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…rolling Sapstain: Trials of Product Group II on Selected Western Softwoods

Donald J. Miller
Jeffrey J. Morrell
Maureen Mitchoff

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The Authors

Donald J. Miller and Jeffrey J. Morrell are associate professors, and Maureen Mitchoff is a graduate research assistant, Department of Forest Products, Oregon State University, Corvallis, OR.

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Abstract

Environmental restrictions have induced many sawmills to seek alternatives to pentachlorophenol (penta) or similar chlorinated phenols to control fungal sapstains on green lumber. 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 inches x 4 inches x 8 feet) exposed outdoors for 2 and 6 months.

Solutions of BUSAN® 1009, MBT (Saptol-7), and RODEWOD® 2280-40400 used in laboratory tests protected all three woods. Conditioners added to some solutions had no beneficial effect.

Medium-to-strong solutions of the preventives used in field trials provided good-to-excellent protection for Douglas-fir studs for at least 2 months of warm-season storage; MBT solutions also protected hem-fir and pine studs. Weak solutions of some preventives protected studs for at least 3 months during cool weather. Permatox 101 usually provided the best protection during prolonged storage, but none of the preventives tested for 6 months protected pine well.

Introduction

Discoloration of moist wood by molds and deeply penetrating fungal stains, particularly under warm, damp conditions, substantially lowers the value of some grades of lumber. A practical way to prevent such damage is to treat freshly sawn surfaces of green lumber that cannot be rapidly dried with an effective fungicide. Such treatments have made the shipment of bright, green lumber to overseas markets feasible.

Environmental restrictions against the use of sodium pentachlorophenate (penta), a traditional and effective treatment for controlling fungal stains and most molds, have induced many mills to seek alternative fungicidal treatments. An ideal fungicide would be as effective as penta, but not hazardous to humans or the environment. Numerous potential alternatives to the traditional penta-based formulations have been introduced or tested during the past few years and more are likely to be produced. Other field and laboratory tests of alternative fungicides conducted during the 1980's on U.S. and Canadian woods are cited in the previous report of our trials (1986-87) of six products for controlling sapstain on Douglas-fir, hem-fir, and pine lumber (Miller and Morrell, 1989).

This second report describes additional laboratory and field trials (1987-88) that compare the efficacy of the same penta product (Permatox 101) with that of several alternatives. NYTEK™ GD, which had been evaluated in our previous study, was included in the laboratory tests. NYTEK™ GD plus a conditioner was included in both field and laboratory tests.

Procedures

Test Material

Freshly sawn, sound, green studs (2 by 4 inches) of Douglas-fir (*Pseudotsuga menziesii* Mirb. Franco var. *menziesii*), mixed hem-fir from western hemlock (*Tsuga heterophylla* Raf. Sarg.) and fir (*Abies* sp.), and sugar pine (*Pinus lambertiana* Dougl.) were selected for high sapwood content and freedom from fungal stains. 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 the hem-fir lumber, which does not have discernible sapwood. Pine lumber was selected for sapwood content by personnel at the cooperating mill. At each of three collections, about 100 studs of each species were collected; 90 were allocated to field trials, and 10 were frozen for small-scale laboratory tests.

Sapstain Preventives Tested

All of the alternative preventives tested are less hazardous than penta (Table 1). BUSAN® 1009 is a different formulation from BUSAN® 1030, previously tested. NYTEK™ GD, previ-

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

Preventive			Concentrations tested (% total a.i.)								
			Laboratory tests						Field tests		
Trade name	Chemical name	a.i. (%)	1	2	3	4	5	6	Low	Med.	Strong
BUSAN® 1009	Methylene bis thiocyanate	10	0.067	0.10	0.13	0.15	0.20	0.40	0.16	0.21	0.42
	2-(thiocyanomethyl) thiobenzothiazole	10									
MBT (Saptol-7)	Methylene bis thiocyanate	10	0.10	0.20	0.40	0.50	0.80	1.60	0.39	0.58	0.75
NYTEK™ GD (alone)	Copper-8-quinolinolate	10	(0.0152	0.0182	0.0212	0.0243	0.273	0.303)[1]	——	No test	——
NYTEK™ GD plus 4160 conditioner	Copper-8-quinolinolate	10	(0.0152	0.0182	0.0212	0.0243	0.0273	0.0303)[1]	(0.024	0.031	0.046)[1]
	4160 (additive)[2]	0									
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									
QUINDEX® N-10	Copper-8-quinolinolate	10	(0.01	0.0125	0.0143	0.0167	0.025	0.050)[1]	(0.027	0.031	0.038)[1]
RODEWOD® 200EC	Azaconazole	18.5	0.047	0.094	0.141	0.188	0.282	0.370	——	No test	——
RODEWOD® 200EC plus borax	Azaconazole	18.5	1.547	1.594	1.641	1.688	1.782	1.870	—	1.65[3]	—
	Borax[2]	52.8									
RODEWOD® 200EC plus DF50	Azaconazole	18.5	0.047	0.094	0.141	0.188	0.282	0.370	—	—	0.30[4]
	DF50[2]	50.0	0.027	0.053	0.080	0.107	0.160	0.200			
RODEWOD® 2280-40400	Azaconazole	4.3	0.079	0.159	0.238	0.317	0.476	0.952	0.22	—	0.44
	Didecyl dimethyl ammonium chloride	43.0									

