Treatability and Effectiveness of Preservatives against Termites and Fungi on *Juniperus procera* and *Eucalyptus deglupta* Sawn Timbers

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Ethiopian Institute of Agricultural Research

Treatability and Effectiveness of Preservatives against Termites and Fungi

on

Juniperus procera and *Eucalyptus deglupta* Sawn Timbers

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Contents

Introduction

Bio deteriorating agents' damage on forest products in the area of construction, furniture, and standing trees is a big problem in Ethiopia. This is one of the major causes in the country that led inappropriate utilization and destruction of forests and endangering of certain valuable timber species such as *Juniperus procera*, *Hagenia abyssinica*, *Cordia africana*, *Podocarpus falcatus* and *Pouteria adolfi-friederici* where the first four have been proclaimed not to be harvested from both federal and regional forests of the country (TGE, 1994) and the last one has been proclaimed by the Oromiya Regional State (Oromiya Regional State, 2003).

The major sources of construction material, forest industries, and wood-based energy sectors are the natural forests while plantations contribute about 10% (PTA, 1990). In Ethiopia, there are more than 320 timber species that can supply saw log/lumber, but indeed have not been properly utilized. In 2010,the gap between total demand (about 85 million m^3) and supply (about 11.5 million m^3) of industrial, construction and fuel wood was about 73 million m^3 (EFAP, 1994), where demand exceeding the supply by more than 730%. This has led to excessive and illegal cutting of trees and utilizing of more agricultural residues to meet the high deficit has been faced, which in turn has a negative impact on soils and agricultural crops.

J. procera has been considered as one of the most versatile, prominent structural/ construction, furniture, invaluable industrial and aesthetic material in the country, which has been used without adequate knowledge of its durability and other properties. *J. procera* is among the few highly exploited, improperly utilized, and endangered species while Eucalyptus E. *deglupta* is an introduced and fast-growing species for promotion and sustainable utilization. *E. deglupta* is not yet known by the development sectors, manufactures, and end users in the country. Besides, wood properties and silvicltural research results were not yet adequately disseminated and popularized.

Wood quality requirements for sawn dried (seasoned) and dressed end products can be grouped into five main categories: mechanical properties (bending, stiffness, tensile, compression strength, hardness), dimensional stability (low distortion, shrinkage, and collapse), biological performance (consistent color, durability), and manufacturing performance (good gluability, machining), and log processing performance (low splits, low distortion) (Armstrong, 2003).

Among the overlooked major causes of forest destruction in the country are severe degradation of wood, wooden structures and commodities both in service and in storage in the country occurred by bio-deteriorating agents, moisture, shrinkage, seasoning defects and mechanical wear. These losses have lead to low quality of logs, timbers and low recovery rate at sawmills, further processing and manufacturing of products, and short service life of structures and products which in turn, results in frequent and excessive mining of the remaining forests for different construction, industry and furniture purposes. This has been resulted in more deforestation and loss of considerable amount of forest, labor, finance and other resources.

In all tropical and sub-tropical regions, termites at larval stage are the most wood destructing pests (Nicholas, 1985, Grace et al., 1998; Wing and Cheok, 2001). Thus, the potential damage of termites on forests and forest products considered an important economic consideration throughout the tropics, both in the selection and growth of plantation species and the manufacture and utilization of the resulting wood products (Grace et al., 1998). Fungi also cause the greatest economic losses by discoloring and decomposing wood (Nicholas, 1985; Groves, 1990).

The termites and fungi groups found in Ethiopia are diverse and less known. A total of 570 species of termites, representing 89 genera and four families, have been reported, where 87.5% of the species and 67% of the genera are endemic to Ethiopia and the surrounding regions (Krshina and Weesner, 1970). The biodeteriorating agents of wood, forests, and crops found in the country are diverse and their damages and losses are damaging to standing trees, forest products and agricultural crops. Sixty-one species representing 25 genera and four families namely *Kalotermitidae, Hodotermitidae, Rhinotermitidae,* and *Termitidae* have been reported in the country, out of which 10 species are indigenous to Ethiopia and the adjacent regions (Krishna and Weesner, 1970; Cowie et al., 1990; Abdurahman Abdulahi, 1991). From Menagesha, Munessa-Shashemene and Teppi forests of the country, wood decaying basidiomycetes species of 142 has been recorded on *P. adolfi-friederici*, *J. procera* and *P. falcatus* fallen logs (Adane Bitew, 2002).

