Comparison of Performance of Wood Extractives as Preservatives in Field Tests against Termites and Decay in the USA and Pakistan

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ABSTRACT

Increasing environmental regulations have limited the use of certain broad spectrum synthetic pesticides as wood preservatives creating a need for more environmentally benign wood preservative systems. Biocidal compounds from natural products have been proposed as alternatives to commercial wood preservatives, but field data from long term performance testing is lacking. To investigate long term performance of wood extractives, stakes and blocks of southern pine (SP) and cottonwood (CW) were treated with heartwood extractives of four durable wood species commonly used in Pakistan. Treated samples were exposed to decay and termites using two American Wood Protection Association (AWPA) standard field evaluation methods: AWPA E26 and AWPA E7 in Mississippi (USA) and Lahore (Pakistan). After one year of exposure in Pakistan, solvent treated SP and CW test samples were severely destroyed by *Heterotermes indicola* in both tests. In both tests, wood treated with extractives from *Pinus roxburghii* and *Cedrus deodara* incurred higher levels of termite attack at both sites compared to their extractives + oil (Linseed). Decay ratings for *Dalbergia sissoo*, *Cedrus deodara*, and *Pinus roxburghii* treated wood were also lower than other treatments at both sites. Positive control E7 stakes treated with Cu-NAP and E26 blocks treated with borate showed slight attack by termites and decay at the Lahore site, however there was no attack observed at the Mississippi site. Solid heartwood *P. roxburghii* and *C. deodara* E7 stakes had average decay ratings of less than 5 at the Lahore site. However, there was no attack observed on E7 stakes at the Mississippi site except in *P. roxburghii*. There was higher termite pressure by *Heterotermes indicola* in Pakistan compared to *Reticulitermes flavipes* at the Mississippi site. Lower decay or termite ratings were observed on wood treated with extractives in combination with linseed oil at either site after 12 months.

Keywords: Field test, wood extractives, linseed oil, termite, decay fungi, AWPA E7, AWPA E26

INTRODUCTION

Despite the vulnerability of wood to fungal decay and termite infestation, it is generally accepted that the heartwood of several tree species can be naturally resistant to biodegradation. This resistance, or durability, is commonly due to the sequestration of naturally produced extractives in heartwood as a tree matures and ages (Kadir et al., 2014). Extractives are abundant in heartwood as compared to sapwood, the latter being more prone to decay and termite attack (Taylor et al., 2003). Extractives have been shown to play a pivotal role in the inherent durability of naturally durable wood species (Kirker et al., 2013, Arango et al., 2006). Previous studies have shown that pressure treating of non-durable wood with heartwood extractives removed from durable wood species can provide a measure of protection to the non-durable wood (Adegeye et al., 2009). The need for increased investigation in this area is reflected by the concern of environmental groups and government agencies over the potential health and ecological hazards associated with some wood preservatives currently in use (Asamoah et al., 2011, Hingston et al., 2001). Previous studies focused on laboratory investigations of transferable durability, but field data is limited for these types of studies. The goal of this study was to evaluate extractives of durable wood species of economic importance in Pakistan and assess suitability as potential solvent-borne treatments for non-durable wood species in the field. To do this, two AWPA standard field evaluation methods were employed: a ground proximity test (AWPA E26), where tested samples are placed in covered arrays slightly above the ground, and a more harsh ground contact test (AWPA E7), where sample test stakes are placed in ground contact.

MATERIAL AND METHODS

Test samples and extraction

Heartwood of four durable species, *Tectona grandis* L.f., *Dalbergia sissoo* DC*, Cedrus deodara* (Roxb. ex D.Don) G.Don, and *Pinus roxburghii* Sarg were purchased from a local timber market and shipped to Starkville, MS. After air drying, these were converted into shavings using a planer. Shavings were extracted using 300 ml of an ethanol-toluene (2:1) solvent system according to the ASTM D1105-96 (ASTM 2014). Shavings (12-15 g) were added to ~20 soxhlet apparatuses with a small pad of cotton below and above shavings in each and extraction ran for six hours. The resulting aliquots were evaporated to dryness at reduced pressure by using a rotary evaporator (BUCHI, Rotavapor R-114). The dried residue was re-dissolved with ethanol-toluene (2:1) for a final concentration of 100 mg/ml based on the dry weight of the extractive residue. This was used as a stock solution for the extractive treatment.

Evaluation of extractives as wood preservatives using ground proximity and field stake tests

A ground proximity test method was initiated following the AWPA E26 (Figure 1) (AWPA, 2014b). Test block specimens, 12.5×3.75×2.5 cm, were cut from the sapwood of Southern pine (SP) and cottonwood (CW) boards. A ground contact field stake test was initiated according to the AWPA E7 (Figure 2) (AWPA, 2014a). Stakes, 45.7×1.9×1.9 cm, were cut from the sapwood of southern pine (SP) or cottonwood (CW) boards. Each treatment was replicated five times for both tests. After conditioning at 33°C, 62 ± 3% R.H, all blocks and stakes were labeled with durable, inert, and corrosion resistant tags.