[1] Percent copper metal
[2] Added to solution
[3] Includes 1.46% a.i. of borax
[4] Used only on pine. Includes 0.10% a.i. of DF50.

ously tested, was included again with 4160, a conditioner. Both QUINDEX® N-10 and NYTEK™ GD contain the same active ingredient, copper-8-quinolinolate. Four different RODEWOD® products were tested. Neither MBT (Saptol-7) nor the RODEWOD® products are available at the present time in the United States. 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.

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.

Sapwood samples of Douglas-fir, sugar pine, and hem-fir (1/4 inch x 1 inch x 6 inches), which had been frozen for storage, were numbered and steamed at 212°F for 20 minutes to eliminate any fungi established in the wood. Preliminary trials indicated that steaming did not adversely affect the degree or rate of staining. These procedures were a modification of those used in our previous test. The Douglas-fir and hem-fir were pressure-soaked in water for 1 hour at 120 psi, and the pine was vacuum-soaked for 30 minutes to raise the wood moisture contents to 80-100%. Specimens that were too wet were air dried until their weights were in the desired moisture content range.

All of the sapstain-preventive treatments were evaluated on each of the wood species. Six different concentrations were formulated for each chemical product (Table 1), and each concentration was tested on seven replications per wood species. Each specimen was dipped for 30 seconds and then allowed to air dry for 30 minutes.

After drying, the specimens were flooded with a mixture of spore suspensions containing *Alternaria alternata*, *Aspergillus niger*, *Ulocladium atrum*, *Penicillium claviforme*, *Rhinocladiella atrovirens*, and *Phialophora heteromorpha*. The fungi had been grown on malt agar media until the mycelia covered the plates. After distilled water was added to the plates, the growing surface of each was scraped to dislodge spores, and the water-spore suspension was decanted collectively into a spray bottle for application.

The inoculated sample pieces were stickered and placed in plastic bags—one preventive-treated species per bag. The bags were then incubated at 90°F and 90% relative humidity for a minimum of 6 weeks. The specimens were resprayed with the spore suspension at 1-week intervals until the untreated controls were overgrown with sporulating fungi.

When the untreated specimens from each test had developed stain, the treated specimens were rated 0 to 10 for degree of stain on the following scale:

Rating	Degree of damage
0	no stain
1	minor stain or mold (<5% coverage)
2	stain increasing (10-15% coverage)
3	15-20% stain coverage
4	20-30% stain coverage
5	30-50% stain coverage
6	50-60% stain coverage
7	60-75% stain coverage
8	75-90% stain coverage
9	Heavy stain, all surfaces (90-95% coverage)
10	Severe stain, some decay may also be evident

Stain ratings for treated specimens were compared to those for untreated controls exposed to the same conditions.

Field Trials

Trials of medium-strength solutions began in late April and early May, 1987. Strong solutions were included in the testing later in May and June as the weather warmed and the potential for staining increased. Trials of weak solutions were delayed until cool October weather, when less protection is needed (Figure 1).

Studs were treated within 24 to 36 hours after being sawn. Each was individually dipped to half its length for 15 seconds in solutions containing low, medium, or high concentrations of the products listed in Table 1. Each treatment (product x concentration x wood species) was replicated on 15 studs. Treated studs were close-piled in bundles, each bundle containing 6 products x 1 concentration x 1 species x 15 replications—a total of 90 studs. Bundled studs were tightly strapped, end-coated, and then wrapped in black plastic sheeting to retard drying and uniformly promote favorable conditions for staining throughout the bundle.