Macrotermitinae, especially subterranean termites have been considered as the only causes of greatest threat to wooden houses and other constructions in the country, which led to partial or complete rebuilding in 3-5 years (Wood, 1986). According to personal observations and communications, in the different parts of the country, destruction of wood-based constructions with soil and moisture contact applications have been occurred, even within

1-2 years short time, which have been caused by subterranean termites and/or fungal mutual attack. In the country, termites' damage on crops and wooden constructions have been estimated at 20% - 50%, which in some places has led to total crop and construction losses (Wood, 1986).

Preservative treatments can open the opportunity to new and wide application of timber species, which are susceptible for bio deterioration and refractory to treatments (Willeitner and Liese, 1992). Where natural durability and a good technical design alone could not guarantee long durability for wooden structures, the service life of constructions and furniture can be significantly increased by proper wood preservative treatments (Willeitner and Liese, 1992).

In Ethiopia, for the evaluation of termites and fungal damages, timbers natural durability and performance of applied preservatives, there have been only a few wood protection/ preservation research activities carried out on a few timber species, in very few agro ecological zones and majority for short periods, less than five years (Holmgren, 1963; Zawde Berhane and Yusuf, 1974; Wood, 1986; Melaku Abegaz and Addis Tsehay, 1988; Cowie, 1990; Wood, 1991; WUARC, 1995; Tsegay Bekele, 1996; Adane Bitew, 2002; Getachew Desalegn et al., 2003; Getachew Desalegn et al., 2007; Ofgaa Djirata et al., 2007; Wubalem Tadesse and Getachew Desalegn, 2008). At Zeway and Bako research stations,32 timber species and three preservation measures have been studied for 13 and 11 years, respectively (Getachew Desalegn et al., 2003; Getachew Desalegn et al., 2007). These are so far the longest preservation researches in the country while this study is among the shortest ones due to project time limitation.

Among the challenges and gaps in forest products processing and appropriate utilization are lack of information on

- Treatable and naturally durable construction and furniture timber species;
- Effective control measures and application techniques against bio deteriorating agents at each agro -ecological zone and locality; and
- Substitutes for the endangered timber species.

Objectives

- To determine treatability of *J. procera* and *E. deglupta* sawn timbers with preservatives;

- To investigate natural durability of the two sawn timber species at field;
- To evaluate performance of the applied biodeteriorating protection measures on timber stakes against subterranean termites and fungal attack at Miesso research station; and
- To select effective wood preservatives and application techniques that can improve durability and endure utilization of the two timber species in the area.

Materials and Methods

Study site

The field test was conducted at a graveyard station in the vicinity of Miesso-town, Eastern Hararge Zone. Mieso is located at about 24 km Northwest of Asebe-Teferi Town and about 300 Km from the capital city Addis Ababa. The station is geographically located at 09° 14' N and 40° 45' E. In the area, indicators of occurrence of termites were observed and the damages of biodeteriorating agents on wooden structures and furniture have been serious.

Miesso has an altitude of 1349 m and bimodal rainfall with a mean annual rainfall of 717 mm. April and August receive the maximum rainfall and October to February is the dry spell (Alelign Kefyalew et al., 1996). It has mean annual minimum and maximum temperatures of 14.1°C and 33°C, respectively.

Study materials

The test was conducted on the specimens (stakes) collected form matured trees of the two timber species. The selection and logging of sample trees of *J. procera* was from Arba-Gugu (Arsi) natural forest while *E. deglupta* was from Forestry Research Center (FRC) growth trial research at Aman site (Mizan-Teferi). Log samples of *J. procera* and *E. deglupta* were harvested and collected from 10 matured and morphologically defect-free trees having 50 and 14 years age, a mean height of 50 m and 35 m, and mean breast height diameter (dbh) of 65 cm and 37 cm, respectively. Trees were felled and bucked into 5 m logs. Logs green (> 30% MC) were transported to Forest Products Utilization Research Laboratory.