Figure 1. Ground proximity test (AWPA- E26) set up in USA (left) and Pakistan (right).

All test samples were treated using full cell vacuum-pressure with initial vacuum of -91 kPa (gauge) for 30 minutes and then the pressure was applied at 1034 kPa (gauge) for 60 minutes. The blocks and stakes were treated with a 7.5 mg/ml extractive solution alone or in combination with linseed oil at an extractive concentration of 4.25 mg/ml + 20 % oil. For the E7 test, stakes were treated with oil-based copper naphthenate (Cu-NAP) to a retention of 1.2 kg/m^3 (AWPA 2014). These were used as a ground contact positive chemical control. For the E26 ground proximity test, blocks were treated with a borate solution (Disodium Octaborate Tetrahydrate (DOT); as Tim-Bor®) at 4.5 kg/m^3 for the positive chemical control in this test (AWPA 2014). After conditioning and re-weighing, the blocks and stakes were placed at field sites in Saucier, Mississippi, USA, and Lahore, Pakistan.

Figure 2. Field stake test (AWPA- E7) set up in USA (left) and Pakistan (right).

RESULTS

AWPA E26 Southern Pine

The average ratings for the SP test specimens in the ground proximity (AWPA E26) exposure test at each site at the end of 12 months is shown in Table 1. At the Saucier, Mississippi site, solvent treated blocks had an average rating of 9.7. Southern pine blocks treated with *P. roxburghii* extractives showed slight termite damage (9.6). Termite mud tubes (MT) were observed on blocks treated with *T. grandis* and *D. sissoo* extractives. At this site, the *T. grandis* + oil treatment showed discoloration and softening associated with superficial microbial colonization (9.9). At the Lahore, Pakistan site, SP blocks treated with solvent were severely attacked by termites with an average rating of 3.8, while blocks treated with linseed oil only showed moderate termite attack (8.4). *Pinus roxburghii* extractive treated blocks had some termite attack (8.6) and termite mud tubes were found extensively on the array of blocks after 12 months. Discoloration caused by decay was noted on the solvent treated blocks and blocks treated with extractives of *P. roxburghii*. There was also slight decay (9.8) and termite attack (9.6) on borate treated blocks at the Lahore site.

Table 1. Average decay and termite ratings for treated southern pine AWPA E26 blocks in field tests in Lahore, Pakistan, and Saucier, Mississippi, USA

Treatments	Lahore, Pakistan		Saucier, Mississippi	
	Average rating		Average rating	
	Decay	Termite	Decay	Termite
Solvent	9.6	3.8 (MT)	10	9.7 (A)
Linseed oil	9.6	8.4 (MT)	10	10
T. grandis	10	9.6 (MT)	10	9.8 (MT)
D. sissoo	9.7	9.4 (MT, A)	10	9.8 (MT)
C. deodara	10	9.8 (MT)	10	10
P. roxburghii	9.7	8.6 (MT, A)	10	9.6 (MT)
T. grandis + oil	9.8	9.9 (MT)	9.9	10
D. sissoo + oil	10	10 (MT)	10	10
C. deodara +oil	9.9	9.9 (MT, A)	10	10 (MT)
P.roxburghii +oil	9.6	9.7 (MT, A)	10	9.9 (MT, A)
Borate (DOT) 4.5 kg/m^3	9.8	9.6	10	10

MT= Presence of mud tubes on blocks; A= presence of active termites

AWPA E26 Cotton Wood

Table 2 shows the average ratings for the cottonwood (CW) test specimens in the two field tests at each location. At the Saucier, Mississippi site, CW blocks treated with *P. roxburghii, C. deodara*, and *T. grandis* extractives showed minor termite attack after 12 months (9.2). Cottonwood blocks treated with *P. roxburghii* + oil and *C. deodara* + oil also showed minor termite attack. There were no signs of decay or termite attack on the blocks treated with borate or extractives of *T. grandis* or *D. sissoo* in combination with linseed oil. After 12 months at the Lahore site, blocks treated with solvent, *P. roxburghii*, *D. sissoo*, *C. deodara* extractives, and *T. grandis* + oil, *C. deodara* + oil, *P. roxburghii* + oil, or borate showed signs of slight decay. All treatments at the Lahore, Pakistan site, showed signs of termite attack. Blocks treated with solvent only were completely destroyed after 12 months (1.2). Linseed oil treated blocks also incurred severe termite attack (6.4). *Cedrus deodara* (6.4) and *P. roxburghii* (5.3) extractive treated CW blocks were heavily attacked by termites.