Wrapped bundles were stored outdoors on treated bunks in a location exposed to sun and weather at Corvallis, Oregon. Bundles were roofed with 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 *(Cephaloascus fragrans)* were evaluated twice; the first evaluation included the extent of brown mold growth and the second disregarded it. Brown mold 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.

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 of Douglas-fir and pine or of the entire surface of hem-fir. Cambial surfaces, which are particularly susceptible to dark, rapid mold growth, were disregarded. 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.

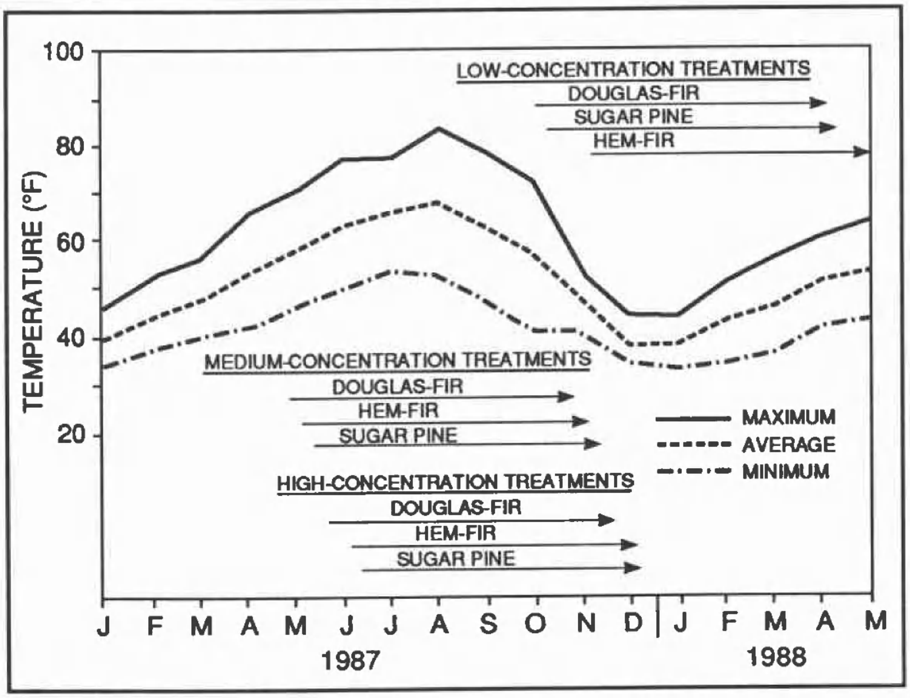

Figure 1. Average monthly temperatures at Corvallis, Oregon, during field trials of Product Group II on Douglas-fir, hem-fir, and sugar pine.

Results and Discussion

Laboratory Trials

The results obtained with each chemical were compared to those from untreated controls. Chemicals that had a stain rating of less than 3.0 had adequate performance. In tests on Group I chemicals described in our previous report (Miller and Morrell, 1989), a rating of 2 was sufficient; however, the procedures used to evaluate the Group II chemicals were more severe and a higher stain rating was deemed comparable. On the basis of this criterion, most of the chemicals were capable of protecting pine, hem-fir, or Douglas-fir sapwood, although certain chemicals failed to protect some species (Table 2). For example, QUINDEX® and NYTEK™ GD failed to protect pine and Douglas-fir, but protected hem-fir. Both of these formulations contain copper-8-quinolinolate as the active ingredient. The addition of a conditioner slightly improved the performance of NYTEK™ GD on Douglas-fir, but had little effect on the other species. RODEWOD® 200EC plus borax or DF50 failed to protect hem-fir.

Several chemicals provided excellent protection to all three species. RODEWOD® 2280-40400 protected all of them at the lowest level tested. MBT and BUSAN® 1009 provided protection to pine and Douglas-fir at all levels tested. They also protected hem-fir at active ingredient levels at 0.40% (MBT) and at 0.20% (BUSAN® 1009). Similarly, RODEWOD® 200EC provided protection at an active ingredient level of 0.188% for hem-fir and Douglas-fir and 0.094% for pine. Permatox 101 provided protection to all three species, although the levels required were somewhat higher than those normally employed in commercial practice.

Several variations of RODEWOD®, including the addition of borax and DF50, appeared to decrease the protective effect of the active ingredient. These additives may have altered solubility or the normal wood/chemical interactions, thereby decreasing efficacy. These changes highlight the need to critically evaluate additives for their effect on efficacy.

