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Termiticidal Effect of Neem Extracts on the Wood of *Khaya senegalensis*

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ABSTRACT

This study was aimed at developing cheap and eco-friendly wood preservatives from various parts of neem tree for the control of termite (Isoptera: Termitidae). Extracts were prepared from the seed (neem seed oil), leaf and bark of *Azadirachta indica* (neem) and compared with Chlorpyrifos. A total of 60 wood samples were used for this study. After Grave-yard experiment untreated wood samples of *Khaya senegalensis* were found to be highly susceptible to termite attack. The type of the extract used, their mixtures and combination with chlorpyrifos significantly influenced the degree of resistance of the wood to termite attack ($p < 0.05$). Wood treated with neem oil and bark extract were susceptible to termite attack but their level of resistance to attack was 40.32% better than untreated wood. Leaf extract was classified as effective when compared to some other plant extracts. Combinations of the neem extracts with 2% chlorpyrifos offered the most discernible level of protection. Thus the harmful effect of chlorpyrifos could be drastically reduced when combined with plant extract. This will not only be a cheaper method but will provide an eco-friendly protection against termite attack.

Key words: Neem extracts, chlorpyrifos, Grave-yard test, eco-friendly preservative, test samples

INTRODUCTION

Wood had variety of usage and had been directly linked to civilization of man (Tolunay *et al.*, 2008). It is one of the most frequently used materials for construction purposes worldwide. In Nigeria, more than 80% of timber products are used for constructional purposes such as building, furniture, railway sleepers, transmission poles, pulp and paper, plywood, veneers, composites board, matches, fuel (coal industry) and fuel wood (Akanbi and Ashiru, 2002). The fact that wood can be used for both in-door and out-door services and exposed to different weather conditions shows that wood can be used for many years if properly preserved. This quality makes wood more attractive for construction and furniture production. However, due to diversity in nature and character in wood, exploitation of tree for structural and construction purposes was selective and limited to strong and durable species (Oluwafemi and Adegbeniga, 2007; Kayode, 2007). One of the major factors contributing to this limited selectivity is the question of its long-term natural endurance to the processes of natural degradation. When wood is used as a construction material, it is generally treated with a chemical preservative to prevent damage by bio-deteriorating agents (Goktas *et al.*, 2007). Wood as a construction material is prone to damages by termites, thus posing a lot of social and economic problems since it requires additional labour and expenses to replace damaged wood. A review of the natural durability of 1500 commercial wood species worldwide shows that 191 of

the commercial species are very resistant to bio-deteriorating agents, 189 are resistant, 298 moderately resistant and 826 nonresistant (Scheffer and Morrell, 1998). The implication of this is that majority of commercial wood species required preservatives treatments to increase their service life. *Khaya senegalensis* which is widely sorted as construction material in timber markets located in sudano-sahelian region with deficit timber supply (Sotande *et al.*, 2010) is classified among the nonresistant timber species.

Termite is one of the major bio-deteriorating agents affecting wood in service. They are highly destructive polyphagous insect. The food of termites is essentially cellulosic materials including wood paneling, paper products, cardboard boxes, art canvases, the paper covering of sheetrock and carpeting etc. Degradation of wood by termites is a chronic problem in many tropical regions particularly in the Sub Sahara Africa, resulting in serious monetary and material losses with far reaching impact on the increasing demand for timber (Obi *et al.*, 2008). Out of more than 42 genera of termite (Tho, 1992), subterranean termite *Coptotermes* appears to be the most prevalent genus foraging around buildings and in houses (Tho and Kirton, 1990), infesting also forest plantation living trees (Kirton *et al.*, 1999). Subterranean termites annually cause damage to homes worth millions of dollars (Hiziroglu, 2009). Additionally, termites of the genera *Schedorhinotermes*, *Globitermites*, *Odontotermes*, *Macrotermes* and *Microtermes*, are also reported as important pests in agricultural crops (Rath and Tidbury, 1996) trees, logs, timbers and other cellulosic materials. Wood can be effectively protected from termite attack by treating the wood with pesticide effective chemicals. There are many effective preservative chemicals used against wood pests in the world of which chlorpyrifos is adjudged one of the household insecticides used in wood protection against fungal decays, soft rot, insect groups, termites and borers (Ahmed *et al.*, 2010). Impregnating wood by applying suitable chemicals is the most preferred preservation method and present a lot of economical gain (Iya and Kwaghe, 2007) but some toxic chemicals, used for wood preservation, contain serious pollution risks to the environment. These man-created problems, Badshah *et al.* (2005) opined had further resulted in phytotoxicity, mammalian toxicity, pesticides residues, insect resistance, insect outbreaks and increased cost of production. Also, apart from the environmental risk posed by some of these chemicals the relatively high cost of procurement and low availability often contributed to their low level of adoption in developing countries like Nigeria.

