Controlling Sapstain: Trials of Product Group I on Selected Western Softwoods

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Contents

British/Metric Conversion

1 inch = 2.54 centimeters

1 foot = 0.3048 meters

°F = 1.8 (°C) + 32

Abstract

Environmental restrictions have induced many sawmills to seek alternatives to pentachlorophenol (penta) or similar chlorinated phenols to control fungal sapstains on green lumber. Five alternative preventives were evaluated against a traditional penta product (Permatox 101) on Douglas-fir, hem-fir, and pine lumber in an accelerated 6-week test on small specimens in the laboratory and in field trials on bundled studs (2 inch x 4 inch x 8 ft) exposed outdoors for 2 and 6 months.

Strong solutions of most alternative preventives provided good protection of Douglas-fir and hem-fir studs for at least 2 months during warming spring weather; some also protected pine studs. Permatox 101 provided superior protection during prolonged outdoor storage, but may permit surface growth of brown mold.

Introduction

Discoloration of wood by fungi, either on the surface or internally, causes substantial losses to lumber mills, particularly when thick-sapwood species are milled under warm, humid conditions. Chlorinated phenols have been used extensively to control staining fungi from the time wood is cut until it dries (<20% moisture content). Increasingly tight environmental restrictions have driven many mills to seek alternatives to penta and similar chlorinated phenols to control fungal stains. An ideal alternative would be as effective as penta, but generate nonhazardous waste that could be used as landfill or incinerated as boiler fuel.

Interest in sapstain preventives with low toxicity to nontarget organisms goes back more than a decade (Unligil 1976). The search has generated a growing list of potential candidates, many already used as biocides. Several laboratory and field tests of the efficacy of prospective preventives on U.S. and Canadian woods have been reported recently (Cserjesi and Johnson 1982, Cassens and Eslyn 1983, Smith *et al.* 1987). Cserjesi (1980) recommended a procedure for field testing of sapstain-control chemicals, but methods for both laboratory and field tests have varied among investigators (American Society for Testing and Materials 1988, Drysdale and Preston 1982, Eslyn and Cassens 1983). Pine sapwood, generally regarded as being highly susceptible to fungal staining, has been the commonly used medium for small-scale accelerated tests in the laboratory.

This report compares the efficacy of a traditional sapstain preventive (pentachlorophenol) with some alternatives in parallel field and laboratory trials on several western softwoods. Similar trials of a second group of products are in progress.

Procedures

Lumber Collection

Test material was chosen from sound, green, sappy lumber, freshly sawn and free of visible fungal stain. Lumber from old logs that had been stored for long periods was avoided. Rough green studs (2 by 4 inch) were selected by the senior author from bundles of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco var. *menziesii*) and mixed hem-fir lumber from hemlock (*Tsuga heterophylla* [Raf.] Sarg.) and fir (*Abies* sp.). Douglas-fir studs had sound, bright sapwood along the length of at least one face. The presence of wane, an indicator of underlying sapwood, was used to select hem-fir lumber, which does not have discernible sapwood. Pine lumber, routinely sawn during the night shift, was selected by personnel at the cooperating mill for high content of sapwood and size (2 x 4 inch). The first collection was of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.). All subsequent collections were of sugar pine (*P. lambertiana* Dougl.), which was regarded by the mill personnel to be more of a problem.

Constraints on the maximum lapsed time between sawing and dipping of the test lumber limited the material collected to about 100 pieces of each lumber type, which allowed 15 replicates of each of six dip treatments for the field trial. The remaining material was frozen for use in small-scale laboratory tests.

Sapstain Preventives Tested

Some of the sapstain preventives tested (Table 1), including BUSAN® 1030, PQ-8, and

NP-1, were among the most popular alternatives to penta being used in local mills at the time of the study. A less widely used product, NYTEK™-GD, was included because of its relative safety in handling. Protek +, the least hazardous, contained no toxic ingredients. Permatox 101, containing pentachlorophenol, provided the standard for comparison; however, comparisons with Permatox 101 should note trends, rather than give strict credence to differences of a few percentage points.

