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Field performance of treated green bamboo (*Bambusa vulgaris* Schrad. ex J.C. Wendl. var. *vulgaris* Hort.) with extracts from neem

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Abstract: Bamboo is highly prone to bio-degradation. Most of the conventional inorganic wood preservatives, employed to prolong its service life, are of major environmental concern, as their use continues to generate substantial global awareness. Thus, preservatives safe to the ecosystem are increasingly being sought. This present study examines the efficacy of extracts from an eco-friendly organic source, neem (*Azadirachta indica*) on the durability of green bamboo (*Bambusa vulgaris* var. *vulgaris*.) using the graveyard/field test. A batch of seventy *B. vulgaris* stakes (250x50x10mm) were pressure-treated with 0.5 and 1 per cent *A. indica* extracts from bark, leaves, roots and seeds. Seventy other untreated stakes served as the control. Stakes were exposed to termites and other bio-degraders for sixteen weeks. Deterioration of the bamboo stakes was assessed using their percentage losses in mass and hardness as well as visual durability ratings. The control stakes performed worse against termite attack than those treated. However, stakes treated with 1 per cent extract from seed resisted attack better than those with 0.5 per cent concentration. In general, extracts from *A. indica* seeds conferred better durability on the treated stakes than those impregnated with extracts from the vegetative parts.

Key words: Azadirachta indica, Bambusa vulgaris, durability rating, hardness loss, organic preservatives.

INTRODUCTION

Bamboo, as an organic ligno-cellulolytic raw material is liable to microbial and insect attacks that usually contribute to significant economic losses. Its hollow stem (culm) closed at frequent intervals (nodes) comprises about 50 per cent fibers, especially in the outer one-third of the wall and 10 per cent vessels and sieve tubes, while it lacks the typical tertiary wall present in most woody cells (Grosser and Liese, 1971; Liese, 1987; Dobriyal *et al.*,1994). Unfortunately, such variation in structural composition adversely influences its durability compared to several timber species, although it contains extractives and ash (Antwi-Boasiako, 2004). Thus, several techniques have been developed to enhance its durability (Dobriyal *et al.*, 1994).

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Chemical preservatives have been employed globally to increase the service-life of organic materials, including bamboo and wood, aimed at conserving them for sustainable utilization. Unfortunately, many of the active ingredients in these traditional wood preservatives are harmful and have hitherto posed major concerns to human health, beneficial non-target organisms and the environment. They result in ecological disturbances and often development of resistance in several agents of bio-degradation. As a result, over the past few decades, there has been substantial worldwide consciousness to develop safe, eco-friendly preservatives, since certain plants contain natural chemicals such as extractives and ash, which protect wood against bio-deterioration (Onuorah, 2000; Antwi-Boasiako, 2004). Most sought after preservatives are those effective but mammalian non-toxic and easily bio-degradable than their synthetic counterparts. In this regard, many plant-based formulations have been in use, while several serve as insecticides or general pesticides. The extracts from the leaves of plants including *Ipomea carnea* (Saxena and Dev, 2002) and *Azadirachta indica* (Swathi *et al*., 2004) have been employed effectively as natural preservatives often in their semi-purified form. These have several advantages including their slow releasing action with prophylactic measures, which prevent multiplication of insect population. *A. indica* has been established to produce compounds of low toxicity and degrade rapidly in the environment, which protect it from damaging insects. The present study employs *A. indica* extracts from the vegetative and reproductive parts as natural preservatives for the assessment of the treatability and durability of *Bambusa vulgaris* Schard. ex J.C. Wendl. var. *vulgaris* Hort. for various end-uses in service.

MATERIALS AND METHODS

Preparation of *A. indica* extracts and their concentration determination

Samples from three vegetative parts (*i.e.,* leaf, bark and root) and seeds of *A. indica* were collected from Ayikuma in the Greater Accra Region of Ghana. They were washed, air-dried and milled into powder with Marlex electric mill. Distilled water was added to each ground sample in the ratio of 20:1 (*i.e.,* 10 l distilled water: 500 g powder), stirred thoroughly, decanted after 24 h and then sieved to obtain the sediment-free, liquid extract. To determine the concentration of each extract, 10 ml of each mixture was dried in a Petri dish of known mass to obtain a powdery mass of the extract. Its concentration was determined using mass (g)*100/volume (ml). Two concentrations (1 and 0.5%) of each extract were employed for the treatment of the stakes before field exposure.

Preparation of bamboo stakes for impregnation before field-testing

B. vulgaris var. *vulgaris* defect-free mature culms were harvested at ground level from the inner portions of two bamboo clumps at the Botanic Gardens of Kwame Nkrumah University of Science & Technology (KNUST), Kumasi-Ghana. Each culm was cut into 15-node pieces and kept in leaning positions for two weeks for air-drying and depletion of sugar contents. Internodes 4-8 of each culm were split into pieces, planed and cut into stakes (250 x 50 x 10 mm). Seventy replicates were prepared for each treatment and their moisture contents (MC) taken using a Holzmeister LG9 pin type moisture meter before impregnation.

