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EVALUATING THE DURABILITY AND RESISTANCE OF PINUS PATULA SSP. TECUNUMANII WOOD TREATED WITH USED MOTOR OIL TO TERMITE AND FUNGAL INFESTATION

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Abstract:
Termites, beetles, and fungi are the main deteriorating agents on forest products and services within Ethiopia's industry and construction sectors. This study aimed to assess the natural durability of Pinus patula ssp tecunumanii lumber and the efficacy of used motor oil (UMO) in protecting against subterranean termites and fungal damage. Sixty-four lumber samples (stakes) measuring 2x5x50cm were treated with UMO using hot-and-cold dipping (HCD) and brushing methods, besides untreated controls. These samples were then installed at Bako and Adami Tulu Graveyard Research Stations for observation over four and a half years. At the final evaluation period, the mean damage caused by subterranean termites at Bako station on P. tecunumanii stakes treated with UMO using HCD, brushing, and untreated controls was 47%, 90%, and 96%, respectively, while fungal damage rates were 23%, 69%, and 42%, respectively. At Adami Tulu station, termite damage rates on treated stakes were 30% (HCD), 61% (brushing), and 63% (untreated), with fungal damage rates of 0%, 38%, and 53%, respectively. The UMO treatment using HCD method doubled the service life of P. tecunumanii lumber stakes compared to untreated controls. Therefore, applying used motor oil using the HCD method is recommended to enhance the durability of P. tecunumanii lumber for ground and moisture contact applications.

Key words: *Bio-deteriorating agents, control measures, fungi, lumber stakes, natural durability, subterranean termites.*

INTRODUCTION

Degradation caused by biodeterorating agents like fungus, termites, beetles, and marine borers The renewable forest products (wood and bamboo-based products) and services have been utilized by the Ethiopian people to contribute to their console and ever-increasing demands. Termites, *powder-post beetles* and fungi damage on forest products in the areas of construction and industry sectors (Tadesse and Desalegn 2008). Bio-deteriorating agents' damage is among the overlooked major causes of forest destruction in Ethiopia (Desalegn et al. 2012). This caused Ethiopia's forests to be frequently harvested and endangering some of the most important indigenous lumber species, including *Juniperus procera, Hagenia abyssinica, Cordia africana, Podocarpus falcatus,* and *Pouteria adolfi-friederici* (Kaba et al. 2018).

In Ethiopia, ground dwelling termites considered as the only causes of greatest threat to wooden houses and other constructions that led to partial or complete rebuilding in 3-5 years' time. However, destruction of wood and bamboo culms-based constructions with soil and moisture contact and indoor applications in the different parts of the country have been occurred, even within 1-2 years short time, which has been caused by *subterranean termites* and/or fungal mutual damage (Desalegn 2015). There have been

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few research activities carried out in Ethiopia on evaluating termite and fungal damages on natural durability and effectiveness of control measures against bio-deteriorating agents (Desalegn 2014; Desalegn et al. 2015; Desalegn 2015). Controlling measures application against bio-deteriorating agents will increase the service life of products and their aesthetic values, thereby decreasing frequent harvesting of the available scarce resource, replacing and maintaining the degraded lumber and bamboo culms-based structures and forest products could be minimized and kept under economic threshold (Reinprecht 2016).

The lumber tree species *Pinus patula ssp. tecunumanii* (here after, *P. tecunumanii)* has been home-grown exotics and fast-growing species that have different uses for promotion and rational utilization (McCARTER & Birks 1985). Basic lumber characteristics of *P. tecunumanii* were not studied and known in Ethiopia by the development, industry and construction sectors, and end users as alternative construction and industry material. Due to this natural durability of *P. tecunumanii* lumber and performance of control measures research against *subterranean termites* and fungal damage was conducted at Forest Products Innovation Center of Excellence (FPICE). Specific objectives were to: (i) investigate natural durability of *P. tecunumanii* sawn lumber species at fields (outdoors), (ii) evaluate performance of used motor oil treatments against bio-deteriorating agents and application techniques resources.

