DIFFUSION OF DISODIUM OCTABORATE TETRAHYDRATE INTO SOUTHERN YELLOW PINE TO CONTROL WOOD-INFESTING BEETLES

WILLIAM H ROBINSON AND ROBERT A. BARLOW
Urban Pest Control Research Center, Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0319, USA

Abstract—Emulsions of chemicals applied to the surface of seasoned softwoods results in a residue 1-3 mm below the surface, and can provide control of wood-infesting beetles. Borate compounds can be delivered to wood surfaces in sufficient quantities for subsequent diffusion to depths below the surface. The penetration of boron depends on the presence of free water in the wood cells. Penetration at 24 h and 6 wk of a 10% (AI) dilution of disodium octaborate tetrahydrate (DOT) into southern yellow pine (*Pinus* sp.) blocks was investigated following one and two applications and exposure to 85% and 50% RH environments. DOT treated and untreated wood was sectioned (50 um per slice) with a microtome from the treated surface to five depths: 50, 950, 2000, 2500, and 3000 um, and analyzed for boron. The boron content of each wood slice (ppm) was performed by a dry ashing procedure using inductively coupled plasma spectrometer (ICP). Factors influencing penetration of DOT into the southern yellow pine blocks were maximum application volume, 16-19% initial WMC, and exposure to a 85% RH environment following treatment. Two applications of 10% DOT to wood with 16-18% WMC, followed by 6 wk in a 85% RH environment resulted in greater amounts of boron detected at the 3000 um depth than did other treatments. The results of the evaluations reported here indicate that the amount of boron detected on and below the wood surface, to the depth of approximately 2 mm, should provide protection from wood-infesting beetles.

INTRODUCTION

The larvae of longhorn and powderpost beetles infesting structural timber can feed for an extended time, and at varying depths below the wood surface. While limited infestations of these pests cause only cosmetic damage, continued reinfestation and feeding can lead to severe structural damage. Strategies for the prevention or control of wood-infesting beetles include applying insecticides as a gas to the entire structure, or as a water- or solvent-based spray to exposed wood, or as a pressure-injected spray below the wood surface. The depth of penetration and duration of liquid insecticides used for wood protection depend on the wood species treated, the insecticide formulation, and the environment. In general, applying insecticides to seasoned softwoods results in a stable residue 1-3 mm below the treated surface (Berry and Orsler, 1983; Serment, 1986; Powell and Robinson, 1991). Emulsions of pentachlorophenol and lindane have been used successfully to control wood infesting beetles, such as the old house borer, anobiid, and lyctid powderpost beetles (Durr, 1954; Morgan and Purslow, 1973). Chlorpyrifos and the pyrethroids, permethrin and cypermethrin have also been used for wood protection (Powell and Robinson, 1992; Robinson, 1991).

There is considerable interest in the use of water-soluble polyborates, such as disodium octaborate tetrahydrate, to protect structural wood from wood-destroying insects (Williams and Mauldin, 1985; Williams and Amburgey, 1987; Grace and Yamamoto, 1992). Taylor (1967) summarized the toxicity of boron compounds for wood-infesting beetle larvae. She reported boric acid concentrations of 0.4-0.6 kg/m^3 to be lethal to *Hylotrupes bajulus* (L.) larvae (Taylor, 1967). Soumi and Akre (1992) reported on the control of the anobiid, *Hemicoelus gibbicollis* (LeConte) with borates.

Borate compounds can be delivered to the surface of wood in sufficient quantities for subsequent diffusion below the surface. Diffusion is the process by which boron is transported from a zone of high concentration to one of low concentration. The initial penetration of boron in the top layer of wood, and diffusion below the surface depends on the presence of free water in the wood cells (Smith and Williams, 1969). This prerequisite has usually limited the use of borate treatments to unseasoned lumber which has a high (30%) wood moisture content, or to pressure treatment of seasoned wood. Recently, borate formulations have been developed for treating seasoned wood by

Proceedings of the First International Conference on Urban Pests.
K.B. Wildey and Wm H.Robinson (editors). 1993

surface spraying (Becker, 1976; Creffield et al., 1983; Puettmann and Williams, 1992), or subsurface injection. The product label directions for treating seasoned timber with borates recommends to thoroughly wet exposed wood surfaces with two applications within 24 h (U. S. Borax Inc., Valencia, CA).

The diffusion of borates in seasoned wood is enhanced with increased wood moisture content (WMC) and surface loading (Smith and Williams, 1969). The moisture content of structural wood normally infested with beetles can range from 7-18% (Durr, 1954; Williams, 1983). The wood moisture content depends on the location within the structure, and seasonal differences in ambient relative humidity (RH) (Peck, 1932; Bois, 1951). Although there is data to show that borates can diffuse into green wood with high (35%) WMC, there is limited data on the diffusion of borates into structural wood, which has a WMC of 7-18%. The objectives of the research presented here are to evaluate the initial penetration into the outer layer and subsequent diffusion of a 10% water dilution of disodium octaborate tetrahydrate into southern yellow pine (Pinus sp.) with low (8-10%) and high (16-18%) WMC.