Solution strengths were based solely on the recommendations of the cooperators for their respective products. A low concentration is the weakest that would be suggested with expectations of success. A medium concentration would normally be recommended to a client. Strong solutions should provide adequate protection under hazardous storage conditions.

Misuse of a strong (1:33) dilution of penta, rather than a medium (1:50), in some experiments was an unfortunate compliance with the label recommendation for dipping bulk-piled lumber.

Laboratory Trials

The accelerated tests in these trials were intended more to provide a quick and preliminary comparison of the efficacies of various products than to identify solution strengths to be used in the field trials. They also tested a greater range of solution strengths than those recommended by suppliers.

The frozen lumber was defrosted and cut into a series of samples (0.25 x 1 x 6 inches long), which were numbered and steamed for 10 minutes at 212°F before treatment. The samples were dipped in graded solutions of each test chemical (Table 1) for 30 seconds. At least six concentrations were tested for most chemicals; concentrations were chosen to permit fuller evaluation of performance of the chemical at very low concentrations. Each treatment was replicated on seven samples of each species. Treated samples were drained on racks until the surface was free of visible droplets and then placed on plastic racks above a water bath in a plastic box (12 x 18 x 6 inches high). 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, was sprayed collectively on the upper surface of each specimen. The boxes were closed and incubated at 90°F in a humidified chamber for 6 weeks.

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 stain ratings were less than or equal to 2.0.

Field Trials

Field trials, normally scheduled for warm weather, were begun in August, 1986, because of the immediate needs of product vendors and local lumber producers. Only medium and low concentrations of dipping solutions were included then, since these trials would extend into a cooling period. Trials of strong solutions were reserved until spring, when the onset of warm weather would test the effectiveness of the chemicals most severely. Lumber for field trials of Douglas-fir and hem-fir was dip-treated within 24 to 30 hours after being sawn. Pine, which was collected from a more distant source, was treated within 36 hours, including overnight wet storage under a water mist, if necessary.

Studs were distributed consecutively into six treatment groups for dipping into test solutions (Table 1). Studs were dipped individually to half-length for 15 seconds as recommended by Cserjesi (1980), drained briefly, and stacked with their dipped ends together and best sapwood face for testing upturned. The undipped end of each stud served as its control.

Each test bundle contained six treatment groups of 15 studs each; studs were stacked by treatments, and stacks were assembled side by side. All specimens in a bundle were of the same wood, and the treatment strength was either low, medium, or strong. Each bundle was tightly strapped, end-coated, and covered with black plastic sheeting to retard drying and to uniformly promote favorable conditions for staining throughout the bundle.

Wrapped bundles were stored outdoors on treated bunks in a shaded location (Cserjesi 1980) through winter of 1986-87, but had to be moved in spring 1987 to a location more exposed to sun and weather. Bundles were roofed with

TABLE 1.
CHEMICALS TESTED AS SAPSTAIN CONTROL AGENTS.

Preventive		a.i.[1]	Concentrations tested (% total a.i.)[1]									
			Laboratory tests							Field tests		
Trade name	Chemical name	(%)	1	2	3	4	5	6	7	Weak	Medium	Strong
BUSAN® 1030	2-(thiocyanomethylthio) benzothiazole	30	1.2	0.6	0.3	0.23	0.15	0.12	nt	0.24	0.32	0.94
NYTEK™-GD	Copper-8-quinolinolate	10	0.046	0.023	0.013	0.007	0.006	nt	nt	(0.027	0.031	0.046)[2]
PQ-8	Copper-8-quinolinolate	5.4	0.020	0.010	0.008	0.005	0.004	0.003	nt	(0.005	0.010	0.020)[2]
	Copper + borax[3]									0.38	0.75	1.47
NP-1	Didecyl dimethyl ammonium chloride	64.8	1.44	0.72	0.36	0.29	0.24	0.21	0.16	0.34	0.52	0.67
	3-iodo-2-propynyl butyl carbamate	7.6										
Permatox 101	Sodium tetrachlorophenate	2.4	1.50	1.00	0.50	0.25	nt	nt	nt	0.31	0.90[4]	0.90
	Sodium pentachlorophenate	20.4										
	Sodium metaborate anhydrous	3.1										
	Phenylmercuric acetate	0.4										
Protek +	Acrylic emulsion—no fungicidal additive		(50.0	20.0	11.11	6.67	3.33	0.67	nt)[5]	(6.25	10.00	16.67)[5]