Recently, great interest has been focused on some wood preservatives that are relatively cost-effective chemicals and have minimal toxicity to mammals and the environment. Ability of wood and natural plant extractives to protect wood against wood degrading fungi and insects has been one possible approach for developing new wood preservatives (Kartal *et al.*, 2004). The use of traditional plant materials in the management of insect pest such as termite control which is cheap, easily reached and assembled in the developing countries had been reported by Owusu (2000). Though most of these traditional methods are of little use in the developed countries, they still play a significant role in pest control programs in the developing countries. However, despite the wide array of studies on the use of plant materials such as neem extracts in the management of insect pest of agricultural produce (Makanjuola, 1989; Lowery and Isman, 1993; Lale and Abdulrahman, 1999; Meikle *et al.*, 2005) there is scarcity of research information on the efficacy of the use neem extracts in wood preservation bearing in mind the need to preserve wood in order to reduce the rate of harvest and avoid cost of replacing termite-damaged wood structures. There is therefore a need to intensify promotion of traditional organic control strategies in order to reduce over reliance on conventional insecticides and thus prevent environmental contamination. The objective of this work was to study the termicidal effects of neem extracts and their modifications in wood preservation.

MATERIALS AND METHODS

Study area: The study was carried out for 10 weeks (25th of February to 10th April, 2010) in the Orchard of the Faculty of Agriculture, University of Maiduguri, located in the north-eastern part of Nigeria, on latitude 11°30"N and longitude 14°45"E. The climate is hot and dry for most part of the year. The average annual rainfall is 650 mm with a relative humidity of 42-49%. The soil type is generally sandy loam and well drained (Folorunso and Olorunju, 1986).

Extract from neem seed oil, bark and leaf: Mature fresh neem fruits were gathered from neem stands within the University Campus and soaked in water for depulping. The depulped seeds were later sun-dried after which they were grinded into powdery form. The powder obtained was then moistened with hot distilled water and pressed to extract the oil.

Similarly, fresh barks were peeled from healthy trees, chipped and air dried at room temperature for 2 weeks. The air dried barks were thereafter grinded and made to pass 2 mm sieve. The processing of neem leaves followed the same procedure except that the leaves were only air-dried for 1 day before grinding. The 20 g of the ground materials were separately tied in white cloth and extracted in 100 mL hot distilled water at 100°C. The aqueous extracts obtained were then filtered separately and stored in carefully labeled dark conical flask until used.

Meanwhile in order to test the efficacy of the neem extracts, its performance was compared with Chlorpyrifos which is an Organophosphorus Pesticide (OPP) effective in termite and other soil insect control by contact and ingestion.

Treatment of wood samples with neem extracts and chlorpyrifos: Sixty freshly sawn wood samples of *Khaya senegalensis* of dimension; 60×30×20 mm were used for the experiment. The wood samples were first oven dried at 85°C to constant moisture content. Five wood samples of known weights were thereafter soaked in each aqueous neem extracts and chlorpyrifos pesticide separately for 24 h. Similarly, another five sets of known weight samples were soaked in mixture of the extract while another set was soaked in mixtures of the extracts and 2% Chlorpyrifos pesticide also for 24 h. The soaked samples were then separated on a wire mesh and kept at room temperature over night to air dry to workable moisture content. The weight of each sample was noted again in order to obtain the amount of extracts absorbed by each sample before the Grave-yard field experiment using the formula stated below:

$$\% \text{Absorbtion} = \frac{W_1 - W_2}{W_2} \times 100 \quad (1)$$

Where:

W_1 = Oven dried weight of the wood samples

W_2 = Air dried weight of treated samples

Grave-yard field experiment: The Grave-yard experiment was carried out for 10 weeks. The wood samples were buried 5 m radius round a termitarium within the Orchard leaving some length above the ground level and mulched with dry grass. In order to make the environment conducive for termite infestation the grass was watered once daily. Standard method for laboratory evaluation to determine resistance to subterranean termites (AWPA, 1999) was modified in order to evaluate the degree of resistance of the treated woods to termite attack. Each sample was assessed weekly

for resistance or otherwise of the wood samples to termite infestation by visual observation. The samples were re-pegged in their respective positions after each inspection. Also that the end of the field study (after 10 weeks) the percentage weight loss of each of the sample was evaluated using the formula stated below:

$$\% \text{Weight loss} = \frac{W_b - W_a}{W_b} \times 100 \quad (2)$$

Where:

