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Controlling Hardwood Sapstain: Trials of Stain-Preventive Products on Red Alder Lumber

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Contents

British/Metric Conversion

1 inch = 2.54 centimeters
1 foot = 0.3048 meters
°F = 1.8 (°C) + 32

Abstract

Production of hardwood lumber (mostly red alder) has been a small but growing part of the forest products industry in the Pacific Northwest. In laboratory tests, Rodewod® 200 EC plus borax protected alder at nearly all levels tested. Eight other chemicals provided some protection at the highest level tested. Fungal-stain preventive treatments were evaluated on red alder lumber in both an accelerated 6-week test on small specimens in the laboratory and on bundled boards (1 inch x 4 inches x 8 feet) exposed outdoors for 2 or 6 months. Strong solutions of RODEWOD® 300, PQ-8 plus borax, and Permatox 101 protected freshly sawed red alder lumber that was solid-piled and stored for 2 months during which summer temperatures peaked. None of the treatments provided good protection through 6 months of storage that included summer weather.

Introduction

Hardwoods are a small but increasingly important part of the forest products industry in the Pacific Northwest. Beachy (1987) found increases of 57% in production of hardwood lumber (board foot basis) and 76% in value of shipments (unadjusted for inflation) from 1977 through 1985, with only 30% of the net annual growth of hardwood sawtimber being harvested. Of the 19.9 million board feet of hardwood sawtimber growing in the region, 65% is red alder, *Alnus rubra* Bong. Prices of popular types of red alder lumber increased 8 to 10% during 1987 and 1988 (Anonymous 1989).

Although the supply of red alder timber in Washington is ample (Little 1978), recent difficulties have threatened the supply in Oregon (Anonymous 1989). Availability of alder logs often is tied to coincident softwood harvesting and so may be erratic. Furthermore, a degrading fungal stain that penetrates from log ends and discolors the wood limits accumulation of an inventory of alder logs seriously. Under severe staining conditions, log storage may be curtailed to 5 to 8 weeks (Hildenbrand 1972).

Another problem arises from nonfungal staining of lumber. Freshly sawed alder soon darkens from a pale ivory to mottled yellow, tan, or deep red; staining is worse during periods of warm days and cool nights, such as autumn (Kozlik 1987). Karchesy (1975) studied the chemistry of these rapidly forming stains and identified a likely precursor, but the exact mechanism of the staining remains unknown. Mottled lumber is often more difficult to sell, since a uniform color is preferred in the upper grades used for furniture manufacture.

In order to improve color uniformity, alder lumber is steamed in the first stage of kiln-drying. If kiln capacity is temporarily insufficient, producers stockpile stickered lumber and allow it to partially air-dry, completing drying when kiln space becomes available. Air-drying helps to retard fungal staining and mold growth on the lumber during stockpiling, but air-dried lumber requires presteaming for 2 to 2-1/2 times longer than does freshly sawed material (Kozlik 1987). Solid-piled lumber (not stickered) dries slowly and may need less presteaming, but is vulnerable to serious fungal damage. Morrell (1987) identified *Ceratocystis picea* as the cause of a reddish-purple fungal stain that appeared frequently in alder lumber solid-piled for several days during hot weather. His laboratory tests indicated that dipping alder in a suitable fungicidal solution before stacking might prevent staining by *C. picea*. Mold also may develop on alder lumber dried at low temperatures used in dehumidification kilns.

Currently alder lumber is stickered and kiln-dried as soon as possible after sawing. The usefulness of fungal-stain preventives on alder lumber is generally unknown. This report of field and laboratory trials on red alder lumber compares the efficacy of a traditional fungal-stain preventive (pentachlorophenol) with some alternatives.

Procedures

Sapstain Preventives Tested

Of the 16 sapstain preventives tested (Table 1), Saptol-7 and the RODEWOD® formulations are not currently available in the United States. Solution strengths tested were based on the recommendations of cooperators for use on softwoods; there has been little or no experience

Table 1. Products tested as preventives of sapstain in red alder and the concentrations used in field and laboratory tests.