[1] Total active ingredients (a.i.), percent of solution weight. NYTEK™-GD = copper as metal, PQ-8 = copper as metal, and as copper + added borax.
[2] As percent copper metal.
[3] Borax added to PQ-8 solution.
[4] High concentration was used mistakenly, in compliance with manufacturer's recommendation for bulk-piled pine lumber.
[5] Percent of Protek + in the test solutions.
nt: not tested.

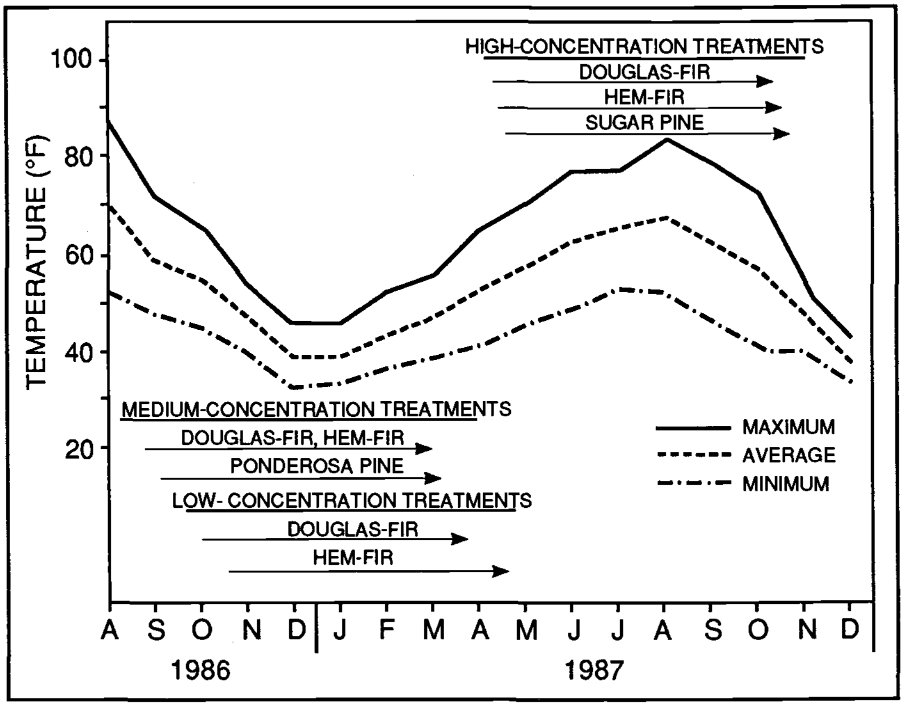

Figure 1. *Average monthly temperatures at Corvallis, OR, during sapstain-control trials.*

flakeboard panels and shielded from solar heating of their south- and west-facing black plastic surfaces. Average monthly temperatures were recorded near outdoor storage sites (Figure 1).

After approximately 2 and 6 months of outdoor storage, the bundles were opened and each specimen was examined visually for extent and intensity of discoloration over its upturned face. Those with adequate staining or fungal growth on the control end (≥50% of undipped sapwood or face area) were examined and rated on the treated face. Studs visibly infected with brown mold were evaluated twice; the first evaluation included the extent of brown mold growth and the second disregarded it. Brown mold (*Cephaloascus fragrans*) growth characteristically is relatively light-colored and superficial. It is usually disregarded by lumber graders unless associated with a more serious defect, such as decay. Wood surfaces that were discolored after 2 months of storage often had become bleached or overrun by subsequent fungal activity after 6 months, particularly during warm weather.