Table 2. Average decay and termite ratings for treated cottonwood AWPA E26 blocks in field tests in Lahore, Pakistan, and Saucier, Mississippi, USA

Treatments	Lahore, Pakistan		Saucier, Mississippi	
	Average rating		Average rating	
	Decay	Termite	Decay	Termite
Solvent	9.1	1.2 (MT, A)	10	9.8
Linseed oil	9.8	6.4 (MT)	10	10
T. grandis	10	9.5 (MT)	10	9.2 (A)
D. sissoo	9.9	8.2 (MT, A)	10	10 (MT)
C. deodara	9.8	6.4 (MT)	10	9.2 (A)
P. roxburghii	9.3	5.3 (MT, A)	10	9.2 (MT, A)
T. grandis + oil	9.9	8.3 (MT, A)	10	10
D. sissoo + oil	10	9.3 (MT)	10	10
C. deodara + oil	9.8	8.6 (MT)	10	9.5
P.roxburghii + oil	9.6	8.3	10	9.9 (MT, A)
Borate (DPT) 4.5 kg/m^3	9.7	9.2	10	10

MT= Presence of mud tubes on blocks; A= presence of active termites

AWPA E7 Southern Pine

Table 3 shows average decay and termite ratings after 12 months for SP stakes in Saucier, Mississippi, and Lahore, Pakistan. *Pinus roxburghii* + oil and Cu-NAP were the only treatments that showed no signs of decay in Mississippi. Stakes treated with solvent only and stakes treated with extractives of *C. deodara* or *P. roxburghii* and their combination with oil showed termite attack. There was no attack by termites or decay on stakes treated with Cu-NAP. Ratings from the Lahore site showed moderate to slight decay for stakes of all treatments except Cu-NAP. Heavy termite attack occurred on stakes treated with solvent (2.2), linseed oil (4), and *C. deodara* extractives (4.2). *Tectona grandis*, *D. sissoo*, *P. roxburghii*, and *P. roxburghii* + oil treated stakes showed moderate termite attack at the Lahore site. While *T. grandis* + oil, *D. sissoo* + oil, and *C. deodara* + oil treated stakes showed no signs of termite attack at this site. Cu-NAP treated stakes did not show any presence of decay but there was some slight surface attack by the termites on stakes (9.9) at the Lahore site.

Table 3. Average decay and termite ratings for treated southern pine AWPA E7 stakes in field tests in Lahore, Pakistan, and Saucier, Mississippi, USA

Treatments	Lahore, Pakistan		Saucier, Mississippi	
	Average rating		Average rating	
	Decay	Termite	Decay	Termite
Solvent	8.1	2.2	9.5	10
Linseed oil	9.8	4.0	9.9	10
T. grandis	9.8	8.7	9.9	10
D. sissoo	9.5	7.6	9.8	10
C. deodara	8.8	4.2	9.9	9.0
P. roxburghii	8.9	9.2	9.8	9.4
T. grandis + oil	9.2	10	9.9	9.9
D. sissoo + oil	9.2	10	9.9	10
C. deodara + oil	9.0	10	9.7	9.6
P.roxburghii + oil	8.6	7.3	10	9.4
Cu-NAP 1.2 kg/m^3	10	9.9	10	10

Cu-NAP = Copper Naphthenate

AWPA E7 Cottonwood

Table 4 shows the average decay and termite ratings for CW stakes at both sites after 12 months. At the Mississippi site, the *C. deodara* treated stakes had the lowest rating of 7.6 for decay and 9 for termites after 12 months. All other treatments except Cu-NAP (10) showed minimal signs of attack by either termites or decay at this site. At the Lahore site, moderate decay was seen in solvent only and *P. roxburghii* treated stakes. Other treatments, with the exception of *T. grandis* and Cu-NAP, showed slight signs of decay at this site after 12 months. Stakes treated with *P. roxburgh*ii + oil showed some decay with an average rating of 8.6. Solvent control stakes were completely destroyed by termites (0) after 12 months at Lahore. The linseed oil (7.4), *P. roxburghii* (7.5), *T. grandis* (8), *C. deodara* (4.4), and *P. roxburghii* extractives + oil (8.7) treated stakes were moderately attacked by the termites after 12 months. There was slight attack by termites (9.8) on stakes treated with Cu-NAP at this site.