W_b = Weight of oven dried wood samples before grave yard field experiment

W_a = Weight of oven dried wood samples after grave yard field experiment

Termite collection, maintenance and walking trail experiment: Termites, *Macrotermes* sp. were collected from a termitarium within the University Orchard early in the morning. The maintenance and design of the walking trail experiment was then made in accordance to the method described by Owusu *et al.* (2008). The termites collected were introduced into a bowl containing dried grasses inter-layered with soil to serve as substrate and food source during the maintenance or breeding of the termites. Adult workers (4-5 weeks old) were separated from the collection and used for the walking trail experiment. The extracts and their combinations were used to moisten 5 g of soil samples. The untreated and moist soil samples were then randomly arranged and thinly spread in a 12 cm diameter bowl as depicted in Fig. 1. An adult *Macrotermes* sp. worker was then released into the middle of the bowl and allowed to walk freely. As the termite tried to locate a suitable host for settlement, its walking trails were traced up to 5 min after release. The experiment was repeated five times with different termite and position of the moist soil samples in each replicate. The walking trails of the termite were observed to determine the possible mode of action of the neem extracts and their various combinations.

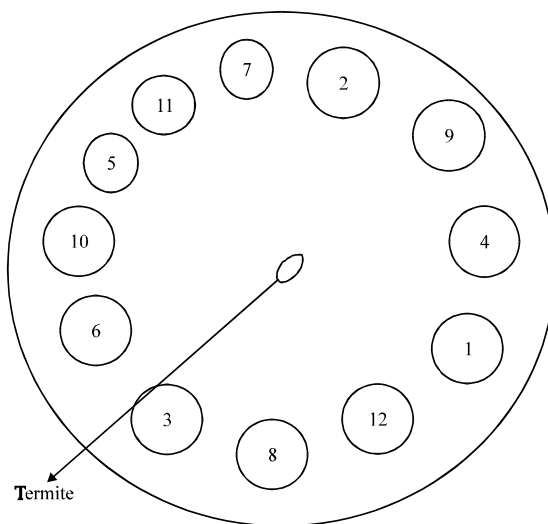


Fig. 1: Random arrangement of untreated and soil treated with neem extracts and Chlorpyriphos for walking trail experiment. Key: 1: Neem oil extract (O), 2: Bark extract (B), 3: Leaf extract (L), 4: Chlorpyriphos (Ch), 5: O+B, 6: O+L, 7: O+Ch, 8: B+L, 9: B+Ch, 10: L+Ch, 11: O+B+L+Ch, 12: C

Statistical analysis: The data obtained in all the bioassays were subjected to the analysis of variance. Means were separated using Duncan's Multiple Range Test in order to test the levels of significance.

RESULTS AND DISCUSSION

Percentage absorption: The type of the extract used remarkably influenced the percentage absorption by the wood samples (Table 1). On the average, wood soaked in leaf extract had highest absorption percentage while the least absorption was obtained in wood soaked in mixture of neem oil and chlorpyrifos. Among the extracts, wood soaked in leaf extract had significantly highest percentage absorption (9.42%) followed by 6.92 and 2.83% absorbed by wood soaked in bark extract and neem oil respectively. The high viscosity of the neem oil might have been responsible for the low percentage absorption. The implication of this is that unlike the bark and leaf extracts, neem oil requires some degree of formulation in order to improve its ability to flow and penetrate micro pore in the wood to be protected. Hence, when the extracts were combined, the degree of absorption was improved. The highest absorption of 6.55% was obtained in wood samples soaked in mixture of bark and leaf extracts while the least, 3.38% absorption was obtained in wood soaked in mixture of neem oil and bark extract. The percentage absorption followed the same trend when each extract was combined with chlorpyrifos. The highest absorption of 7.70% was obtained in wood samples soaked in mixture of leaf extract and chlorpyrifos followed by 6.20 and 2.51% obtained in wood samples soaked in mixtures containing bark extract and chlorpyrifos and, neem oil and chlorpyrifos, respectively.