The extent of discoloration, including areas that were overrun or bleached by fungi, was estimated visually as a percentage of the area of the sapwood or of the entire surface. Cambial surfaces, which are particularly susceptible to dark, rapid mold growth, were disregarded. The intensity of discoloration also was estimated visually, based on the criteria of Roff *et al.* (1980) for light, medium, and heavy (dark) stain, with categories added for light-to-medium and medium-to-dark discolorations. Studs that had dried during storage to <27% moisture content about 1/8 inch below the test surface were not rated unless staining was already well advanced.

Results and Discussion

Laboratory Trials

Five chemicals produced effective control of stain and mold fungi for at least one concentration tested (Table 2). Protek +, however, required a 50% concentration to limit stain on hem-fir or pine, and this concentration was ineffective on Douglas-fir.

Both BUSAN® 1030 and NP-1 consistently protected all three wood types at low concentrations. BUSAN® 1030 was least effective on hem-fir and most effective on Douglas-fir, while NP-1 was uniformly effective on all three species. Each formulation of copper-8-quinolinolate provided less protection on one species. NYTEK™-GD was effective on Douglas-fir only at the highest treatment level (0.046%), and PQ-8 was least effective on pine. These differences may reflect distribution of these chemicals on the wood surface or wood-chemical interactions that reduce the effectiveness of these chemicals.

In general, Permatox 101 was effective on pine at field-use concentrations; effects on Douglas-fir and hem-fir were less consistent. However, increased concentration of Permatox 101 did improve stain control. Although Perma-

TABLE 2.

STAIN CONTROL IN SMALL-SCALE LABORATORY EVALUATIONS OF PROTECTIVES.

Preventive	Concentration[1]	Stain rating[2]		
		Douglas-fir	Hem-fir	Pine
BUSAN® 1030	1.20	0.3	0.0	0.0
	0.60	0.1	1.3	0.0
	0.30*	0.3	2.1	0.6
	0.23	1.0	3.4	2.7
	0.15	1.7	2.6	4.9
	0.12	1.0	3.1	6.6
	0.00	3.3	5.5	7.8
NYTEK™-GD	0.046	2.0	0.0	0.0
	0.023	3.0	0.0	0.0
	0.013	4.1	1.0	1.1
	0.007	5.1	1.6	3.3
	0.006	5.4	1.9	4.7
	0.000	5.4	4.7	8.1
PQ-8	0.020	nt	0.4	2.9
	0.010	nt	0.6	3.0
	0.008	nt	2.1	2.9
	0.005	nt	3.4	2.5
	0.004	nt	3.9	3.0
	0.003	nt	6.3	2.9
	0.000	nt	6.2	8.0
NP-1	1.44	0.6	0.0	0.0
	0.72*	0.0	0.9	0.4
	0.36	0.4	1.3	1.4
	0.29	1.1	1.1	0.7
	0.24	1.6	0.0	0.0
	0.21	3.0	2.0	2.4
	0.16	2.3	0.5	2.1
	0.00	3.4	1.7	4.6
Permatox 101	1.50	3.1	2.6	1.8
	1.00	2.6	3.6	2.2
	0.50*	2.5	4.4	4.1
	0.25	3.5	5.7	4.5
	0.00	6.9	8.1	8.8
PROTEK +	50.000	3.9	2.1	1.1
	20.000	5.6	4.0	3.7
	11.111*	6.9	8.3	6.1
	6.667	6.0	8.1	6.9
	3.333	5.3	6.7	6.9
	0.667	6.6	8.3	7.6
	0.000	4.8	8.4	8.5

[1] Active ingredient basis for BUSAN® 1030, NP-1, and Permatox 101, percent copper basis for NYTEK™-GD and PQ-8.