The laboratory trials indicate that several formulations, including BUSAN® 1009, MBT, RODEWOD® 200EC, and RODEWOD® 2280-40400, provided protection equal to or better than Permatox 101, the comparison standard. Several of the other chemicals provided protection to some species (Table 2).

Table 2. Ability of selected chemicals to prevent fungal stain of sugar pine, hem-fir, or Douglas-fir sapwood in an accelerated laboratory test.

Chemical trade name	Wood species	Degree of stain[1]						
			Active ingredient level[2]					
		Control (0)	1	2	3	4	5	6
BUSAN® 1009	pine	8.6	1.4	0.4	0.0	0.3	0.3	0.1
	hem-fir	6.3	3.6	4.1	2.7	3.0	2.3	2.4
	Douglas-fir	6.6	1.1	1.3	0.7	0.0	0.0	0.0
MBT (Saptol-7)	pine	8.9	1.3	1.7	0.1	0.7	1.0	0.0
	hem-fir	7.7	3.4	3.3	2.9	2.9	2.0	2.0
	Douglas-fir	8.4	1.9	2.1	1.9	2.3	2.1	1.6
NYTEK™ GD (alone)	pine	6.3	6.1	6.7	5.7	6.7	5.4	6.6
	hem-fir	6.9	4.4	5.0	3.0	3.7	2.7	1.9
	Douglas-fir	5.3	3.7	5.0	5.6	3.7	7.6	6.9
NYTEK™ GD plus 4160 conditioner	pine	7.4	7.1	6.4	7.6	6.7	6.9	6.7
	hem-fir	5.8	4.3	4.7	5.1	2.4	1.8	2.9
	Douglas-fir	6.5	6.0	4.1	4.0	4.3	4.9	4.0
Permatox 101	pine	7.0	6.9	4.9	4.6	2.7	2.9	3.0
	hem-fir	7.0	6.0	5.4	4.4	5.1	4.0	3.1
	Douglas-fir	7.6	7.1	5.6	4.7	4.4	3.6	3.3
QUINDEX® N-10	pine	6.7	6.3	6.3	8.3	5.3	5.0	4.6
	hem-fir	8.1	5.7	4.4	5.1	4.1	3.6	2.6
	Douglas-fir	7.1	3.7	3.5	4.9	4.3	4.0	3.7
RODEWOD® 200EC	pine	5.1	3.1	2.6	1.6	1.7	0.4	0.3
	hem-fir	6.4	5.7	6.6	3.4	2.9	3.1	0.3
	Douglas-fir	8.0	5.4	5.7	3.6	1.6	1.9	0.9
RODEWOD® 200EC plus borax	pine	6.7	6.0	4.9	4.7	4.6	3.9	3.1
	hem-fir	6.7	7.0	6.3	5.1	5.1	5.0	4.0
	Douglas-fir	9.3	7.0	6.9	6.3	5.1	4.0	2.3
RODEWOD® 200EC plus DF50	pine	6.0	4.0	5.9	5.3	5.4	5.0	5.1
	hem-fir	7.0	6.9	6.4	6.3	6.3	4.9	5.1
	Douglas-fir	8.4	3.1	3.1	3.3	2.4	2.7	1.7
RODEWOD® 2280-40400	pine	6.9	1.4	0.7	0.0	0.3	1.1	0.0
	hem-fir	4.4	3.1	2.4	0.7	1.0	0.4	0.7
	Douglas-fir	6.7	2.7	3.6	1.9	1.4	2.0[3]	1.3

[1] Degree of stain based upon ratings from 0 (no stain) to 10 (completely discolored). Each value represents the mean of 7 specimens.
[2] For active ingredient levels, see Table 1.
[3] Decay present.

Field Trials

Untreated controls

The extent of staining on the untreated control ends of studs is summarized in Table 3. Staining and surface discoloration of untreated wood of the three species groups was generally similar to that found in previous trials. Untreated hem-fir, as before, did not discolor as rapidly nor as darkly as sapwood of Douglas-fir or sugar pine, especially during cool weather. Hem-fir studs stained so slowly on their untreated control ends during cool winter weather that 6 months of storage time elapsed before staining was adequate (≥50% of untreated face area) for an evaluation of the respective treated ends. Observations on intensity (darkness) of stains were made after 2 to 3 months of storage. Later observations were sometimes confounded by bleaching action of post-staining fungal activity, especially during warm weather.

Table 3. Extent of staining on untreated (control) ends of softwood studs stored at Corvallis, Oregon (n = number of boards evaluated).