Table 4. Average decay and termite ratings for treated cottonwood AWPA E7 stakes in field tests in Lahore, Pakistan, and Saucier, Mississippi, USA

Treatments	Lahore, Pakistan		Saucier, Mississippi	
	Average rating		Average rating	
	Decay	Termite	Decay	Termite
Solvent	7.9	0.0	9.1	9.4
Linseed oil	9.6	7.4	9.9	10
T. grandis	10	8.0	9.4	10
D. sissoo	8.9	6.6	9.9	10
C. deodara	8.6	4.4	7.6	9
P. roxburghii	8.4	7.5	9.6	10
T. grandis + oil	9.6	9.7	9.9	10
D. sissoo + oil	9.2	9.3	10	10
C. deodara + oil	9.2	9.5	10	10
P.roxburghii + oil	8.6	8.7	9.9	9.6
Cu-NAP 1.2 kg/m^3	10	9.8	10	10

Cu-NAP = Copper Naphthenate

Average Decay and Termite Ratings for Solid Heartwood Blocks and Stakes

Table 5 shows the average ratings for solid heartwood E26 blocks and E7 stakes of each of the four wood species exposed in each test after 12 months at both sites. There were no signs of decay for all species of heartwood E26 blocks in Mississippi after 12 months. At Lahore, E26 blocks of all species showed slight signs of decay with average ratings $\geq$ 9.4. The E26 termite ratings showed that heartwood blocks of *P. roxburghii* were slightly attacked at both sites after 12 months. *Tectona grandis* and *D. sissoo* were not attacked by termites at either site after 12 months.Heartwood E7 ground contact stakes of *P. roxburghii* were slightly decayed at the Mississippi site (9.7). At the Lahore site, *C. deodara* (3.2) and *P. roxburghii* (5) test stakes were severely decayed. Solid heartwood stakes of *T. grandis* showed slight decay (9.7) and stakes of *D. sissoo* incurred moderate decay damage (8.4). Termite ratings showed *P. roxburghii* stakes incurred slight termite attack in Mississippi (9.7) but severe damage at the Lahore site by *Heterotermes indicola* (3.7). *Dalbergia sissoo* and *C. deodara* treated stakes were moderately attacked and stakes of *T. grandis* were slightly attacked by termites at the Lahore site.

Table 5. Average decay and termite ratings for solid heartwood AWPA E26 blocks and AWPA E7 stakes in field tests in Saucier, Mississippi, USA, and Lahore, Pakistan.

Location	Heartwood	E26 Blocks		E7 Stakes	
		Decay	Termite	Decay	Termite
Saucier, Mississippi (USA)	*T. grandis*	10	10 (MT)	10	10
	D. sissoo	10	10	10	10
	C. deodara	10	10	10	10
	P. roxburghii	10	9.4 (MT, A)	9.7	9.6
Lahore (Pakistan)	*T. grandis*	9.8	10 (MT)	9.2	9.7
	D. sissoo	9.4	10 (MT)	8.4	7.8
	C. deodara	9.5	9.8 (MT, A)	3.2	8.2
	P. roxburghii	9.5	9.2 (MT, A)	5	3.7

MT= Presence of mud tubes on blocks; A= presence of active termites

DISCUSSION

Linseed oil and extractive combinations seemed to add some protection from termite attack to the treated non-durable wood in field exposure tests. This may be due to the hydrophobicity of oil, a process that has been tested and observed in earlier studies in combination with natural or synthetic biocides. Lyon et al. (2007) used linseed oil and boron to develop a low toxicity wood treatment against *Coptotermes formosanus* Shiraki and *Reticulitermes santonensis* De Feytaud. In field studies using linseed oil, Treu et al. (2004) found boiled and maleinized linseed oil was promising for the protection of wood against decay, which is in agreement with our results. Edlund (2004) showed that treatment with linseed oil at high retention gave better resistance against decay, but not against discoloring fungi, which agreed with our findings. Heartwood extractives in combination with oil had not been tested against decay and termites under field conditions until our study. This test is currently ongoing and we will continue to evaluate the blocks and stakes at each site annually. Our results from the first year of field testing indicate that extractives from *T.grandis*, *D. sissoo*, *C. deodara*, and *P. roxburghii* may be of some benefit as wood preservatives in certain regions where subterranean termites are present.

ACKNOWLEDGEMENTS

The authors wish to thank Craig Bell, USFS FPL, Starkville, MS, for installation of samples, Dr. Khalid Zamir Rasib (FC College University, Lahore) for providing site to install samples, Dr. Hamid Borazjani, Mississippi State University, for use of his laboratory facilities, Amy Bishell and Steve Halverson (FPL, WI) for help during treatment of samples. Authors also highly appreciate the funding support by Higher Education Commission of Pakistan (HEC) and USDA-FS International Program.

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Las Vegas, Nevada
April 9-11, 2017

VOLUME 113

AMERICAN WOOD PROTECTION ASSOCIATION
P O BOX 361784 • BIRMINGHAM, ALABAMA 35236-1784 • USA

ISSN 0066-1198

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