Preventive	Active ingredient	a.i.[1] (%)	Concentrations tested (% total a.i.)[1]								
			Laboratory tests						Field tests		
			1	2	3	4	5	6	Weak[2]	Medium[2]	Strong[2]
BRITEWOOD S	Sodium ortho-phenylphenate	23.0	0.09	0.18	0.27	0.36	0.72	1.44	—[3]	—	—
BUSAN® 1009	Methylene bis (thiocyanate)	10.0	0.067	0.10	0.13	0.15	0.20	0.40	0.16	0.21	0.42
	2-(thiocyanomethylthio) benzothiazole	10.0									
BUSAN® 1030	2-(thiocyanomethylthio) benzothiazole	30.0	0.12	0.15	0.23	0.30	0.60	1.20	0.24	0.32	0.94
NP-1	Didecyl dimethyl ammonium chloride	64.8	0.21	0.24	0.29	0.38	0.72	1.44	0.34	0.52	0.67
	3-iodo-2-propynyl butyl carbamate	7.6									
NYTEK™-GD	Copper-8-quinolinolate	10.0	(0.015	0.018	0.021	0.024	0.027	0.030)[4]	—	—	—
NYTEK™-GD + 4160 conditioner[5]	Copper-8-quinolinolate	10.0	(0.015	0.018	0.021	0.024	0.027	0.030)[4]	(0.024	0.031	0.046)[4]
Permatox 101	Sodium tetrachlorophenate	2.4	0.089	0.176	0.264	0.352	0.792	1.056	0.31	0.61	0.90
	Sodium pentachlorophenate	20.4									
	Sodium metaborate anhydrous	3.1									
	Phenylmercuric acetate	0.4									
PQ-8	Copper-8-quinolinolate	5.4	(0.003	0.004	0.005	0.008	0.010	0.020)[4]	(0.005	0.010	0.020)[4]
	Copper + borax[6]								0.38	0.75	1.47
PROTEK +	Acrylic emulsion, no fungicide		1.62	3.33	6.67	11.11	20.00	50.00	—	—	—
QUINDEX® N-10	Copper-8-quinolinolate	10.0	(0.010	0.013	0.014	0.017	0.025	0.050)[4]	(0.027	0.031	0.038)[4]
RODEWOD® 200EC	Azaconazole	18.5	0.047	0.094	0.141	0.188	0.282	0.370	—	—	—
RODEWOD® 200EC + borax	Azaconazole	18.5	(0.047	0.094	0.141	0.188	0.282	0.370)[7]	—	—	—
	Borax[6]	52.8									
RODEWOD® 200EC + DF 50	Azaconazole	18.5	0.074	0.147	0.221	0.295	0.442	0.570	—	—	—
	DF 50[5]	50.00									
RODEWOD® 300	Azaconazole	13.4	—	—	—	—	—	—	0.30	0.59	0.90
	Proprietary	13.4									
RODEWOD® 2280-40400	Azaconazole	4.3	0.079	0.159	0.238	0.317	0.476	0.952	—	—	—
	Didecyl dimethyl ammonium chloride	43.0									
Saptol-7	Methylene bis (thiocyanate)	10.0	0.10	0.20	0.40	0.50	0.80	1.60	0.39	0.58	0.75

[1] Total active ingredients (a.i.), percent of solution weight. (Values for Protek +, which has no active ingredient, are percent Protek + in the test solutions.) QUINDEX N-10 and NYTEK™-GD = copper as metal, PQ-8 = copper as metal, and as copper + added borax.
[2] Weak solutions contained the lowest concentration that would be expected to control fungal growth; medium-strength solutions were at the concentration recommended for normal use; strong solutions were of a concentration appropriate for storage under hazardous conditions.
[3] –, not tested.
[4] As percent copper metal.
[5] Added to solution.
[6] Borax added to solution.
[7] 1.46% boric acid equivalent not included in % total a.i. of concentration tested.

with use on red alder. A low concentration of preventive is the weakest solution that would be expected to control fungal growth. A medium-strength solution would be recommended for normal use. A strong solution should provide adequate protection under hazardous storage conditions.

Permatox 101, containing pentachlorophenol, was the standard for comparison; however, comparisons with Permatox 101 should note trends, rather than give strict credence to differences of a few percentage points.