MATERIALS AND METHODS

P. tecunumanii is a plant of medium to high elevations in the tropics, growing in areas with a mean annual rainfall within the range 1000 - 3000mm and a dry season of up to 6 months. Plants are not very resistant to frost (Bekele 2007). Pine species in general require a sunny position if they are to grow well and, whilst the different species have their own soil preferences; most will thrive in a light well-drained sandy or gravelly loam and prefers fertile soil (Anonymous 2023). *P. tecunumanii* is a very fast-growing tree - in reforestation projects in Colombia trees grew up to 2.5m per year in height in the first eight years after establishment on suitable sites, though growth has been slower in other regions (Anonymous 2023).

For this study, Pinus tecunumanii trees were grown at the Bonga elimination trial site of the Central Ethiopia Forestry Development Center (CEFDC), located about 449km from Addis Ababa near Bonga town. This site, positioned at an altitude of 1700m, experiences a mean annual rainfall of 1700mm and an average annual temperature of 21°C (Desalegn et al. 2020). At 14 years old, these trees displayed mean heights and diameters of 25.16m and 21.2cm, respectively, with varying volumes per hectare (Mihretu 2004).

P. tecunumanii Trees/wood samples representative of merchantable log size was selected and harvested (Fig.1a). These trees averaged 40.8m in height, 42.8cm in diameter at breast height (dbh), and had a total volume of 13.4m^3. The selected trees exhibited desirable morphological traits, possessing straight, defect-free stems. After felling, the logs were cross-cut into 2.5m lengths up to a top merchantable diameter of 12cm and transported to Forest Products Innovation Center of Excellence (FPICE) while still green. At FPICE, they were sawn into 3cm thick boards using a mobile circular sawmill, then seasoned to 12% moisture content. Subsequently, sixty-four lumber samples, each measuring 2x5x50cm (thickness, width, and length), were prepared and treated with hot and cold dipping (HCD) and brushing using used motor oil. These samples were then installed and studied at the Bako and Adami Tulu study sites.

Fig. 1.
P. tecunumanii trees during sample selection at Bonga (a), logs prepared to be sawn in sawmill (b).

Study stations

The study sites were Bako and Adami Tulu 258km and 167km away from Addis Ababa respectively. Bako is geographically located at 090 06’ and 370 09’ in the Sub-humid, mid latitude sub-tropical climate, Shewa plateau. It is found in the tepid to cool sub-humid highland major agroecological zone and tepid to cool sub- humid mountains sub-agro ecological zone (Anonymous 2011). It has an altitude of 1650m, total annual rainfall of 1210mm, and the mean annual minimum and maximum temperatures of 13.20C and 27.90C, respectively and major soil types are nitisols. Adami Tulu is geographically located in the 709´N and 3807´E and it is found Semi-arid climate, in the hot to warm sub-humid hot land major agroecological Zone, and hot to warm hub-humid gorges sub-agroecological zone (Desalegn et al. 2007). It has an altitude of 1645m, total annual rainfall of 766mm and annual mean minimum and maximum temperatures of 12.30C and 27.70C, respectively and major soil type is sandy soil.

Lumber stakes treatments with used motor oil

A preventive measure utilizing a mixture of used motor oil from vehicles, specifically Shell Rimula diesel oil 40 and Helix Ultra 40 engine oil in equal parts, was employed to combat damage from bio-deteriorating agents on lumber stakes. This treatment involved immersing the stakes in a tank containing cold used motor oil, gradually heating the oil to 90°C, for over four hours to reduce viscosity, and then allowing the stakes to cool for 24 hours before cleaning off excess oil and air-seasoning them for a week prior to installation. Detailed procedures for this hot-and-cold dipping method with used motor oil can be found in prior works (Desalegn et al. 2003; Kebede et al. 2011). Additionally, half-sized stakes were brushed with used motor oil and left to air dry for a week.

As controls, untreated lumber stakes of *P. tecunumanii* were also prepared to assess the natural durability of the lumber species. The durability of the lumber species and effectiveness of the control measures were evaluated according to adapted grades from British standards, ranging from very perishable to very durable, based on resistance against subterranean termite and fungal damage (Leroy et al. 2023).