The green logs were bucked into 2.5 m bolts and sawn to 3 cm thick and width equal to log diameter. Tangential boards were prepared at mobile circular sawmill by applying through-and-through type of sawing method. In this method tangential, radial, and longitudinal surfaces were made clear. All the treatability (laboratory) and field (graveyard) test stakes were made free from damages and visible defects. Stakes were prepared and selected proportionally from each tree and log along height at 0.5 m interval, and marked with identification codes using an indelible pencil. For the treatability with preservative (absorption and retention) and permeability (penetration) tests, as well as field studies (natural durability and effectiveness of preservatives), 140 stakes, i.e.. ten stakes per timber species having dimensions of 2 x 5 x 50 cm each from different planks of the species (NWPC, 1971) were applied.

The basic density (oven dry weight/nominal green volume) of each stake was determined using oven drying of stakes to about 15% moisture content (MC) (IUFRO, 1972) cited in (Willeitner and Liese, 1992). Mean density of each species was determined from the ten stakes having a dimension of 2 x 2 x 3 cm in the tangential, radial, and longitudinal directions, respectively (ISO/DIS 4469, 1975). For the different treatments and tests, stakes with comparable densities and MC were used to minimize variation among stakes and preservative treatments.

Treatability and permeability tests

Pressure treatment

For both laboratory treatability and field stakes treatments, the major 11 impregnation (pressure treatment) procedures of CCA preservative (FAO, 1994; Willeitner and Liese, 1992) used in the study at ambient temperature were:

- preparing standard stakes, coding of each stake on aluminum metal sheet/tag and fixing at 5 cm from the top end;
- measuring initial (before treatment) weight of each stake;
- mixing CCA with appropriate solvent, water and adjust the required concentration (3%), (iv) stacking timber stakes in the bogie, loading into the impregnation cylinder/vessel and closing the door firmly;
- setting initial vacuum at 0.06 N/mm^2 for 30 minutes to avoid/reduce air from the wood stakes so as to provide maximum space for the preservative;
- filling impregnation cylinder with preservative solution, increasing pressure to maximum, adjusting treatment pressure to 1 N/mm^2 and maintaining for 1 hour to induce preservative into wood;
- releasing pressure and draining the preservative from the impregnation cylinder;
- setting final vacuum at 0.06 N/mm^2 for 30 minutes to drain surplus preservative from the treated stakes and get clean surface;
- releasing vacuum and withdrawing treated stakes from the machine; and
- measuring the final (after treatment) weight of each stake, its uptake, retention and permeability, respectively, and (xi) drying (seasoning) treated stakes by stacking using stickers at least for two weeks to about 15% MC so that the solvent is evaporated and preservative is re-settled and fixed into the wood before field installation

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Non-pressure treatment

Cold dipping treatment

Wooden stakes of both timbers were sunken into a dipping barrel containing CCA and water solution. The tests were maintained for 24 hours, treated stakes withdrawn from the dipping barrel, weighed, and air-dried for two weeks so as to allow fixation of the preservative and solvent evaporation.

Hot-and-cold dipping treatment

Treatability (absorption and retention) of stakes (sapwood and heartwood) with preservatives was determined by weighing the stakes before and after treatment and by using the following formulas (Equations 1 and 2) adapted (FAO, 1994; Willeitner and Liese, 1992):

Preservative Solution Absorption (PSA) (kg/m^3) = (A - B) / V (Equation 1)

Where: A = saturated weight of stakes after treatment (kg) and B = air - dried weight of stakes at about 12% MC before pressure treatment (kg); v = Volume of stakes before impregnation (m^3).

Retention (kg/m^3) = [Weight of CCA/volume of stake] x concentration of CCA (%) = Absorption (kg/m^3) x Concentration (Equation 2)

Mean permeability of each species or penetration of preservative into stakes was determined by crosscutting the treated stakes into 20 cm pieces, 20 cm inwards from both ends, as well as measuring and averaging the depth of chemical penetration of the two sections. Average permeability/penetration (AP) of the species was determined using the adapted formula (FAO, 1994):

Average permeability/penetration (AP) (mm) = $[a_{max} + b_{min}]/2$ (Equation 3)

Where, a_{max} = average maximum depth of penetration (mm) and b_{min} = average minimum depth of penetration (mm).

Based on the extent of average chemical penetration each species was then assigned to one of the four permeability grades (Table 1) (Willeitner and Liese, 1992). Permeability grades applied were: Permeable (> 18 mm penetration), moderately resistant (6-18 mm penetration), resistant (3-6 mm penetration) and extremely resistant (< 3 mm penetration) (Farmer, 1987).