Laboratory Trials

Accelerated laboratory trials were intended more to assess chemical efficacy quickly than to establish field application rates. Although standards for evaluating anti-stain chemicals exist (American Society for Testing and Materials 1988), a variety of procedures are used. In our laboratory trials, red alder samples (0.25 by 1.0 by 6.0 inches) were cut from air-dried lumber that was free of visible defects. Previous trials had indicated that the degree of staining in freshly sawed samples differed little from that in dried and rewetted samples.

The samples were vacuum-soaked in distilled water to raise the moisture content above 100%. Each sample was weighed before and after soaking; samples were aerated until the moisture content was 90 to 100% (determined by weighing samples). The samples were steamed briefly to remove any surface microbial contamination, cooled, and dipped for 30 seconds in a solution of one of the test chemicals. Each chemical was tested at six concentrations (Table 1), with seven replicates per treatment. Untreated control specimens were included for each chemical.

The treated specimens were drained on racks until the surface was free of visible droplets. The samples for each treatment group were sprayed with a spore suspension prepared by flooding cultures of *Phialophora heteromorpha*, *Aspergillus niger*, *Penicillium* sp., *Phialocephala dimorphospora*, *Ceratocystis picea*, *Aureobasidium pullulans*, and *Trichoderma viride* with distilled water. The samples were then sealed in plastic and incubated at 90°F for 12 weeks. The samples were observed weekly for evidence of fungal attack.

At the end of the test, samples were rated on a scale from 0 (no stain) to 10 (completely discolored). Discoloration caused by mold was included in the rating system. Control was deemed effective when ratings were less than 3.0; chemicals were considered to show some promise with ratings of 3.0 to 4.0.

Field Trials

Trials of medium-strength solutions were begun in late May, 1988, with the onset of warm weather. Average monthly temperature was about 55°F (Figure 1). Treatments with strong solutions were delayed until July, when peak temperatures would test effectiveness most severely. Trials of weak solutions were reserved until October and the beginning of cool weather, when least protection would be needed. Test boards were chosen from freshly sawed, 1-inch thick, random-width red alder lumber. Boards selected were sound and free of visible fungal stain; the nonfungal stains described earlier were ignored. Lumber from old, dried logs was

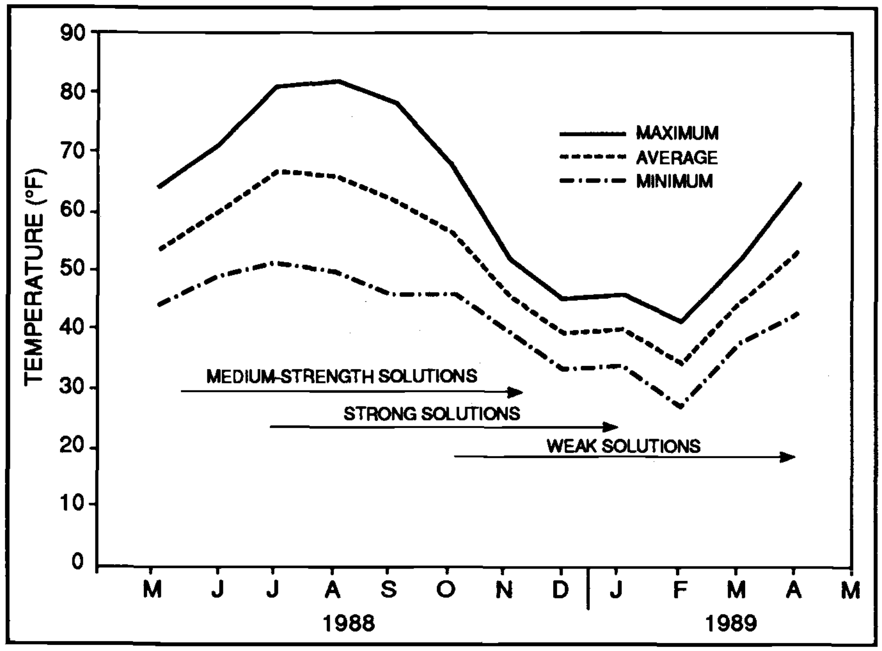

Figure 1. *Average monthly temperatures at Corvallis, Oregon, during field trials of fungal stain preventives on red alder lumber. Arrows indicate duration of trials.*

avoided. Selected boards were ripped to 4-inch widths in such a way as to recover the best possible face (clear and from the outer part of the log) for testing.