Lumber stakes installation and evaluation at grave- yard stations

The grave-yard research stations were demarcated with areas of 20x20m^2 and fenced with barbed wire and live vegetation not to be encroached by men and animals (Fig. 2). Pits for the installation of lumber stakes were dug 25cm deep having a spacing of 25cm between the stakes and 50cm between rows. The coded stakes were labeled and tagged with identification codes and installed at the study grave-yard stations in the prepared pits with half their lengths (25cm) in the ground and the rest half (25cm) above the ground. Stakes were exposed to actual field conditions (rainfall, sunlight, weathering, undergrowth weed, and grass) at the respective grave-yard research station, which created favorable conditions and facilitated the deterioration and/or resistance of treated and untreated stakes against abiotic and biotic factors. The grass in the stations wasn’t mowed every month like plantations and crop fields to avoid disturbing the deterioration. The undergrowth weeds and grass were removed only during inspection and data collection periods to make the inspection and data collection activities simple and to avoid fire incidence during the dry periods. Tests on the natural durability of stakes, performance of control measures, and application methods were conducted simultaneously at the grave-yard stations.

a b

Fig. 2.
P. tecunumanii stakes layout (a) and (b) graveyard research station at Adami Tulu.

Visual inspection supported by sounding and indenting methods were used to evaluate the deterioration rate of each treated and un-treated lumber stake against *subterranean termites* and fungal damage (Desalegn et al. 2007). Performance evaluation of research stakes was carried out at three, six, 12 months after installation, and every year thereafter. Each stake was carefully removed from its pit, mostly after rainy season, the presence and extent of damage by termites and/ or fungi was inspected, evaluated and recorded. Grades from one to five (1-5) were adapted and used to determine bio-deterioration of lumber research stakes: 1 = Sound, no decay and termite damage (100% resistance); 2 = local, superficial/moderate (75% resistance); 3 = slight, limited (50% resistance); 4 = sever and deep (25% resistance); and 5 = failure/complete damage (0% resistance) (BS EN 351-1 2007). Evaluation at the graveyard was continued until at least 50% of the underground parts of the untreated stakes were completely degraded or fell down (Willeitner and Liese 1992; Highley 1995).

Data analysis

Multifactor ANOVA/ combined analysis using SAS software version 9.00 statistical software package was used to determine damage by subterranean termite and fungi and effectiveness of preservatives. Least significance difference (LSD) test was used to check the damage difference among Bio-deteriorating agents/mean separation among preservatives. Stakes mean damage values that became continuous values were used in the standard ANOVA. For convince of presenting results, scaled values were converted to percentage values.

RESULTS AND DISCUSSION

Appearance of the lumber Pinus tecunumanii (Fig. 4) showed a white to yellowish, with pinkish heartwood and this was in agreement with Gillespie (1992).

Fig. 3.
Lumber picture of P. tecunumanii [Photo by Desalegn].

Damage of Biodeterioration agents and effectiveness of control measures

Mean *subterranean termites* and fungal damage rate (%) on *P. tecunumanii* lumber stakes by treatments, length of exposure periods (four and half year) and graveyard research stations.

Table 1

Mean subterranean termites and fungal damage

graveyard research stations	Treatments	RSTD	RFD
Bako	HCD	96	42
Bako	UMO	90	69
Bako	Control	47	23
Adami Tulu	HCD	63	53
Adami Tulu	UMO	61	38
Adami Tulu	Control	30	0

Note: HCD- Hot and cold dipping, UMO- Used motor oil; RSTD– Rate of subterranean termite’s damage, RFD - Rate of fungal damage and Control- Untreated stakes.

At the same four-and half-year evaluation period, termites mean damage at Adami Tulu station on stakes of *P. tecunumanii* treated with UMO using HCD, brushing application methods, and untreated controls was 30%, 61% and 63%, respectively while that of fungi was 0%, 38% and 53%, respectively. The results revealed that degradation of *subterranean termites* and fungi on *P. tecunumanii* lumber vary with control measures, graveyard stations and length of exposure time (four and half years).

Fig. 4.
P.tecummanii stakes deteriorated by termite and fungi mutual attack.

The results of the multi-factor ANOVA analysis showed that there were significant differences (P<0.001) in the extent of subterranean termite and fungal damages to *P. tecunumanii* lumber among control measures, graveyard stations, length of exposure periods, and between the interactions control measures and stations.