Natural durability stakes treatment

The controls (untreated) stakes for testing the natural durability of each species were not subjected for treatments with preservative chemicals but were getting proper handling during storage, seasoning and processing. This was done to avoid discoloration and deterioration before field installation.

Field tests

Stakes installation at graveyard

Study stakes were installed randomly in the prepared installation holes (hereafter pits) with half their lengths (25 cm) in the ground and the rest half was remaining above the ground bearing identification tags fixed 5 cm from the top end. *J. procera* and *E. deglupta* plots were laid out where each plot was divided into 10 sections for the five sapwood and five heartwood stakes per treatment type. The position of the stakes where each stake is located in each test plot was marked on the layout/sketch map of the experiments. All the stakes were having their identification tags facing the same direction so that they were replaced easily in exactly the same position after every inspection (Fig.2). Tests on the natural durability of stakes and performance of applied preservatives were conducted simultaneously at the field.

Natural durability of timbers and effectiveness of preservatives

Natural durability of each species and effectiveness of preservatives under tropical conditions were assessed and categorized as very perishable (< 6 months), perishable (6 months-1 year), non-durable (1-5 years), moderately durable (5-10 years), durable (10-15 years) and very durable (> 15 years) against biodeteriorating agents based on these authors (Bryce, 1976; Purslow, 1976; Mealku Abegaz and Addis Tsehay, 1988; Willeitner and Liese, 1992; Eaton and Hale, 1993; Desalegn et al., 2003).

Experimental design and data analysis

The design for the laboratory treatability experiment was Completely Randomized Design (CRD) with replication of 10 stakes per study species. The design used in the field experiment was split-plot in a completely randomized design (CRD) with the same replication as laboratory tests. One-way analysis of variance (ANOVA) was used to determine preservative treatability and penetration of each timber species. To determine natural durability of stakes and performance of preservatives against subterranean termites and fungal attack multifactor ANOVA was used. For the analysis mean of the 10 stakes that became continuous values were used in the standard ANOVA (SAS Institute, 2000).

Results and Discussion

Treatability with preservative and permeability of stakes

The results indicated that the mean absorption (uptake) and retention of *E. deglupta* stakes pressure treated with CCA preservative was 200.77 kg/m^3 and 6.02 kg/m^3, respectively while that of *J. procera* stakes was 2.06 kg/m^3 and 0.06 kg/m^3, respectively. Stakes of *E. deglupta* cold dipped with CCA have shown 10.73 kg/m^3 and 0.32 kg/m^3, absorption and retention, respectively while used motor oil treated stakes with hot and cold dipping method was 91.21 kg/m^3 and 2.74 kg/m^3, respectively (Table 1). Stakes of *J. procera* cold dipped with CCA and used motor oil treated with hot and cold dipping methods revealed superficial coatings and no deep penetration. This could be attributed due to *J. procera*'s higher age and density, more heartwood and extractive content. The higher the CCA preservative absorption of the species, the higher was its sapwood content and CCA retention.

There was significant difference ($P<0.01$) in CCA absorption and retention between the two study timber species. *E. deglupta* was the species, which absorbed and retained CCA better than *J. procera*. The results revealed that the chemical absorption and retention of stakes were dependent on the density of each species. Species with low density (*E. deglupta*) absorbed more chemical than the species with high density (*J. procera*) (Table 1). *E. deglupta* was the species, which absorbed and retained CCA better than *J. procera* but its resistance against termite and fungal attack was less than *J. procera* where natural durability exceeding the treated one.

Table 1 Mean treatabiliy and permeability of timbers with different presevatives and application techniques

Timber species	Density (kg/m^3)	Treatments[1]	Treatability		Permeability	
			Absorption (kg/m^3)	Retention (kg/m^3)	Permeability (mm)[2]	Classification of permeability[3]
Eucalyptus deglupta	493.42	CCAP	200.77	6.02	12.30	MR
	427.5	CCAD	10.73	0.32	SC	SC
	412.15	UMO	91.21	2.74	8.30	MR
Juniperus procera	579.81	CCAP	4.17	0.13	SC	SC
	526.81	CCAD	2.06	0.06	SC	SC
	569.91	UMO	5.07	0.15	SC	SC