Percentage weight loss: The degree of attack on the wood samples as a result of termite invasion was measured in terms of the weight loss. The weight loss in treated and untreated samples is shown in Table 1. Termites (*Macrotermes* sp.) were most active in untreated wood samples. On the average, the attack on untreated wood samples was considerably high as depicted by 64.52% weight loss compared to samples soaked in neem oil extract (24.22% weight loss) which are the most attacked treated samples. Thus, termite attack was generally less on treated samples compared to untreated samples. This confirmed effectiveness of extract solutions in enhancing decay resistance

Table 1: The percentage absorption and weight loss of treated wood samples

Extract type*	Percentage absorption	Percentage weight loss
O	2.83±6.55 ^d	24.22±10.21 ^b
B	6.92±3.55 ^b	13.20±7.87 ^e
L	9.42±1.91 ^a	7.56±3.52 ^e
Ch	4.70±4.14 ^c	0.00±0.00 ^f
O+B	3.38±6.82 ^d	12.01±5.27 ^e
O+L	5.50±3.66 ^{bc}	9.32±8.40 ^d
B+L	6.55±5.96 ^b	10.62±6.34 ^d
O+Ch	2.51±2.23 ^d	2.21±4.96 ^f
L+Ch	7.70±1.18 ^a	0.92±1.11 ^f
B+Ch	6.20±3.11 ^b	1.26±5.24 ^f
O+B+L+Ch	7.81±4.33 ^a	1.40±5.86 ^f
C	-	64.52±9.21 ^a

Each value is an average of 5 replicates. Values with the same alphabet in each column are not significantly different at $\alpha = 0.05$ using Duncan multiple range test. *O: Oil extract, B: Bark extract, L: Leaf extract, Ch: Chlorpyrifos pesticide, C: Control (untreated)

of wood (Goktas *et al.*, 2007). The high percentage weight loss observed in samples treated with neem seed oil could be attributed to the fact that neem seed oil does not penetrate the wood samples readily in its raw state. This behaviour of the oil according to Lale and Maina (2003) tends to reduce its overall efficiency in providing uniform control of insect pests. Among the neem extracts, wood samples treated with leaf extract gave the most discernible protection. The percentage weight loss in wood samples treated with leaf extract was 5.64% less than samples treated with bark extract and 16.66% less than wood treated with neem oil. Thus, the weight loss of wood treated with leaf extract was less than 10% and can be termed effective (Bakshi, 1967). This classification of resistance was based on the comparison with other natural resistant durable species (ASTM, 1998). The higher protection offered by leaf extract could be attributed to the higher penetrability of the leaf extract. It could also be the reason why termite does not usually attack neem leaf. Therefore depending on the potency of the material, the degree of protection offered is a function of its penetrability. Meanwhile, though the level of protection offered by neem oil and bark extract was low, the 24.22 and 13.20% weight loss of wood soaked in them, respectively were far better than the untreated wood. This was particularly obvious when the mixture of the extracts was used. From this result, though neem extract does not provide absolute protection to the wood samples, the level of protection offered is comparable to that of Cashew nut (Venmalar and Nagaveni, 2005), *Chromolaena odorata* and *Carica papaya* (Owusu *et al.*, 2008). Meanwhile, when each of the extract was mixed with 2% Chlorpyrifos, the level of protection was greatly improved. For example, though 0.92% weight loss was observed on wood treated with mixture of leaf extract and chlorpyrifos, no visible termite attack was observed. The implication of this is that loss in weight could be attributed to other factor such as soil. Similarly, in wood treated with mixture of bark extract and chlorpyrifos and neem oil and chlorpyrifos only one or two nibbles were seen on the surface of the wood. Thus low concentration of chemical like chlorpyrifos could be added to the neem extracts to enhance its potency level.

Degree of resistance: The degree of resistance of both treated and untreated samples to termite attack over the ten week period of assessment is presented in Table 2 and Fig. 2 and 3. The untreated samples were highly susceptible to termite attack with 75.45% of the section of wood degraded. Attack on the untreated wood samples started manifesting within one week of exposure

Table 2: Rating system for the resistance level of *Khaya senegalensis*

Extract type*	Cross section degraded (%)	Remark
O	18.57	Severely attacked
B	8.31	Moderately attacked
L	3.11	Slight feeding
Ch	0.00	No attack
O+B	2.01	Slight feeding
O+L	0.00	3 nibbles
B+L	0.00	2 nibbles
O+Ch	0.00	No attack
L+Ch	0.00	No attack
B+Ch	0.00	1 nibble
O+B+L+Ch	0.00	No attack
C	75.45	Total destruction