Table 2
ANOVA values on P. tecunumanii treated and un-treated lumber stakes damage rates by subterranean termite and fungi.

Source	Bio-deteriorating agents	DF	Type III SS	Mean Square	F Value	Pr > F
Control measures	T	2	30132.03	15066.02	231.36	<.0001
	F	2	9854.94	4927.47	37.53	<.0001
Duration	T	10	15339.82	1533.98	23.56	<.0001
	F	10	10146.00	1014.60	7.73	<.0001
Station	T	1	14940.14	14940.14	229.43	<.0001
	F	1	3787.88	3787.88	28.85	<.0001
Control measures* Duration	T	20	2211.64	110.58	1.70	0.12
	F	20	2519.73	125.99	0.96	0.54
Control measures* Station	T	2	3870.64	1935.32	29.72	<.0001
	F	2	1624.03	812.02	6.18	0.01
Duration* Station	T	10	708.37	70.84	1.09	0.42
	F	10	430.12	43.01	0.33	0.96

Note *- interaction effects.

Degradation on the majority of samples increased through time. Some of the control samples at Bako station failed starting from the end of first year. Higher biodegradation occurred at year four and half by *subterranean termites* (96%) than fungi (42%) at Bako station on control stakes, while at Adami Tulu station, 63% degradation occurred by *subterranean termites*, and 53% fungi. In general, *subterranean termites* and fungal damage on stakes was in a form of collaboration/symbiosis. First, fungi start deteriorating and this has facilitated *subterranean termites* to degrade more and more through time. At year four and half, damage of *subterranean termites* on control stakes was higher than fungi and high deterioration occurred by *subterranean termites* at Bako station (96%) than Adami-Tulu station (63%) (Fig. 6). *Subterranean termites* at Bako station have been *Microterms* and *Pseudacanthoterms militarious* while that of Adami Tulu, having the same agro-ecology as that of Zeway dominated by subterranean and mound building termite species, *Marcoterms bellicosus* (Joseph 2021).

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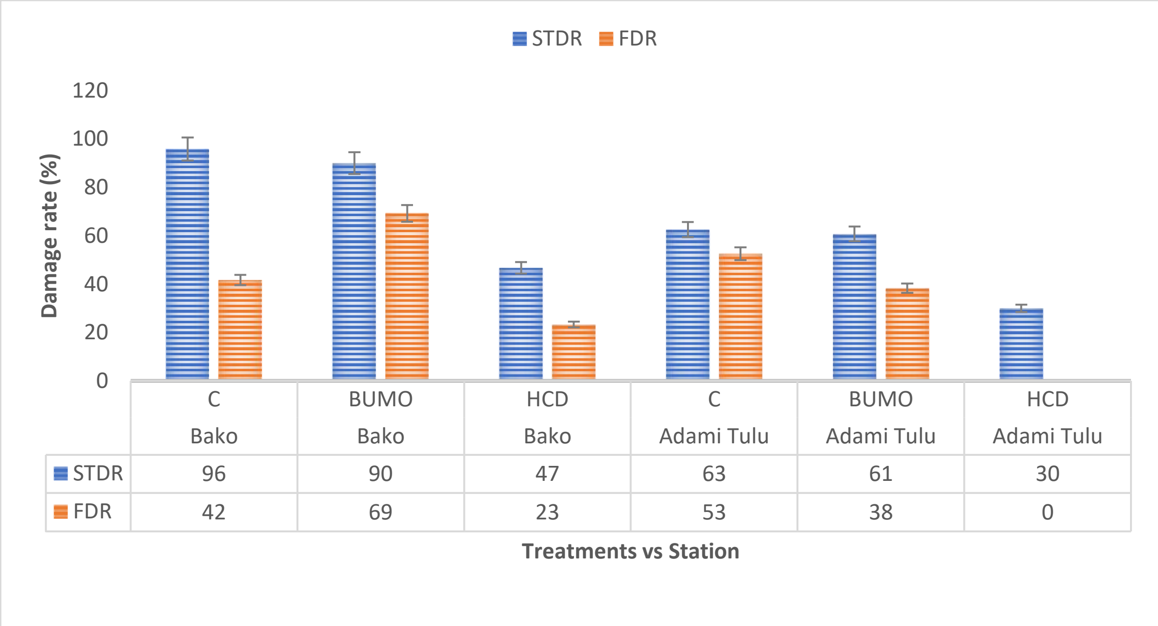

Fig. 5.
Subterranean termite and fungal damage rate at 4.5-year damage evaluation period.