Test boards (1 inch x 4 inches x 6-8 feet) were distributed consecutively into nine treatment groups and dipped in test solutions (Table 1) within 30 hours after being sawn. Boards were dipped individually to half-length for 15 seconds as recommended by Cserjesi (1980), drained briefly, and stacked with dipped ends together and best face for testing upturned. The undipped end of each board served as its control.

Dipped boards were stacked according to preventive treatment. Nine stacks (treatments) of 15 boards each were assembled side-by-side in each test bundle. All treatments in a bundle were either strong, medium-strength, or weak solutions. Each bundle was individually strapped, end-coated, and covered with black plastic sheeting to retard drying and promote uniformly favorable conditions for staining.

Wrapped bundles were stored outdoors. They were roofed with flakeboard panels and shielded from solar heating of the south- and west-facing surfaces.

After 2 and 6 months of outdoor storage, the bundles were opened. Each board was examined visually for extent and intensity of fungal growth and discoloration over its upturned face. Those with adequate fungal stain or growth on the control end (≥50% of undipped face area) were examined and rated on the treated face. The extent of discoloration, including areas overrun or bleached by fungi, was estimated as a percentage of the treated area of the upturned face. The intensity of discoloration was estimated according to the criteria of Roff *et al.* (1980) for light, medium, and heavy (dark) fungal stain, with categories added for light-to-medium and medium-to-dark discolorations. Studs that had dried during storage to <27% moisture content (measured at about 1/8 inch below the test surface by a resistance-type meter) were not rated unless staining was well advanced.

Results and Discussion

Laboratory Trials

The low resistance of alder to decay (Miller 1986) was reflected in the stain tests. Most of the chemicals protected alder only at the highest strength evaluated (Table 2). Permatox 101, the standard for comparison, and four other chemicals — BRITEWOOD S, RODEWOD® 200EC, RODEWOD® 200EC plus DF 50, and RODEWOD® 2280-40400 — provided little or no pro-

Table 2. Average stain rating of red alder specimens treated with preventives in a laboratory trial. (Values are based on visual ratings; 0 = no stain, 10 = completely discolored.)

		Chemical concentration[1]					
Preventive	Control	1	2	3	4	5	6
BRITEWOOD S	8.0	7.0	7.0	8.1	7.0	6.1	7.0
BUSAN® 1009	6.9	5.9	6.6	5.0	5.7	4.3	3.9
BUSAN® 1030	9.0	8.3	7.9	7.4	5.9	4.9	2.9
NP-1	7.6	7.0	6.9	7.9	6.7	6.0	3.3
NYTEK™-GD	9.6	7.4	6.6	4.9	5.1	6.3	2.7
NYTEK™-GD + 4160	8.4	4.7	3.9	5.1	4.6[2]	3.9	2.2
Permatox 101	8.9	7.9	7.6	7.7	7.1	6.9	6.6
PQ-8 + boron	8.3	7.4	6.7	4.6	3.4	3.3	1.6
PROTEK +	7.3	7.7	5.7	3.4	3.1	3.0	7.9
QUINDEX® N-10	8.4	7.6[2]	5.9	5.3	5.0	5.4	2.6
RODEWOD® 200EC	7.4	6.4	6.3	5.6	5.3	4.9	5.1
RODEWOD® 200EC + borax	7.4	4.3	3.1	3.1	1.3	2.7	1.4
RODEWOD® 200EC + DF 50	8.4	5.6[2]	5.0[2]	5.4[2]	4.9	4.9	5.1
RODEWOD® 2280-40400	10.0	10.0	10.0	8.6	8.3	7.7	8.6
Saptol-7	6.1	6.7	5.7	4.4	6.3	4.7	1.4

[1] Chemical concentrations are as given in Table 1 (1 = low, 6 = high).
[2] Samples exhibited evidence of Basidiomycetous decay.

tection at any concentration. Protek +, a latex emulsion that includes no registered pesticide, provided limited protection at three of the higher levels, but none at the highest level tested. This anomaly suggests that this formulation cannot reliably protect alder.