[1] CCAP-Pressure treated; CCAD-Cold dipping with CCA preservative and UMO-Used motor oil dipping; [2] SC-Superficial coating; [3] MR-Moderately resistant

Mean permeability of pressure treated stakes of *E. deglupta* and *J. procera* timbers with CCA was 10.3 mm. Mean permeability of *E. deglupta* stakes pressure treated with CCA and hot-and-cold dipped with used motor oil was 12.3 mm and 8.3 mm, respectively. Superficial coating was obtained for *J. procera* stakes treated with pressure and non-pressure methods using CCA and used motor oil, respectively. Basic density and chemical permeability of each species were negatively correlated. As a result, species with low density was more permeable to CCA preservative penetration (Table 1).

Performance of used motor oil treatment

At the third year of inspection/evaluation, about 60% of used motor oil treated stakes of *E. deglupta* under ground parts were attacked to 22.5% and 2.5% by termites and fungi, respectively. *J. procera* stakes treated with used motor oil were attacked to 20% at the ground line zone and fell down to the ground where 80% of the stakes were degraded on average to 35% by termites and 12.5% by fungi (Table 2). The resistance of *J. procera* stakes treated with used motor oil against termites and fungi was less than that of *E. deglupta* which may be attributed due to the higher age and density, more heartwood and superficial coating with used motor oil treatment. Treatments with used motor oil were less effective than CCA that was in agreement with Getachew Desalegn et al., (2003) and Getachew Desalegn et al., (2007). At Ziway graveyard research station, stakes of *J. procera* treated with used motor oil indicated extended service life of more than five years in the ground contact tests (Getachew Desalegn et al., 2003).

Natural Durability and Effectiveness of CCA Treatments

For subterranean termites attack, the multi-factor ANOVA indicated significant differences ($P<0.01$) between CCA treatments and the control, preservative application techniques (CCA pressure treated and cold dipped; hot and cold dipped with used motor oil); between sapwoods and heartwoods; between the timber species and length of field exposure and evaluation periods (1/4-3years) and in the interactions between timber species and preservatives. The results indicated that all the control stakes of *E. deglupta* underground parts were 100% degraded and fell down to the ground by termites during the first year field exposure and evaluation periods (perishable) while *J. procera* stakes were degraded by termites to 72.5% and intact by fungi (Table 2).

Natural durability of *E. deglupta* was low. Sapwood stakes were more attacked than heartwood ones. For both species no failure among CCA pressure treated stakes. No significant difference occurred between the treated sapwood and heartwood parts, which could be attributed due to the short period of exposure. More than 95% of pressure treated and cold dipped stakes of *J. procera* stakes with CCA preservative were 100% intact by both subterranean termites and fungal attack. At the third year, termites and fungi attacked majority (80%) of the *E. deglupta* stakes pressure treated with CCA to 37.5% and 7.5%, and that of *J. procera* stakes were degraded to 5% by termites and intact by fungi, respectively (Table 2).

The resistance of *J. procera* stakes treated with CCA against termites and fungi was better than that of *E. deglupta*, which may also be attributed due to the higher density, more heartwood, natural resistance/extractive content of *J. procera*, although treatability/retention of *E. deglupta* (6.02 kg/m^3) was much better than that of *J. procera* (0.06 kg/m^3). Out of the CCA cold dipped *E. deglupta* stakes, 20% fallen down to the ground line zone and the other 20% were attacked 70% by termite while the rest 60% were intact. Among *J. procera* CCA cold dipped stakes only 10% were attacked 70% by termite and intact against fungal attack (Table 2).

Performance of untreated stakes and effectiveness of preservatives against subterranean termites and fungal attack were varied. The resistance of stakes treated with CCA and used motor oil against bio-deterioration in the ground and moisture contact applications have been significantly prolonged compared with those of the controls (Table 2 and fig.3a and b). The results revealed that termites were the dominant agents of bio-deterioration at the Miesso station. There was significant difference ($p<0.01$) on the natural durability of *E. deglupta* and *J. procera* stakes. At Miesso station *J. procera* was more durable species from the two timbers since underground parts of all the untreated *E. deglupta* stakes were completely (100%) degraded and fell down to the ground line zone by termites during the first year field exposure period and that of *J. procera* stakes were 27.5% resistant up to 3rd year inspection and evaluation (Table 2 and Fig.3).