Note: HCD-Hot and Cold Dipping vehicles spent used motor oil; BUMO-Brushing with used motor oil; C-Control (Untreated); STDR- Subterranean termite damage rate; FDR- fungal damage rate.

The natural durability of *P. tecunumanii* wood is categorized as non-durable. It is not suitable for ground contact in tropical conditions due to its poor resistance to fungi, termites, and marine borers. However, the denser heartwood does show moderate durability. The heartwood's resistance to preservatives is challenging, possibly due to the presence of numerous tyloses.

Regarding treatment methods, using used motor oil with brushing did not significantly improve protection against termite and fungal damage compared to untreated stakes. Similar results were observed with *Trichilia dregeana* stakes. Brushing treatment only coats the surface of the stakes without deep penetration, leading to decreased effectiveness over time, especially in prolonged exposure to bio-deteriorating agents like those found in graveyards. This ineffectiveness may be due to the treatment's superficial nature, resulting in leaching over time. For short-term protection (around three years), used motor oil with brushing application can be recommended. However, for longer-lasting protection, the hot and cold-dipping treatment using used motor oil significantly extended the service life of *P. tecunumanii* lumber stakes compared to untreated ones. Therefore, for applications involving ground and moisture contact, the hot and cold-dipping method with used motor oil treatment is recommended to enhance the durability of *P. tecunumanii* lumber.

Potential industrial and construction applications of P. Patula ssp tecunumanii

P. tecunumanii offers a versatile range of lumber and forest products and services. The wood of *P. tecunumanii* from both high- and low- elevation sources, when planted as an exotic, has proven in this study to be acceptable for sawn timber, light and general structural uses and flooring. Other studies further proved its suitability for vehicles, food containers, box or crate manufacture, shingles, furniture, cheap joinery, framing, pallets, broom sticks, poles, turnery, fuel wood and kindling for fires, veneer/plywood, particleboard, kraft and thermo-mechanical pulp and paper (Anonymous 2023). *P. tecunumanii* wood is suitable for general structural work while the inner juvenile wood is more suited to box or crate manufacture, shingles, and cheap joinery (Gillespie 1992).

CONCLUSION AND RECOMMENDATIONS

At the Bako and Adami Tulu research stations, experiments were conducted to assess the effectiveness of treating *P. tecunumanii* stakes with used motor oil (UMO) using hot and cold dipping (HCD) and brushing methods, compared to untreated controls, in preventing damage by *subterranean termites* and fungi over a period of four and a half years. Results showed that stakes treated with UMO via HCD experienced 47% and 30% termite damage at Bako and Adami Tulu stations respectively, whereas those treated with brushing had higher damage rates of 90% and 61% at the same stations. Similarly, fungal damage was significantly reduced in stakes treated with UMO using HCD compared to untreated stakes, whereas brushing treatment showed mixed results.

The use of UMO treatment by hot and cold dipping proved to be highly effective in controlling both *subterranean termites* and fungal damage, doubling the service life of *P. tecunumanii* lumber stakes compared to untreated ones when in contact with ground and moisture. Conversely, brushing treatment with UMO was less successful, showing only marginal improvement over untreated stakes. Therefore, it is recommended to employ UMO treatment using the hot and cold dipping method to enhance the durability of *P. tecunumanii* lumber in environments prone to biodegradation.

This study has been constrained by focusing on a single control measure (the disposal of used motor oil from vehicles), two methods of application (hot and cold dipping, as well as brushing), two specific locations (Bako and Adami Tulu), and a relatively short timeframe (four and a half years). Therefore, it is suggested that further research be conducted, exploring various commercial and traditional alternatives for control measures at different research sites and over an extended period. This extended research would aim to address gaps in knowledge and technology regarding the natural durability of lumber species, effective control methods, and application techniques. Ultimately, this would contribute to prolonging the service life of wood products and promoting their rational use in Ethiopia's diverse agro-ecological zones, where biodegradation and the utilization of wood-based products hold economic significance.

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