Of the chemicals tested, RODEWOD® 200EC plus borax provided the most substantial protection, even at the third lowest concentration tested. The borax appeared to enhance the performance of this chemical, although borax alone has limited efficacy as an anti-stain chemical on alder (Morrell 1987).

While the remaining chemicals failed to provide long-term protection to alder at lower application rates, most seemed to provide protection for 2 to 4 weeks before failing and provided protection at the highest levels tested. Lumber producers normally apply sapstain-control chemicals to fresh-sawed lumber when they anticipate short delays in kiln drying. Application of moderate to high concentrations of the chemicals tested here may provide sufficient protection for such needs. For longer protection, higher concentrations must be applied.

Field Trials

More than 90% of the face area of untreated ends of boards usually had discolored after 2 months of storage during warm weather (Table 3). Cool weather retarded staining of controls stored initially during mid-October, which had not stained enough after 2 months to justify evaluating the treated end of most boards. After 6 months, fungal stain or growth usually had spread over more than 90% of the untreated face area and treated ends could be evaluated.

The normal reddish-brown nonfungal discoloration was obviously bleached from the boards during treatment with Saptol-7, especially the strong and medium-strength solutions. However, in several boards selected for initial dark discoloration and tested separately for bleaching, the bleached appearance generally disappeared within a few days.

Permatox 101, RODEWOD® 300, and PQ-8 + borax provided good protection through the first 2 months for boards dipped in medium-strength solutions in late May (Table 4). After 6 months, which included peak temperatures during August (Figure 1), few or none of the boards remained bright, with the exception of about two-thirds of those treated with Permatox 101; they developed only slight (<5% of treated face) fungal stain or growth. Extensively stained boards (70-100% of treated face) were common in treatments other than RODEWOD® 300.

Treatment with strong solutions of Permatox 101, RODEWOD® 300 and PQ-8 + borax in mid-July protected boards completely or nearly completely for 2 months after they were dipped. Saptol-7 provided reasonably good protection during that time. After 6 months, extensive staining was common except on boards treated with Permatox 101, RODEWOD® 300, and PQ-8

Table 3. Extent of fungal staining on untreated (control) end of red alder boards stored for 2 or 6 months at Corvallis, Oregon (n = number of boards).

Preventive applied to treated end	Percent of untreated test-face area stained								
	n	Mean	Range	n	Mean	Range	n	Mean	Range
		May 25- Aug.2, 1988[1]			July 13- Sept. 13, 1988[2]			Oct. 19- April 17, 1989[3]	
BUSAN® 1009	14	96	90-100	14	94	50-100	14	96	50-100
BUSAN® 1030	14	94	60-100	14	94	70-100	15	95	50-100
NP-1	12	93	70-100	14	91	50-100	15	100	
NYTEK™ + 4160	13	93	70-100	14	94	80-100	15	100	
Permatox 101	14	90	70-100	14	74	50-90	13	96	70-100
PQ-8	14	96	90-100	14	94	80-100	14	94	60-100
QUINDEX® N-10	13	88	50-100	13	87	50-100	15	97	80-100
RODEWOD® 300	12	95	70-100	14	92	50-100	15	99	90-100
Saptol-7	14	100		14	95	70-100	15	99	90-100

[1] Dipped end treated with medium-strength solutions.
[2] Dipped end treated with strong solutions.
[3] Dipped end treated with weak solutions; stored 6 months because of slow staining on control end.

+ borax; about one-half to one-third of those boards remained bright or were slightly stained.

Weak solutions applied in mid-October provided good to excellent protection during the ensuing 2 months of cooling weather (Figure 1). At least 80% of the boards of any treatment remained bright, but staining on control ends was not adequate to justify evaluating the treatments (Table 4). After 6 months, when fungal stain was

Table 4. Percent of red alder boards stained over the indicated percent of area of the treated face, 2 and 6 months after treatment and outdoor storage at Corvallis, Oregon (n = number of boards evaluated).