*O: Oil extract, B: Bark extract, L: Leaf extract, Ch: Chlorpyrifos pesticide, C: Control (untreated)

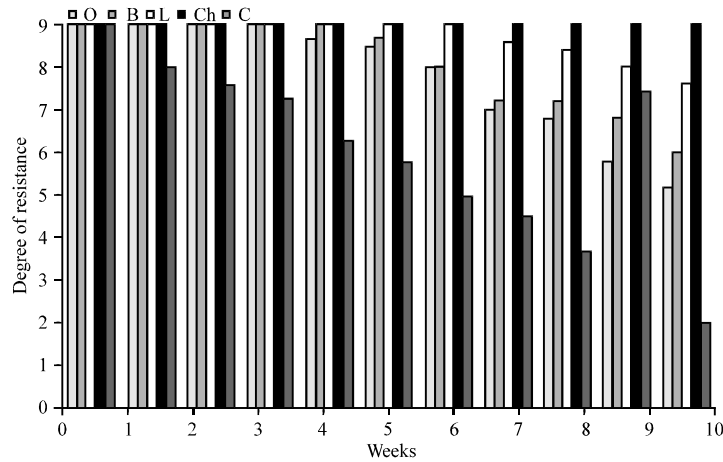


Fig. 2: Degree of resistance of untreated and treated wood samples with time. Key: O: Oil extract, B: Bark extract, L: Leaf extract, Ch: Chlorpyriphos pesticide, C: Control (untreated)

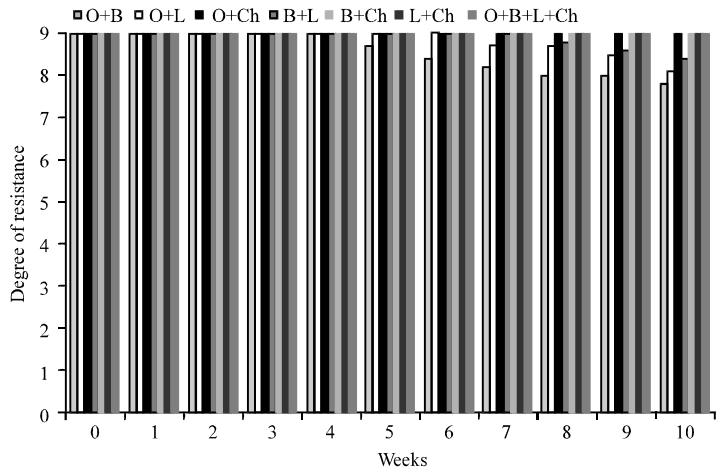


Fig. 3: Degree of resistance of the wood samples treated with neem extract combinations and chlorpyriphos with time

to the grave-yard test. The implication of this is that wood of *Khaya senegalensis* is very susceptible to termite attack. The low natural resistance of the wood of *Khaya senegalensis* to termite attack might be one of the reasons why it was classified among non durable species (Scheffer and Morrel, 1998). Similarly, it was evident that wood samples treated with neem oil began to show some level of susceptibility in the fourth week of exposure to the Grave-yard test while the bark extract treated samples began to show symptom of superficial attack in the fifth week. This corroborates the appreciable weight loss observed in wood treated with both neem oil and bark extract. Leaf extract on the other hand was able to protect the wood samples up to six weeks after which it began to develop 1 or 2 nibbles whereas, chlorpyriphos treated samples remain protected throughout the period of exposure (Fig. 2). Overall, at the end of the tenth week, 18.57% of the cross section of wood samples treated with neem oil was degraded while 8.31 and 3.11% of the cross section of wood samples treated with bark and leaf extract, respectively were degraded (Table 2).

Meanwhile, when the mixture of the extracts was used, appreciable level of protection was achieved. For example, when either neem oil or bark extracts was mixed with leaf extract, the