The results of similar study from Ethiopia at Bako site indicated that untreated stakes of *J. procera* and *H. abyssinica* were the most resistive, while *Podocarpus falcatus*, *Ekbergia rueppeliana* and *Pouteria adolfi-Friderici* were very sensitive to attack by termites. *Olea capensis subsp. macrocarpa* and *J. procera* least attacked by decay fungi while that of *P. adolfi-friderici* and *E. rueppeliana* were highly attacked (Holmgren, 1963). Studies at Zeway showed that all species stakes except *J. procera* were completely destroyed, while *J. procera* was moderately attacked after five years of exposure. In all cases the degree of termite attack was less at Zeway site than it was at Bako (Zawde Berhane and Yusuf, 1974) and Meisso stations. Resistance of treated timbers at Bako revealed that *J. procera* was completely sound during the five years investigation period while *P. falcatus* and *P. adolfi-friderici* were slightly attacked. *Eucalyptus globulus* and *E. rueppeliana* were completely attacked after five years of exposure (Zawde Berhane and Yusuf, 1974).

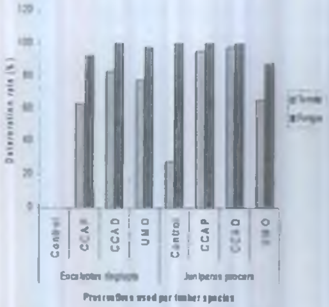

Fig.3a

Fig.3b

Figure 3: Mean results of timbers and preservatives against termite and fungal damage up to 3rd year evaluation (3a), and deterioration trend of *E. deglupta* and *J. procera* timber stakes (mostly attacked by termite) (3b)

J. procera was also among the 12 best naturally durable timber species namely *J. procera*, *Manilikara butugi*, *Eucalyptus camaldulensis*, *Eucalyptus saligna*, *Ocotea kenyensis*, *Cupressus lusitanica*, *Morus mesozygia*, *Prunus africana*, *Fagaropsis angolensis*, *H. abyssinica*, *P. falcatus* and *Warburgia ugandensis*, which resisted termite and fungal attack for more than 10 years at Zeway site (Getachew Desalegn et al., 2003; Getachew Desalegn and Alemu Ggezaghne, 2010) while at Bako station the best seven naturally durable timber species, which resisted termite and fungal attack for more than four years were *M. butugi*, *E. camaldulensis*, *Mimusops kummel*, *M. mesozygia*, *O. capensis subsp. macrocarpa*, *Olea welwitschii* and *Albizia gummifera* (Getachew Desalegn et al., 2007).

The extent of attack varied with timber species, preservatives and application techniques, field station, bio attacking agents (termite and or fungi), treatability (absorption and retention) of stakes, penetration of the preservative and length of exposure time (Getachew Desalegn et al., 2003; Getachew Desalegn et al., 2007). Compared with the site at Zeway and Bako (Getachew Desalegn et al., 2003), the site at Miesso was more favorable for termite attack. The more durable timber species may owe their resistant mainly to their extractives and densities, which serve them as natural preservatives and resistant (Nicholas, 1985; Shirvastava, 1997) against bio deterioration.

The variation in the extent of damage against termites between the timbers was significant which may be attributed due to the age and other variations while for the majority of the stakes the extent of fungal damage and the variation between the timber species was very low (Table 2 and fig.3). CCA treated stakes of *J. procera* resisted fungal attack for more than 13 years at Zeway station (Getachew Desalegn et al., 2003). For both sapwood and heartwood parts, untreated and preservative treated stakes of this experiment, subterranean termites were the dominant agents, indicating more significant damage than fungi (Table 2 and Fig.3).

As the duration of exposure increased, the extent of attack has been increased (Table 2). The third year was the highest attack recorded as compared to the duration of 3rd month and up to 2nd year. The comparative results at Miesso and Zeway for *J. procera* stakes revealed that the termites of Miesso morphologically lower were more aggressive than Zeway site that were morphologically larger. Compared to the control and used motor oil treatments, CCA treatments both with pressure and non-pressure methods was the best effective preservative and application techniques to control termite and fungal attack at Miesso area.

Table 2: Mean resistance results (%) of *E. deglupta* and *J. procera* field stakes treated with different preservatives and application techniques against termite and fungal deterioration at each period of inspection and evaluation.