Preventive (dilution)	Studs evaluated (n) after 2,6 months[1]	Percent of treated face area stained[2]							
		<5	10-30	40-60	70-100	<5	10-30	40-60	70-100
		after 2 months				after 6 months			
Medium-strength solutions (treated May 25, 1988)									
BUSAN® 1009 (1:100)	14, 14	7	21	29	43	0	0	0	100
BUSAN® 1030 (1:100)	14, 14	7	14	21	57	0	0	0	100
NP-1 (1:150)	12, 14	25	42	17	17	0	7	0	93
NYTEK™-GD + 4160 (1:60)	13, 14	15	54	23	8	0	0	0	100
Permatox 101 (1:50)	14, 14	100	0	0	0	64	36	0	0
PQ-8 (1:100)	14, 14	86	14	0	0	0	7	14	79
QUINDEX® N-10 (1:60)	13, 14	0	46	46	7	0	0	7	93
RODEWOD® (1:50)	12, 14	92	8	0	0	14	50	29	7
Saptol-7 (1:16.7)	14, 14	50	36	14	0	0	0	0	100
Strong solutions (treated July 13, 1988)									
BUSAN® (1009 (1:50)	14, 14	14	36	29	21	0	0	0	100
BUSAN® 1030 (1:33.3)	14, 14	29	43	7	21	0	7	29	64
NP-1 (1:100)	14, 14	14	57	29	0	0	14	7	79
NYTEK™-GD + 4160 (1:40)	14, 14	14	29	43	14	0	0	14	86
Permatox 101 (1:33.3)	14, 14	93	7	0	0	57	29	14	0
PQ-8 (1:50)	14, 14	100	0	0	0	36	43	21	0
QUINDEX® N-10 (1:50)	13, 14	15	8	38	38	0	0	0	100
RODEWOD® (1:32.3)	14, 14	100	0	0	0	43	57	0	0
Saptol-7 (1:12.5)	14, 14	79	14	0	7	0	36	21	43
Weak solutions (treated Oct. 19, 1988)									
BUSAN® 1009 (1:133)	*, 14	—*	—	—	—	7	7	29	57
BUSAN® 1030 (1:133)	*, 15	—	—	—	—	0	7	0	93
NP-1 (1:200)	*, 15	—	—	—	—	27	47	7	20
NYTEK™-GD + 4160 (1:80)	*, 15	—	—	—	—	0	40	13	47
Permatox 101 (1:100)	*, 14	—	—	—	—	86	14	0	0
PQ-8 (1:200)	*, 14	—	—	—	—	0	79	14	7
QUINDEX® N-10 (1:70)	*, 15	—	—	—	—	13	40	7	40
RODEWOD® 300 (1:100)	*, 15	—	—	—	—	67	20	13	0
Saptol-7 (1:25)	*,15	—	—	—	—	0	27	33	40

[1] Includes boards having at least 50% stain on untreated control end.
[2] Estimated to nearest 10%.
* Too few boards had stained adequately on untreated control end to justify evaluation of treatments after 2 months.

well established on controls (Table 3), only Permatox 101 provided good protection; RODEWOD® 300 was somewhat less effective, but none of the boards treated with it or with Permatox 101 had stained extensively.

Generally, fungal stains seem to be more difficult to control on red alder than on softwoods. Preventives that performed poorly on red alder, even in strong solutions (Table 4), usually provided good to excellent protection for Douglas-fir, mixed hemlock and fir and, to a lesser degree, sugar pine in similar trials on those woods (Miller 1990).

Conclusions

The following conclusions are based on unusually severe conditions intended to stress the preventives included in these trials. Better protection would be expected under more normal storage conditions.

- In laboratory tests, RODEWOD® 200EC plus borax protected alder at nearly all levels tested. Eight other chemicals provided some protection at the highest level tested. The results illustrate the difficulty of protecting the species from fungal attack.
- Treatment with medium-strength solutions of RODEWOD® 300, PQ-8 + borax, or Permatox 101 should provide good protection from fungal discolorations of solid-piled red alder lumber for at least 2 months of warming weather. Strong solutions should protect solid-piled alder for 2 months including peak summer temperatures. A strong solution of Saptol-7 should provide good, but somewhat less effective, protection.
- Weak solutions of all of the preventives tested should provide good protection for at least 2 months during autumn and winter storage. Permatox 101 should provide good protection through 6 months of cool storage.
- None of the treatments is likely to provide good protection through 6 months of storage that include summer weather.

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