood Technology. McGraw-Hill, New York.

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and economic costs of nonindigenous species in the United States. *BioScience* 50(1):53–65.

Ra, J., H. Barnes, and T. Conners. 2001. Determination of boron diffusion coefficients in wood. *Wood Fiber Sci*. 33(1):90–103.

US Department of Agriculture Animal and Plant Health Inspection Service. 2013. List of regulated hosts and plants proven or associated with *Phytophthora ramorum*. http://www.aphis.usda.gov/plant_health/plant_pest_info/pram/downloads/pdf_files/usdaprlist.pdf. Accessed January 20, 2017.