Preventive applied to dipped end of stud (dilution)	Percent of untreated face area stained								
	Douglas-fir sapwood			Hem-fir			Sugar pine sapwood		
	n[1]	Average	Range	n[1]	Average	Range	n[1]	Average	Range
Medium-strength solutions	Stored 2 months (spring-early summer 1987)								
RODEWOD® 200EC plus borax (1:99)	15	99.7	95-100	8	77.5	70-90	10	95.0	70-100
BUSAN® 1009 (1:100)	15	98.7	90-100	14	75.0	50-100	8	100.0	—
QUINDEX® N-10 (1:60)	15	99.3	95-100	10	76.0	50-100	9	100.0	—
MBT (Saptol-7) (1:16.7)	15	96.7	50-100	12	85.4	50-100	9	100.0	—
NYTEK™ GD plus 4160 (1:60)	15	99.3	90-100	8	80.0	50-100	10	100.0	—
Permatox 101 (1:50)	15	98.7	90-100	7	88.6	50-100	8	98.8	90-100
Strong solutions	Stored 2 months (late spring-early summer 1987)								
RODEWOD® 2280-40400 (1:99)	15	99.7	95-100	7	92.9	50-100	No test		
RODEWOD® 200 EC plus DF50 (1:100)	No test			No test			12	83.3	50-100
BUSAN® 1009 (1:50)	15	99.3	95-100	12	92.5	50-100	13	94.6	60-100
QUINDEX® N-10 (1:50)	15	100.0	—	12	85.0	50-100	10	82.5	50-100
MBT (Saptol-7) (1:12.5)	15	100.0	—	14	91.5	50-100	12	87.9	50-100
NYTEK™ GD plus 4160 (1:40)	15	99.7	95-100	13	84.6	50-100	14	87.1	50-100
Permatox 101 (1:33.3)	15	100.0	—	9	74.4	50-100	13	92.3	60-100
Weak solutions	Stored 3 or 6 months (fall-early winter, 1987; or to spring 1988)[2]								
RODEWOD® 2280-40400 (1:199)	15	97.3	70-100	11	88.2	50-100	7	97.1	80-100
BUSAN® 1009 (1:133)	15	100.0	—	13	93.8	70-100	9[3]	100.0	—
QUINDEX® N-10 (1:70)	15	100.0	—	12	90.0	50-100	8[3]	92.5	70-100
MBT (Saptol-7) (1:25)	15	100.0	—	15	96.0	50-100	12	85.8	50-100
NYTEK™ GD plus 4160 (1:80)	15	95.3	60-100	12	80.0	30-100[4]	8[3]	96.3	80-100
Permatox 101 (1:100)	15	97.3	60-100	11	86.4	50-100	8[3]	86.3	50-100

[1] Includes studs having at least 50% stain on the control end.
[2] Hem-fir controls not stained adequately after 3 months to evaluate treatments; their storage continued until spring 1988.
[3] Excludes studs having sapwood on treated end only.
[4] One stud having 30% stain on control end and 80% on treated end was included.

Not all of the 15 hem-fir studs in a treatment group stained enough on their untreated control ends to permit evaluation of their respective treatment. This uncontrollable lag in stain development reduced the number of replicates that could be rated per treatment, down from 15 studs to as few as 7 (Table 3). The average extent of staining on the control ends of hem-fir studs that could be rated was at least 74% of the untreated face area, which was consistently less than on untreated Douglas-fir sapwood.

Sapwood on the untreated control ends of Douglas-fir studs stained extensively under all storage conditions; all the studs had stained enough to permit evaluation of their respective treated ends. The average extent of staining on the control ends within a treatment group (15 replicate studs) amounted to >95% of their untreated sapwood face area.

Untreated sapwood of sugar pine controls also stained extensively under all storage conditions. It generally stained more than that of the hem-fir controls, but no worse than untreated sapwood of Douglas-fir. A lack of sapwood on some sugar pine studs was not apparent until stain later developed. Deletion of those studs from tests, because they lacked sapwood, caused reductions of replication from 15 to as few as 7 studs (Table 3). The average extent of staining on control ends of the test studs within a treatment group was at least 82% of the untreated sapwood face area. Orange-tan discoloration seen in previous trials was again common on sugar pine heartwood. Attempts to culture the orange-colored wood resulted in the isolation of a *Trichoderma* sp., but no common wood stainers or bacteria.