MATERIALS AND METHODS

Penetration at 24 hours of a 10% (AI) dilution of disodium octaborate tetrahydrate (DOT) was investigated using southern yellow pine (*Pinus* sp.) sapwood. Wood used was free from knots and visible defects, and had a moisture content of 8-18%. It was cut into 4 x 5 x 1cm blocks for treatment. DOT was mixed with water to give a 10% finished dilution, and a pipette was used to deliver 204 ul to one 4cm x 5cm surface of each block. Applying this volume of liquid resulted in a thoroughly wet wood surface. One and two applications, approximately 24 h apart, were made to each block, and there were four replicates of each treatment. Following application, the blocks were maintained at 21°C, 50% RH, or at 26°C, 85% RH for 24 h or 6 wk. Then the center cubic centimeter of each block was removed and sectioned (ca. 50 um per slice) with a microtome from the treated surface to five depths: 50, 950, 2000, 2500, and 3000 um. Ten untreated blocks were sectioned at the same depths, and analyzed for boron. Each wood depth evaluated was represented by three replicates.

Analysis

The boron content analysis of each wood slice was performed by a dry ashing procedure and using inductively coupled plasma spectrometer (ICP). Wood slices were ashed in a furnace (Model 186 Fisher Isotherm) at 460-480 C for 1 hour. The ash was dissolved in 2.5 ml of concentrated HCL, allowed to stand for 20 min, then 5 ml of deionized water was added. After 15 min, 17.5 ml of deionized water was added, to give a final volume of 25 ml and a 1.2 N HCL dilution. The dilution was filtered through ashless filter paper, then transferred to the ICP. Amounts of boron detected for each depth are presented in parts per million (ppm), based on the weight of the wood.

Data analysis

Analysis of data was conducted using analysis of variance techniques (SAS Institute, 1985), means were separated with Tukey's Studentized Range Test. Differences were considered significant at the 0.05% level.

RESULTS AND DISCUSSION

The factors influencing penetration and diffusion of DOT into the southern yellow pine blocks were maximum application volume, high initial WMC, and exposure of treated blocks to a high RH environment following treatment. Two applications of 10% DOT to southern pine blocks with 16-18% WMC, followed by 6 wk in a 85% RH environment resulted in more boron detected at the 3000 um depth than did single or double applications to blocks with 16-18% or 8-10% WMC wood, exposed for 24 h or 6 wk in 50% or 85% RH environments (Table 1, 2). In the untreated blocks there was a mean ($\pm$SEM) 56 + 19 ppm boron detected at all depths.

Table 1. Mean amount (ppm) of disodium octaborate tetrahydrate in five depths of southern yellow pine with 16-19% wood moisture content following 24 h and 6 wk in exposure in 50% RH or 85% RH environment.

Application and evaluation time	x ppm boron/wood slice (SD)				
	Depth below wood surface (microns)				
	50	950	2000	2500	3000
One application					
24 h	5,158ab (214)	1,414a (227)	630a (325)	389abc (212)	178a (156)
6 wk/50% RH	4,434ab (1,291)	1,827a (590)	494a (67)	268ab (25)	197a (10)
Two applications					
24 h	14,201c (3,511)	1,069a (480)	219a (90)	96a (54)	78a (60)
6 wk/85% RH	1,586a (725)	1,275a (405)	1,032a (350)	875a (165)	795a (160)
6 wk/50% RH	8,585bc (764)	3,052b (264)	1,099a (282)	753cb (188)	355a (94)

Means followed by the same letter are not significantly different ($P > 0.05$; Tukey's studentized range test).

Table 2. Mean amount (ppm) of disodium octaborate tetrahydrate in five depths of southern yellow pine with 8-10% wood moisture content following 24 h and 6 wk in exposure in a 50% RH environment.

Application and evaluation time	x ppm boron/wood slice (SD)				
	Depth below wood surface (microns)				
	50	950	2000	2500	3000
One application					
24 h	16,586a (7,510)	4,413a (3,443)	255a (246)	577a (560)	91a (64)
Two applications					
24 h	13,918a (5,199)	2,326a (1,540)	456a (233)	282a (170)	233a (90)
6 wk	10,489a (865)	2,530a (418)	592a (273)	259a (143)	122a (57)

Means followed by the same letter are not significantly different (P0.05; Tukey's studentized range test).