[2] Based upon a stain rating of 0 (no stain) to 10 (completely discolored). Each value represents the average of seven replicates.

* Approximate concentration normally recommended in practice (no recommendation available for NYTEK™-GD, PQ-8).

nt: not tested.

tox 101 reduced staining of Douglas-fir markedly at the lowest level tested (0.25%), little improvement appeared at higher levels. This lack of dosage effect may reflect a limited but tolerant microflora that can continue to slowly grow on and stain the samples.

Field Trials

No product was consistently superior after 2 months of storage. (See Table 3 for fungal staining on untreated controls and Tables 4-6 for staining of treated lumber). Protek +, which is marketed as a sealer, provided no useful control of fungal activity; results of this treatment are not reported. After 6 months, Permatox 101 was the most persistently effective treatment—if brown mold was ignored—except on sugar pine, where it, PQ-8 and a strong solution of BUSAN® 1030 were all similarly effective (Tables 4-6).

Untreated Controls

Staining of untreated control ends of Douglas-fir and pine studs usually had discolored more than 90% of the sapwood area after 2 months of storage (Table 3). Hem-fir controls stained less extensively, especially during cool autumn and spring weather. Staining also was generally of lighter shades of gray in hem-fir than in sapwood of the other species.

Orange-tan discolorations developed on untreated heartwood of some sugar pine studs. Fungi cultured from intensely orange wood were *Trichoderma* sp.; no common wood stainers or bacteria were seen.

Douglas-fir

Studs dipped in medium-strength solutions in August were best protected during the first 2 months of storage by NP-1 (Table 4). After 6 months, most studs in all treatments were discolored. Treatment with a strong solution of Permatox 101 provided excellent protection for 6 months, if brown mold was disregarded.

Most or all of the studs dipped in weak solutions in October remained bright through the first 2 months of storage. Air temperatures fell during that period to a low monthly average of about 47°F (Figure 1), a level at which fungal activity is greatly retarded (Lindgren 1942). After 6 months, during which average air temperature rose again to about 53°F, only studs treated with Permatox 101 remained mostly bright—particularly if brown mold was ignored. However, the incidence of extensively stained studs (70-100% of sapwood face) was generally low in all treatments.

Treatment with strong solutions during early spring (April) provided good protection through the following 2 months. Studs were fully protected by PQ-8 and NP-1. Permatox 101 provided full protection against all fungi but brown mold. After 6 months, which included peak air temperatures during August (Figure 1), few studs not treated with Permatox 101 remained bright, and many had stained extensively. However, Permatox 101 still provided excellent protection if brown mold was ignored.

Hem-Fir

Studs dipped in medium-strength solutions in late August were protected best by Permatox 101, NP-1, and PQ-8 during the first 2 months of storage (Table 5). Few studs remained bright after 6 months, particularly among those treated with BUSAN® 1030 and NYTEK™. At that time, a strong solution of Permatox 101 still provided good protection against all fungi but brown mold.

Studs dipped in weak solutions in October stained slowly. After 3.5 months of storage through the coldest winter temperatures (Figure 1), only 10 to 11 studs in most treatments had stained enough (≥50%) on the control end to allow rating the treatment. Most studs remained bright in all treatments except NP-1 (Table 5). The departure of NP-1 on hem-fir from its otherwise good performance resulted from a high incidence of studs stained on 10% of the treated face area, excluding them from the "bright, <5% stained" category. After 6 months, which included the onset of warming weather, only treatment with Permatox 101 kept most studs bright.

Dipping in strong solutions in mid-April provided good to excellent protection through 2 months of spring (Table 5). Studs treated with BUSAN® 1030, NP-1, or Permatox 101 remained bright or stained only slightly. However, staining was slow, and only 6 to 9 specimens could be rated in some treatments. After 6 months, most studs treated with PQ-8 and all studs treated with Permatox 101 were bright. Other treatments were less effective.