Timber species	Treatments	Duration (3rd month-3rd year)*									
		3rd month		6th month		1st Year		2nd Year		3rd Year	
		Termite	Fungi	Termite	Fungi	Termite	Fungi	Termite	Fungi	Termite	Fungi
Eucalyptus deglupta	Control	22.5	100	15	100	0	90	0	0	0	0
	CCAP	100	100	92.5	100	75	97.5	72.5	97.5	62.5	92.5
	CCAD	100	100	100	100	100	100	85	100	82.5	100
	UMO	100	100	100	100	100	100	95	97.5	77.5	97.5
Juniperus procera	Control	67.5	100	57.5	100	45	100	37.5	100	27.5	100
	CCAP	100	100	100	100	100	100	100	100	95	100
	CCAD	100	100	100	100	100	100	100	100	97.5	100
	UMO	97.5	100	95	100	87.5	92.5	82.5	90	65	87.5

CCAP- CCA pressure treated; CCAD- CCA Cold dipping with CCA preservative and UMO-Used motor oil dipping; Control-untreated.
**- 0 (zero) means fell down to the ground due to termite and/or fungal attack*

Conclusions and Recommendations

The mean absorption, retention and mean permeability of *E. deglupta* stakes pressure treated with CCA was better than that of *J. procera* stakes. Mean permeability of *E. deglupta* stakes treated with used motor oil was 8.3 mm and superficial coatings for *J. procera* stakes. There was significant difference (P<0.01) in CCA uptake and retention between the two study timber species. *E. deglupta* was the species, which absorbed and retained CCA better than J. procera but its resistance against termite and fungal attack was less than *J. procera* where natural durability exceeding the treated one in some cases. The multi-factor ANOVA indicated significant differences (P<0.01) between CCA treatments and the control, preservative application techniques, between the timber species and length of field exposure periods. Termites were the main deteriorating agents. CCA was the best effective preservative to control termite and fungal attack at Miesso area.

Thus, the seasoning and preservative treatments of wood should be given higher priority, as seasoning and preservation measures are better than cure thereby large economic losses and decreasing the scarce available resource, replacing and maintaining the degraded wood and wood-based structures/products could be minimized and kept under economic threshold. In cases where CCA treatment is not needed more environmental friendly and competent chrome and arsenic free preservatives such as Tanalith E or Celcure AC type wood preservatives are recommended (Getachew Desalegn et al, 2010).

Timber preservation measures against the various biodeteriorating agents has to be considered at Miesso in particular and in Ethiopia in general as a necessary measure to increase the durability of wood in service. Preservation also can open the opportunities of using less durable indigenous and home-grown exotic timber species of the country.

The results will have practical application not only to Miesso area but also in areas with similar timber species, agroecological zones, and biodeteriorating agents. This could be beneficial for the potential anticipated beneficiaries of the expected outputs such as farmers, rural and urban households, furniture factories, forest industries, sawmills and joineries, end-users of forest products, construction enterprises/sectors, civil- engineers, vocational training colleges, investors, concessionaires, development agents, foresters, researchers, policy makers, public, NGO's, individuals and the nation at large. This will initiate large scale planting, management, and proper utilization of the two timber species in the country.

E. deglupta should not be used at Miesso and similar hazardous areas for moisture and soil contact construction applications without applying adequate preservation measures. In order to select and use CCA, used motor oil and other potential wood preservatives, the service life intended for the purpose (short or ling service life), place of use (ground contact, above ground, damped...), application techniques (pressure, non-pressure) to obtain adequate loading of the preservative and its cost have to be considered into account.

The industrial and construction wood production programs in Ethiopia, especially at Miesso and similar areas, should give high priority to the treatable and naturally durable as well as potentially valuable and fast-growing timber species such as *E. deglupta* and *J. procera* to augment considerable advantages for end users and other potential stakeholders. Thus these timbers are recommended for making different construction and furniture with adequate preservation measures, large scale plantations establishment and proper management of the stands and processing of products.

Further research activities involving prolonged time, other timber species, other potential preservatives, and application techniques are recommended to fill the information gaps in wood durability, preservation measures, and rational utilization of timbers at the Miesso area and in the different agroecological zones of Ethiopia where biodegradation has economic significance in the country.

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