Wood with 16-18% WMC

Two applications of DOT followed by 6 wk in 85% RH environment resulted in the greatest amount (x 795 ppm) of boron 3 mm (3000 um) below the surface (Table 1). At the 2000 and 2500 um depths there was no difference in the amount of boron detected in the blocks analyzed after 6 wk in the 50% RH environment or blocks the 85% RH environment. At the 950 um depth there was more boron detected in the wood stored 6 wk in the 50% RH environment (x 3,035 ppm) than in the 85% RH environment (x 1,275 ppm). The two applications to wood with 16-18% WMC followed by 6 wk in 50% RH environment is representative of household conditions encountered by professional pest control operators during summer and fall in eastern and southeastern United States (Bois, 1951). During the fall in these regions, structural wood in house attics, basements, and substructure crawlspaces has high (12-18%) WMC, and during the winter months the ambient RH and the WMC of structural wood decrease (Bois, 1951; Dodson and Robinson, 1988). Also during late summer and fall, old house borer larvae and other wood infesting beetle larvae are actively feeding. Control strategies, such as spraying exposed surfaces of infested wood with liquid insecticides, are often initiated at this time.

The postapplication diffusion of boron into the wood is evident from the amounts detected on the wood surface and below, 24 h after application, and after 6 wk in the 50% and 85% RH environments. Since the element boron is stable and there is little or no degradation, the decrease in boron on the wood surface following application can be considered the result of diffusion into the wood. This is confirmed by an increase in the boron detected at the 3000 um depth after 6 wk in 85% RH environment, compared to the amounts present 24 h after application (Table 1).

Wood with 8-10% WMC

The mean amounts of boron detected in the 8-10% WMC wood shows the influence of wood moisture content at time of application, and the environment (high or low RH) following treatment on the boron penetration and diffusion (Table 2). There is no difference in the amount of boron detected at any depth in wood from the one or two applications, measured at 24 h or 6 wk in a 50% RH environment. Apparently, there is little diffusion of boron from the surface of the wood to depths below unless the wood moisture content is more than 8-10%.

The control strategy of two applications to wood with 8-10% WMC followed by 6 wk in a low RH environment is representative of household conditions during winter and early spring in eastern and southeastern regions of the United States (Bois, 1951). At this time, structural wood in house attics and basements has low WMC (Bois, 1951). The period of early spring includes the time adult anobiid and lyctid powderpost beetles emerge from infested wood in eastern and southeastern U. S. (Williams and Waldrop, 1978). Boron residue on the wood surface and in the upper layers would provide control of these pests.

Toxicity to wood-infesting beetles

The effectiveness of surface applications of DOT to protect seasoned wood from wood-infesting beetles is linked to the penetration of a lethal amount of boron into the top layer of wood, and the subsequent diffusion of boron into lower layers. Taylor (1967) reported that in pine sapwood, 1,000 to 1,900 ppm boron (approximately 0.4 to 7.7 kg/m^3) is necessary to prevent attack by first-stage old house borer and anobiid beetle larvae. In the investigations reported here, two applications of DOT to the southern yellow pine blocks with 8-10% or 16-18% WMC resulted in mean concentrations of 1,000 ppm in the top 2 mm of wood. One surface application resulted in mean boron concentrations of 1,000 in approximately the top 1 mm of wood (Table 1). After 6 wk in 50% or 85% RH environments an amount of boron reported lethal to first-stage beetle larvae (Taylor, 1967) remained on the surface of the blocks. On the surface or below there is adequate boron concentrations to provide long-term protection of the wood.

The results of the evaluations reported here indicate that the amount of boron detected on and below the wood surface, to the depth of approximately 2 mm, can provide protection from wood-infesting beetles. Diffusion of large amounts of boron deep into the structural wood is not necessary for protecting it from an initial insect attack or reinfestation. Lethal quantities of boron are necessary only in the outer 1 cm of the wood to provide control of wood-infesting beetles (Baker and Taylor, 1967). Seasoned softwood has a gradient of nutritional values, decreasing from the outside inwards, for wood-infesting beetles (Schuch, 1937; Becker, 1949). Long (1978) reported that kiln or air-drying pine planks increased the amount of simple sugars concentrated at the surface of the wood. The larvae of wood-infesting beetles, such as the old house borer and anobiid powderpost beetles, regularly feed in the outer, more nutritious, layers of seasoned wood (Serment 1986). In this region they are likely to contact the toxic residues of surface-applied boron compounds.

ACKNOWLEDGMENTS

We thank Nancy Phillips, VPI&SU, Soil Testing and Plant Analysis Laboratory, for her help with the boron residue data, and Nonggang Bao, Urban Pest Control Research Center, VPI&SU, for his assistance in technical calculations. George Rambo, G. Rambo & Associates, reviewed and improved the manuscript.

REFERENCES

Baker, J. M. and Taylor, J. M. (1967). Testing liquid insecticides of eradication action against wood boring insects. *Rec. Conv. Brit. Wood Pres. Assoc.*: 5-22.