TABLE 3.
EXTENT OF STAINING ON UNTREATED (CONTROL) END OF STUDS STORED FOR 2 MONTHS (SEE FIGURE 1 FOR ACTUAL DATES).[1]

Preventive applied to dipped end of stud (dilution)	Percent of untreated face area stained								
	Douglas-fir			Hem-fir			Pine		
	n	Average	Range	n	Average	Range	n	Average	Range
	Stored early/mid-autumn, 1986			Stored early/mid-autumn, 1986			Ponderosa pine, stored autumn 1986		
Medium-strength solutions									
BUSAN® 1030 (1:100)	15	98.7	90-100	15	98.7	80-100	15	97.0	80-100
NYTEK™-GD (1:60)	15	100.0		15	99.2	90-100	15	96.7	90-100
PQ-8 (1:100)	15	98.0	90-100	14	90.7	50-100	15	95.7	80-100
NP-1 (1:100)[2]	15	98.0	90-100	14	99.3	90-100	15	94.0	70-100
Permatox 101 (1:33)	15	99.7	95-100	13	95.4	50-100	15	91.3	70-100
	Stored mid-/late autumn, 1986			Stored mid-autumn/winter, 1986[3]					
Weak solutions									
BUSAN® 1030 (1:133)	15	100.0		11	87.3	50-100		no test	
NYTEK™-GD (1:70)	15	98.7	85-100	10	88.0	50-100		no test	
PQ-8 (1:200)	15	100.0		10	87.0	60-100		no test	
NP-1 (1:200)	15	97.7	80-100	14	89.6	50-100		no test	
Permatox 101 (1:100)	15	100.0		11	87.3	50-100		no test	
	Stored spring, 1987			Stored spring, 1987			Sugar pine, stored spring, 1986[4]		
Strong solutions									
BUSAN® 1030 (1:33)	15	100.0		12	85.8	50-100	8	89.4	70-100
NYTEK™-GD (1:40)	15	100.0		8	78.8	50-100	10	99.0	90-100
PQ-8 (1:50)	15	100.0		12	87.1	50-100	11	97.3	80-100
NP-1 (1:100)[5]	15	99.0	90-100	9	85.5	50-100	9	96.7	80-100
Permatox 101 (1:33)	15	98.3	80-100	6	86.7	50-100	11	94.1	70-100

[1] Because later fungal activity bleached some stains, percent staining after 6 months is not shown.
[2] Mixed in error at 1:100; should have been diluted 1:150. Solution used on ponderosa pine analyzed by Koppers at 1:128.
[3] Stored 3.5 months because of slow staining.
[4] Some sugar pine studs having sapwood on treated end only had no untreated control.
[5] Solution used on sugar pine analyzed by Koppers at 1:144.

TABLE 4.
STAINING OF DOUGLAS-FIR STUDS 2 AND 6 MONTHS AFTER TREATMENT AND OUTDOOR STORAGE AT CORVALLIS, OR. (SEE FIGURE 1 FOR ACTUAL DATES.) VALUES IN PARENTHESES EXCLUDE BROWN MOLD DAMAGE.