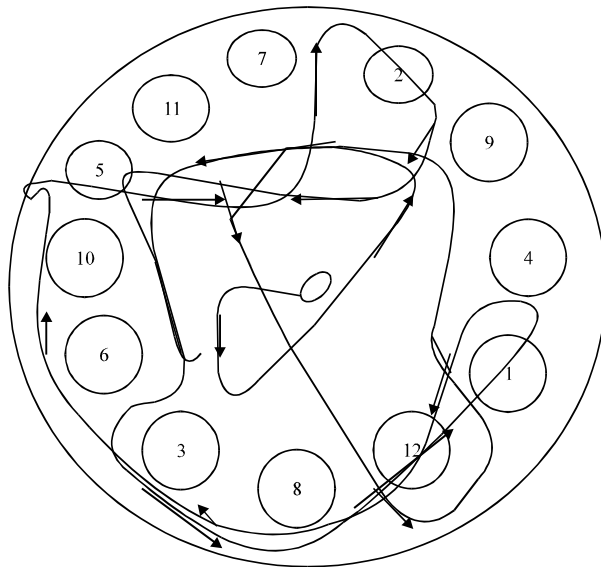


Fig. 4: Typical paths of termite in the bowl containing untreated and soil treated with neem extracts and chlorpyrifos. Key: 1: Neem oil extract (O), 2: Bark extract (B), 3: Leaf extract (L), 4: Chlorpyrifos (Ch), 5: O+B, 6: O+L, 7: O+Ch, 8: B+L, 9: B+Ch, 10: L+Ch, 11: O+B+L+Ch, 12: C

degree of protection was increased up to the seventh week before 1 or 2 nibbles began to develop on the wood (Fig. 3). Hence, the degree of resistance of wood treated with mixture of neem extracts was greatly increased as depicted by only 2.05% of the cross section of the wood samples treated with mixture of neem oil and bark extract and, nearly total resistance offered by mixtures of neem oil with leaf extract and bark extract with leaf extract at the end of the tenth week (Table 2). This finding confirmed the effectiveness of modified neem extracts reported by Moyin-Jesu (2010). Meanwhile, when each of the extract was mixed with 2% chlorpyrifos, none of the wood samples was attacked throughout the test period. The degree of protection offered by chlorpyrifos when used singly could be responsible for the total resistance observed as presented in Table 2 and illustrated in Fig. 3. The implication of this finding is that chlorpyrifos offers an effective protection against termite attack. But it has been shown that chlorpyrifos contains sulfotep which is a highly toxic impurity and thus harmful (Allender and Keegan, 1991; Ambrus *et al.*, 2003). Therefore, a high level of protection offered when neem extract was combined with 2% chlorpyrifos suggested that low level of the chemical could be combined with plant extracts to achieve high level of protection against termite attack thereby reducing the harmful effect of the chemical. This could more effective if used in modified form with mixtures of the extracts.

Walking trail experiment: The arrows in Fig. 4 indicate the release and walking trail of the termites in the plastic container. In all cases, the termite avoided walking and settling on soil treated with leaf extract, chlorpyrifos chemical and the mixture of chlorpyrifos chemical with neem extracts. To some extent, the termite settled conveniently on soil treated with neem oil extract and on the control. The repulsive action of the leaf extract and chlorpyrifos could be attributed to this behavioural movement of the termite and could also be responsible for effectiveness of the neem extract and high level of protection offered by chlorpyrifos against termite attack. This

observation agrees with Asogwa *et al.* (2009) and Cuthbertson *et al.* (2007) that some insects like termite use airborne phytochemical cues in both long and short range discrimination for avoiding the efficacy of treatment. Similarly, presence of the active ingredient Azadiractin and the bitterness of the extract could also be responsible for this behaviour.

CONCLUSION

Development of more environmentally acceptable preservatives which is a priority in the wood preservation industry today, has opened the door to plant based wood preservatives. The plant extracts can offer substantial advantages for wood protection, providing decay resistance against termite at low cost, low mammalian toxicity and ease of handling and treatment. In the present study the neem extracts have been found to have a varied level of protection against termite attack. The level of protection offered by neem oil and bark extract was considered low. But neem leaf extract was effective when compared to some plant extracts. It is worthy of note that even though Chlorpyrifos offered total protection to the wood samples throughout the test period, there was no significant difference when compared with when the mixtures of the neem extracts was used. The implication of this is that each of the mixture of neem extract could be utilized effectively for termite control. Similarly, their nontoxic effect and safety makes them encouraging. However, where long protection is needed, low concentration of chlorpyrifos could be added to mixture of the extracts to enhance their efficacy. This will not only offers a discernible protection but will also minimize the harmful effect of the chemical. The treatment combination will also reduce the cost of termite treatment which has been the bane of the people in the rural areas. Therefore, the use of the plant extract could be exploited to develop new wood preservatives to protect wooden structures, agricultural crops, plants and trees, as these are less harmful to the environment and humans.

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