Douglas-fir

Studs dipped during late April 1987 in medium-strength solutions were well protected for 2 months by all treatments (Table 4). Treatment with Permatox 101 provided excellent protection through 6 months if damage from brown mold was disregarded; other treatments were considerably less successful.

Strong solutions applied in mid-May 1987 generally provided even better protection over a 2-month period, although little improvement

Table 4. Percent of n Douglas-fir studs stained over the indicated percent of area of the treated face, after treatment and outdoor storage at Corvallis, Oregon. Values in parentheses exclude brown mold damage.

Preventive (dilution)	Number (n) of studs evaluated after 2, 6 months[1]	Percent of treated face area stained							
		Bright, <5	10-30	40-60	70-100	Bright, <5	10-30	40-60	70-100
Medium-strength solutions (dipped April 28, 1987)		after 2 months				after 6 months			
RODEWOD® 200EC plus borax (1:99)	15,14	93	7	0	0	21	7	7	64
BUSAN® 1009 (1:100)	15,14	87	13	0	0	0	0	7	93
QUINDEX® N-10 (1:60)	15,14	93	7	0	0	0	7	14	79
MBT (Saptol-7) (1:16.7)	15,14	93	7	0	0	29	14	7	50
NYTEK™ GD plus 4160 (1:60)	15,13	87	13	0	0	0	15	0	85
Permatox 101 (1:50)	15,11	73(100)	20(0)	7(0)	0	18(91)	45(9)	18(0)	18(0)
Strong solutions (dipped May 19, 1987)									
RODEWOD® 2280-40400 (1:99)	15,14	100	0	0	0	14	29	14	43
BUSAN® 1009 (1:50)	15,14	100	0	0	0	7	7	36	50
QUINDEX® N-10 (1:50)	15,14	93	7	0	0	0	21	29	50
MBT (Saptol-7) (1:12.5)	15,14	100	0	0	0	64	21	7	7
NYTEK™ GD plus 4160 (1:40)	15,14	73	27	0	0	7	14	7	71
Permatox 101 (1:33.3)	15,14	100	0	0	0	79(93)	14(7)	0	7(0)
Weak solutions (dipped October 2, 1987)		after 3 months							
RODEWOD® 2280-40400 (1:199)	15,15	93	7	0	0	40	27	13	20
BUSAN® 1009 (1:133)	15,15	80	13	7	0	13	33	13	40
QUINDEX® N-10 (1:70)	15,15	40	47	7	7	0	13	27	60
MBT (Saptol-7) (1:25)	15,15	100	0	0	0	73	20	0	7
NYTEK™ GD plus 4160 (1:80)	15,15	20	40	20	20	0	0	20	80
Permatox 101 (1:100)	15,15	100	0	0	0	80(100)	20(0)	0	0

[1] Includes studs having at least 50% stain of sapwood on control end.

was possible in some cases. The increased dosages also reduced the occurrence of extensively stained studs with discoloration over 70 to 100% of the treated face area after 6 months of storage.

Most of the low-strength solutions applied in early October 1987 provided good-to-excellent protection during the following 3 months of cooling weather (Table 4, Figure 1). After 6 months of storage, studs treated with Permatox 101 and MBT had the best protection and were the brightest and least extensively stained.

Hem-fir

The number of studs in the hem-fir treatments was reduced after 2 months of storage by inadequate staining activity on the control end of some studs.

Most of the treatments with medium-strength solutions applied in early May 1987 provided reasonably good-to-good protection during the first 2 months of storage; extensively stained studs were rare (Table 5). After 6 months of storage, however, there were few bright studs, except those treated with Permatox 101. Extensively stained studs were common among most of the other treatments.

Studs dipped in strong solutions during early June 1987 were fully protected by MBT and Permatox 101 during the following 2 months of storage as air temperatures ap-

Table 5. Percent of n hem-fir studs stained over the indicated percent of area of the treated face, after treatment and outdoor storage at Corvallis, Oregon. Values in parentheses exclude brown mold.