Becker, G. (1949). Investigations on the nutritional physiology of the larvae of the old house longhorn beetle. *Z. verlag. Physiol.* 29: 315-388.

Becker, G. (1976). Treatment of wood by diffusion of salts. *Jour. Inst. Wood Sci.* 7: 30-36.

Berry, R. W. and Orsler, R. J. (1983). Emulsion-based formulation for remedial treatment against woodworm. *Building Research Estab. Information Paper*, IP 15/83, 4 pp.

Bois, P. J. (1959). Wood moisture content in homes, seasonal variations in the southeast. *For. Prod. J.* 9: 427 - 430.

Creffield, J. W., Greaves, H. and Howick, C. D. (1983). Boracol 40 - A potential remedial and preventative treatment for lyctids. *Inter. Res. Group on Wood Preserv.* Doc. No. IRG/WP/1192.

Dodson, B. L. and Robinson, W. H. (1988). Penetration and permanence of chlorpyrifos in pine sapwood. *Mater. und Organ.* 23: 209-223.

Durr, H. (1954). The European house borer, Hylotrupes bajulus (Coleoptera: Cerambycidae) and its control in western Cape Province. *Bull. No. 337 (Entomol. Ser. No. 40) Union of South Africa Dept. Agriculture* 71 pp

Grace, J. K. and Yamamoto, R. T. (1992). Termiticidal effects of a glycol borate wood surface treatment. *For. Prod. Jour.* 42 (11/12): 46-47.

Long, K. D. (1978). Redistribution of simple sugars during drying of wood. *Wood Science* 11 (1): 10-12.

Morgan, J. W. W. and Purslow, D. F. 1973. Volatile losses of wood preservatives. *Rec. Ann. Conv. Brit. Wood Pres. Assoc.* 9: 173-192.

Orsler, R. J. and Stone, W. S. (1982). Remedial spray treatments used against insect attack. Part 1: Permanence and distribution. *Mater. und Organ.* 17: 161-180.

Peck, E. C. (1932). Moisture content of wood in dwellings. *USDA Circ.* No. 239, 24 pp.

Powell, P. K. and Robinson, W. H. (1991). Penetration of chlorpyrifos injected into structural wood. *Mater. und Organ.* 25: 211-218.

Powell, P. K. and Robinson, W. H. (1992). Penetration and permanence of permethrin in four softwoods. *J. Econ. Entomol.* 85: 1818-1821.

Puettmann, M. M. and Williams, L. H. (1992). Penetration of southern pine floor joists by borate/glycol formulations. Wood *Protection 2* (1): 29-34.

Robinson, W. H. (1991). Penetration of chlorpyrifos into five softwood species. *Jpn. J. Environ. Entomol. Zool.* 3: 196-201.

SAS Institute. (1985). SAS user's guide: statistics, version 5. *SAS Institute, Inc.* Cary, NC.

Schuch, K. (1937). Beitrage zur Ernahrungsphysiologie Larve des Hausbockkafers (Hylotrupes bajulus L.). *Z. Entomol.* 23: 547-558.

Serment, M. (1986). Comparative evaluation of the barrier effect against Hylotrupes bajulus L. of different types of wood preservatives. *Inter. Res. Group on Wood Preserv. Doc.* No. IRG/WP/1307.

Smith, D. N. and Williams, A. I. (1969). Wood preservation by the boron diffusion process- the effect of moisture content on diffusion time. *J. Inst. Wood Protect.* 22: 3-10.

Soumi, D. A. and Akre, R. D. (1992). Control of the structure-infesting beetle Hemicoelus gibbicollis (Coleoptera: Anobiidae) with borates. *J. Econ. Entomol.* 85: 1188-1193

Taylor, J. M. (1967). Toxicity of boron compounds to the common furniture and house longhorn beetle. *Inter. Pest Contr.* 9 (1): 14-17.

Williams, L. H. (1983). Wood moisture levels affect Xyletinus peltatus infestations. *Environ. Entomol.* 12: 135-140.

Williams, L. H. and Amburgey, T. L. (1987). Integrated protection against lyctid beetle infestations. IV. Resistance of boron-treated wood (Virola spp.) to insect and fungal attack. *Forest Prod. Jour.* 37: 10-17.

Williams, L. H. and Mauldin, J. K. (1985). Integrated protection against lyctid beetle infestations. II. Laboratory dip-diffusion treatment of unseasoned Banak (Virola spp.) lumber with boron compounds. *USDA Forest Service Note* S-313, 8 pp.

Williams, L. H. and Waldrop, J. D. (1978). Adult Xyletinus peltatus seasonal flight, diel activity and associated environmental i nfluences. *Ann. Entomol. Soc. Amer.* 71: 567-574.