Preventive (dilution)	Number of studs evaluated (n) after 2, 6 months[1]	Percent of studs (n) stained							
		Percent of treated face area stained[2]				Percent of treated face area stained[2]			
		Bright, <5	10-30	40-60	70-100	Bright, <5	10-30	40-60	70-100
		after 2 months				after 6 months			
Medium-strength solutions (treated August 22, 1986)									
BUSAN® 1030 (1:100)	15,15	40 (47)	33 (27)	20	7	20 (27)	27	7	47 (40)
NYTEK™-GD (1:60)	15,15	47 (60)	27 (13)	13	13	7 (13)	33 (27)	33	27
PQ-8 (1:100)	15,15	60 (73)	27 (13)	13	0	20 (40)	27 (20)	27 (13)	27
NP-1 (1:100)[3]	15,15	93	7	0	0	40	27	13	20
Permatox 101 (1:33)[4]	15,15	73 (100)	27 (0)	0	0	33 (93)	33 (0)	0	33 (7)
Weak solutions (treated October 1, 1986)									
BUSAN® 1030 (1:133)	15,14	93	7	0	0	36	29	29	7
NYTEK™-GD (1:70)	15,14	73	7	20	0	7	57	14	21
PQ-8 (1:200)	15,14	80	20	0	0	29	43	14	14
NP-1 (1:200)	15,14	80	20	0	0	29	50	21	0
Permatox 101 (1:100)	15,14	100	0	0	0	86 (93)	14 (7)	0	0
Strong solutions (treated April 7, 1986)									
BUSAN® 1030 (1:33)	15,14	93	7	0	0	7	0	36	57
NYTEK™-GD (1:40)	15,14	87	7	0	7	7	7	7	79
PQ-8 (1:50)	15,14	100	0	0	0	14	7	14	64
NP-1 (1:100)	15,13	100	0	0	0	0	8	8	84
Permatox 101 (1:33)	15,12	80 (100)	20	0	0	50 (92)	42 (8)	8	0

[1] Includes studs having at least 50% stain of sapwood on control end.
[2] Estimated to nearest 10%.
[3] Mixed in error at 1:100; should have been 1:150.
[4] Strong solution.

TABLE 5.
STAINING OF HEM-FIR STUDS 2 AND 6 MONTHS AFTER TREATMENT AND OUTDOOR STORAGE AT CORVALLIS, OR. (SEE FIGURE 1 FOR ACTUAL DATES.) VALUES IN PARENTHESES EXCLUDE BROWN MOLD DAMAGE.

Preventive (dilution)	Number of studs evaluated (n) after 2, 6 months[1]	Percent of studs (n) stained							
		Percent of treated face area stained[2]				Percent of treated face area stained[2]			
		Bright, <5	10-30	40-60	70-100	Bright, <5	10-30	40-60	70-100
Medium-strength solutions (treated August 20, 1986)		after 2 months				after 6 months			
BUSAN® 1030 (1:100)	15,15	47	40	7	7	7	27	27	40
NYTEK™-GD (1:60)	15,15	53	33	7	7	7	47	7	40
PQ-8 (1:100)	14,14	78	7	7	7	36	43	14	7
NP-1 (1:100)[3]	14,15	79	14	0	7	33	40	13	13
Permatox 101 (1:33)[4]	13,13	93 (100)	8 (0)	0	0	69 (85)	15 (8)	8 (0)	8
Weak solutions (treated October 17, 1986)		after 3.5 months[5]							
BUSAN® 1030 (1:133)	11,15	73	27	0	0	13	40	40	7
NYTEK™-GD (1:70)	10,15	90	10	0	0	47	20	13	20
PQ-8 (1:200)	10,14	80	10	0	10	21	29	29	21
NP-1 (1:200)	14,15	43	50*	7	0	13	33	33	20
Permatox 101 (1:100)	11,15	100	0	0	0	73 (87)	27 (13)	0	0
Strong solutions (treated April 14, 1986)		after 2 months							
BUSAN® 1030 (1:33)	12,14	100	0	0	0	50	7	21	21
NYTEK™-GD (1:40)	8,11	75	12	0	12	18	36	27	18
PQ-8 (1:50)	12,14	83	0	8	8	79	14	7	0
NP-1 (1:100)	9,14	100	0	0	0	50	29	21	0
Permatox 101 (1:33)	6,12	100	0	0	0	100	0	0	0

[1] Studs having at least 50% stain on untreated face.
[2] Estimated to nearest 10%.
[3] Mixed in error at 1:100; should have been 1:150.
[4] Strong solution.
[5] Few studs had stained on the control end after 2 months of storage.
* Most studs had 10% of face stained.