Preventive (dilution)	Number (n) of studs evaluated after 2, 6 months[1]	Percent of treated face area stained							
		Bright, <5	10-30	40-60	70-100	Bright, <5	10-30	40-60	70-100
Medium-strength solutions (dipped May 6, 1987)		after 2 months				after 6 months			
RODEWOD® 200EC plus borax (1:99)	8,13	75	25	0	0	15	23	31	31
BUSAN® 1009 (1:100)	14,14	57	29	7	7	0	14	21	64
QUINDEX® N-10 (1:60)	10,13	50	50	0	0	0	31	31	38
MBT (Saptol-7) (1:16.7)	12,14	92	8	0	0	0	14	0	86
NYTEK™ GD plus 4160 (1:60)	8,14	88	0	12	0	7	50	29	14
Permatox 101 (1:50)	7,14	86(100)	14(0)	0	0	64(100)	14(0)	7(0)	14(0)
Strong solutions (dipped June 4, 1987)									
RODEWOD® 2280-40400 (1:99)	7,15	71	14	0	14	7	27	27	40
BUSAN® 1009 (1:50)	12,15	75	17	8	0	7	7	0	87
QUINDEX® N-10 (1:50)	12,15	42	42	0	17	0	0	20	80
MBT (Saptol-7) (1:12.5)	13,15	100	0	0	0	7	20	13	60
NYTEK™ GD plus 4160 (1:40)	12,15	75	25	0	0	13	27	27	33
Permatox 101 (1:33.3)	9,14	100	0	0	0	93(100)	7(0)	0	0
Weak solutions[2] (dipped November 4, 1987)									
RODEWOD® 2280-40400 (1:199)	—,11					18	18	45	18
BUSAN® 1009 (1:133)	—,13					46	15	23	15
QUINDEX® N-10 (1:70)	—,12					8	33	8	50
MBT (Saptol-7) (1:25)	—,15		Not evaluated[2]			73	13	13	0
NYTEK™ GD plus 4160 (1:80)	—,12					17	17	0	67
Permatox 101 (1:100)	—,11					73	18	9	0

[1] Includes studs having at least 50% stain of untreated face on control end.
[2] Not enough stain for evaluation after 4 months of storage.

proached their annual peak in August (Table 5, Figure 1). Most of the other treatments provided reasonably good protection, and few studs had stained extensively. After 6 months, Permatox 101 still provided a high level of protection; extensively stained studs were common among all other treatments.

Studs dipped in low-strength solutions during early November 1987 generally had not developed enough stain on their untreated control ends after 4 months of cold-weather storage to allow evaluation of the treated ends (Table 5). Average maximum temperatures, which fell below 45°F during December 1987 and January 1988 (Figure 1), would have drastically retarded the further development of any initial staining. After 6 months of storage, treatments with MBT and Permatox 101 had provided the best protection and the greatest percentages of bright studs. None of the studs treated with those chemicals were extensively stained.

Sugar pine

A lack of sapwood on some pieces reduced the number of studs suitable for these trials.

Studs dipped in medium-strength solutions during mid-May 1987 were fully protected by MBT over the following 2 months of storage, but other treatments were less effective (Table 6). RODEWOD® 200EC plus borax was at least as good as Permatox 101, while the BUSAN® 1009

Table 6. Percent of n sugar pine studs stained over the indicated percent of area of the treated face, after treatment and outdoor storage at Corvallis, Oregon. Values in parentheses exclude brown mold.

Preventive (dilution)	Number (n) of studs evaluated after 2, 6 months[1]	Percent of treated face area stained							
		Bright, <5	10-30	40-60	70-100	Bright, <5	10-30	40-60	70-100
Medium-strength solutions (dipped May 13, 1987)		after 2 months				after 6 months			
RODEWOD® 200EC plus borax (1:99)	10,13	40	50	10	0	0	8	8	85
BUSAN® 1009 (1:100)	8,12	62	25	0	12	0	0	0	100
QUINDEX® N-10 (1:60)	9,12	0	33	11	55	0	0	0	100
MBT (Saptol-7) (1:16.7)	9,12	100	0	0	0	0	17	42	42
NYTEK™ GD plus 4160 (1:60)	10,14	0	10	20	70	0	0	0	100
Permatox 101 (1:50)	8,13	37	37	12	12	0	0	23	77
Strong solutions (dipped June 11, 1987)									
RODEWOD® 200EC plus DF50 (1:100)	12,12	67	33	0	0	17	25	33	25
BUSAN® 1009 (1:50)	13,13	85	15	0	0	0	15	23	61
QUINDEX® N-10 (1:50)	10,11	20	20	20	40	0	0	9	91
MBT (Saptol-7) (1:12.5)	12,12	92	8	0	0	8	17	17	58
NYTEK™ GD plus 4160 (1:40)	14,15	29	43	14	14	0	0	7	93
Permatox 101 (1:33.3)	13,13	92(100)	8(0)	0	0	8(23)	77(69)	15(8)	0
Weak solutions (dipped October 8, 1987)		after 3 months							
RODEWOD® 2280-40400 (1:199)	7,7	43	29	14	14	14	0	14	71
BUSAN® 1009 (1:133)	10,10	80	20	0	0	20	60	20	0
QUINDEX® N-10 (1:70)	9,10	67	0	33	0	0	40	20	40
MBT (Saptol-7) (1:25)	12,12	100	0	0	0	33	67	0	0
NYTEK™ GD plus 4160 (1:80)	10,10	20	70	0	10	0	10	30	60
Permatox 101 (1:100)	10,10	100	0	0	0	30	60	0	10

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

treatment was better. After 6 months, there were no bright studs in any of the treatments and extensively stained pieces were common.

Strong solutions of MBT, Permatox 101, and BUSAN® 1009 applied in mid-June 1987 provided good-to-excellent protection during the following 2 months of storage as summer temperatures neared their August peak (Figure 1, Table 6). Treatment with RODEWOD® 200EC plus DF50 yielded fewer bright studs, but there were no extensively stained pieces in any of those four treatments after the first 2 months of storage. After 6 months there were few bright studs, and extensive staining was common in all treatments except Permatox 101 and, to a lesser degree, RODEWOD® 200EC plus DF50.

Studs dipped in low-strength solutions of BUSAN® 1009, MBT, and Permatox 101 during early October 1987 had good-to-excellent protection during the next 2 months as temperatures fell toward their December-January lows (Figure 1, Table 6). Those treatments continued to provide the best protection throughout the 6-month storage period, although most of those studs became stained over 10 to 30% of their dipped sapwood face area.

Conclusions

Laboratory Trials

BUSAN® 1009, MBT, and RODEWOD® 2280-40400 protected all three wood species tested, while QUINDEX® and NYTEK™ GD were unable to protect one or more species. The addition of various "conditioners" to formulations appeared to have no effect or, in some cases, had a negative effect, on chemical performances. Thus, the need exists to thoroughly evaluate the influence of such additives.

Field Trials

These conclusions are based on storage conditions intended to stress the treatments. Better product performance can be expected under more realistic field conditions.

- During warming weather of spring and early summer, when average monthly high temperatures rise above 65°F, medium-to-strong solutions of the products included in these trials should provide good-to-excellent protection of Douglas-fir for at least 2 months. Strong solutions of most products can provide virtually complete protection during that time. MBT was the best of the strong solutions (other than Permatox 101) tested on hem-fir and sugar pine stored for 2 months.
- During cooling autumn weather, when average monthly high temperatures fall rapidly below approximately 55°F, low-concentration (weak) solutions of most of the trial products should provide good-to-excellent protection for Douglas-fir and hem-fir for at least 3 months. A weak solution of MBT also completely protected sugar pine for 2 months.
- As previously reported for Group I fungicides, Permatox 101 generally provided the best protection of Douglas-fir and hem-fir during prolonged storage (6 months), especially if brown mold is disregarded. None of the tested products performed well on sugar pine for that period of time.
- Also, as reported for the previous trial, stain tended to develop slower and have a lighter shade on hem-fir than on sapwood of Douglas-fir or sugar pine, particularly during cool weather.

Literature Cited

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Miller, Donald J., Jeffrey J. Morrell, and Maureen Mitchoff. 1989. CONTROLLING SAPSTAIN: TRIALS OF PRODUCT GROUP II ON SELECTED WESTERN SOFTWOODS. Forest Research Laboratory, Oregon State University, Corvallis. Research Bulletin 66. 10 p.

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 inches x 4 inches x 8 feet) exposed outdoors for 2 and 6 months.

Solutions of BUSAN® 1009, MBT (Saptol-7), and RODEWOD® 2280-40400 used in laboratory tests protected all three woods. Conditioners added to some solutions had no beneficial effect.

Medium-to-strong solutions of the preventives used in field trials provided good-to-excellent protection for Douglas-fir studs for at least 2 months of warm-season storage; MBT solutions also protected hem-fir and pine studs. Weak solutions of some preventives protected studs for at least 3 months during cool weather. Permatox 101 usually provided the best protection during prolonged storage, but none of the preventives tested for 6 months protected pine well.

Miller, Donald J., Jeffrey J. Morrell, and Maureen Mitchoff. 1989. CONTROLLING SAPSTAIN: TRIALS OF PRODUCT GROUP II ON SELECTED WESTERN SOFTWOODS. Forest Research Laboratory, Oregon State University, Corvallis. Research Bulletin 66. 10 p.

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