TABLE 6.
STAINING OF PINE STUDS 2 AND 6 MONTHS AFTER TREATMENT AND OUTDOOR STORAGE AT CORVALLIS, OR. (SEE FIGURE 1 FOR ACTUAL DATES.)

Preventive (dilution)	Number of studs evaluated (n) after 2, 6 months[1]	Percent of studs (n) stained							
		Percent of treated face area stained[2]				Percent of treated face area stained[2]			
		Bright, <5	10-30	40-60	70-100	Bright, <5	10-30	40-60	70-100
		after 2 months				after 6 months			
Medium-strength solutions (ponderosa pine, treated September 4, 1986)									
BUSAN® 1030 (1:100)	15,15	73	27	0	0	0	20	27	53
NYTEK™-GD (1:60)	15,15	80	20	0	0	13	20	40	27
PQ-8 (1:100)	15,15	87	13	0	0	27	67	7	0
NP-1 (1:100)[3]	15,15	7	53	13	27	0	0	7	93
Permatox 101 (1:33)[4]	15,15	100	0	0	0	20	53	20	7
Strong solutions (sugar pine, treated April 17, 1987)									
BUSAN® 1030 (1:33)	8,9	100	0	0	0	22	44	22	11
NYTEK™-GD (1:40)	13,13	54	15	8	23	15	8	8	69
PQ-8 (1:50)	12,12	83	17	0	0	33	25	33	8
NP-1 (1:100)[5]	10,11	10	20	20	50	18	0	0	82
Permatox 101 (1:33)	12,13	75	25	0	0	31	31	15	23

[1] Studs having at least 50% stain of sapwood on control end; studs having sapwood on dipped end only are also included.

[2] Estimated to nearest 10%.

[3] Mixed in error at 1:100; sample of used solution was analyzed after use by Koppers Co. at 1:128.

[4] Strong solution.

[5] Solution used was analyzed by Koppers at 1:144.

Pine

Most ponderosa pine studs dipped in medium-strength solutions in September remained bright after 2 months of storage, except those treated with NP-1 (Table 6). After 6 months, few bright studs remained in any treatment—including a strong solution of Permatox 101, which along with PQ-8 had provided the best short-term protection.

All sugar pine studs dipped in a strong solution of BUSAN® 1030 and most of those treated with strong solutions of PQ-8 and Permatox 101 remained bright after 2 months of storage (Table 6). The same treatments provided the best protection, with fewest extensively stained pieces, when storage was prolonged to 6 months. Exclusion of studs found during test to be of heartwood reduced the number of rated specimens to 10 to 13 in most treatments. The results of dipping sugar pine studs in low-strength solutions are not included because of a lack of reference data on their sapwood content and split timing on their collection and treatment.

Conclusions

- During warming spring weather with average monthly high temperatures above 65°F, strong solutions of all products tested in these trials except Protek+ should provide good protection of Douglas-fir and hem-fir for at least 2 months. Sugar pine should be well-protected by strong solutions of BUSAN® 1030, PQ-8, or Permatox 101.
- During cooling autumn weather, with average monthly high temperatures falling below 55°F, weak solutions should provide good protection of Douglas-fir and hem-fir for at least 2 months.
- Permatox 101 provides markedly superior protection for Douglas-fir and hem-fir during prolonged storage, especially if brown mold is disregarded.
- Stain development tends to be slower and lighter on hem-fir than on sapwood of Douglas-fir or pine, particularly during cool weather.
- Of the various woods used in these trials, Douglas-fir provided the most reliable test medium. Sapwood was clearly identifiable, and infection and discoloration of untreated control material was relatively quick.
- In general, results of the laboratory trials were similar to those in the field tests. Thus, small-scale laboratory trials of protectives appear to provide effective indices of appropriate levels for field testing.
- Storage conditions in these tests were intended to maximize stress in treatment conditions and therefore were more severe than normal practice. Better product performance could be expected under more realistic field conditions.

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