Impregnation of the bamboo samples using pressure method

A set of seventy bamboo stakes (after attaining 12-14% MC) were impregnated at 1.2 bar pressure and 124°C for 2 h while immersed in extracts each prepared at 1 per cent concentration from the vegetative and reproductive parts of *A. indica*. Impregnation of stakes was similarly done with the extracts at 0.5 per cent concentration.

Determination of extract retention

Each stake was weighed before and after impregnation. The volume of each extract absorbed and retained by individual stakes was determined. Extract retention was determined using the volume and weight gains by each stake after treatment.

Determination of masses of treated and untreated stakes before field exposure

The masses of all stakes were determined after attaining 12-14 per cent MC. Oven-dry weights of treated stakes (250 x 50 x 10 mm) and also the control stakes were taken at 105 ± 2°C until they attained constant masses. Their moisture contents were determined using the formula:

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight} - \text{Ovendry weight} \times 100}{\text{Ovendry weight}}$$

Mean moisture contents for the two stakes (*i.e.*, for individual treated and untreated stakes) were used to determine the corrected or initial oven-dry masses of all their replicate treated or untreated samples (Anon., 1989 [BS EN 252]) using the formula:

$$\text{Corrected oven-dry weight [CODW] (g)} = \frac{100 \times \text{Fresh weight of stake}}{100 + \text{MC}}$$

MC = Mean percentage moisture content of the two bamboo stakes.
CODW of a bamboo stake was taken as its initial mass before field exposure.

Hardness test for stakes before field exposure

All treated and untreated stakes were subjected to hardness test after attaining 12 per cent MC using Pilodyn, which records the depth of penetration of its pin into each stake at a range of 0 (softest) to 40 mm (hardest) (Anon., 1997; Brunner and Grüsser, 2006). All stakes were then conditioned at 25°C and 65 per cent rh prior to insertion in the field.

Site preparation, insertion of stakes in the field and durability tests

All stakes (treated and untreated) were inserted at a prepared site (60 x 50 m) at the test field, Faculty of Renewable Natural Resources (FRNR) Experimental Farm at KNUST (Fig. 1) using Completely Randomised Design (CRD). Each stake was inserted one-third its length and 50 cm apart from each other.

Figure 1: Freshly inserted stakes at the test site amid termitaria (T).

Visual durability ratings of stakes during field exposure

Observations were made regularly at weekly intervals to examine attacks and damages caused by bio-degraders especially termites at the test field. The extent of stake deterioration was determined according to Anon. (1989) (Table 1).

Determination of mass losses and hardness losses of stakes after field exposure

After four months, stakes were removed from the field, brushed off soil and air-dried until 12-14 per cent. Constant oven-dry mass of each stake was taken at 105 ± 2°C as the final mass. The percentage mass loss for each stake was then calculated as:

Table 1. Visual ratings of the durability of timbers (Anon., 1989 [BS EN 252])

Rating	Extent of deterioration
0	No sign of attack
1	Slight attack
2	Moderate attack
3	Severe attack
4	Failure (total destruction of stake)

$$\text{Percentage mass loss} = \frac{\text{Initial mass (CODW)} - \text{Final mass} \times 100}{\text{Initial mass (CODW)}}$$

The mean masses for replicate bamboo stakes were determined.
The hardness loss for each stake was determined as follows:
Hardness loss = Initial hardness – Final hardness (mm); Mean percentage hardness losses were then determined for replicate stakes.

RESULTS

Retention of *A. indica* extracts in treated stakes

Mean retention of *A. indica* extract was highest for *B. vulgaris* stakes treated with extracts of higher concentration (1%) than for those impregnated with the lower concentration (0.5%) (Figs. 2a,b). Retention was especially highest for stakes treated with 1 per cent seed extracts, but lowest for those treated with 0.5 per cent bark extract. Difference in retention for stakes treated with the two concentrations (0.5 and 1%) of each extract was significant ($P < 0.05$). Similarly, significant differences ($P < 0.05$) existed between retentions of all impregnated stakes except that between stakes treated with 1 per cent leaf and 0.5 per cent seed extracts. Data revealed that for the seed extract, 1 per cent concentration was retained more in all the treated stakes than 0.5 per cent (Fig. 2b).

Performance of *B. vulgaris* stakes against bio-deterioration in the field

The level of resistance of treated and untreated stakes against attack by termites after four-months of field exposure, using durability parameters such as percentage mass and hardness losses as well as visual durability ratings, revealed comparable results.

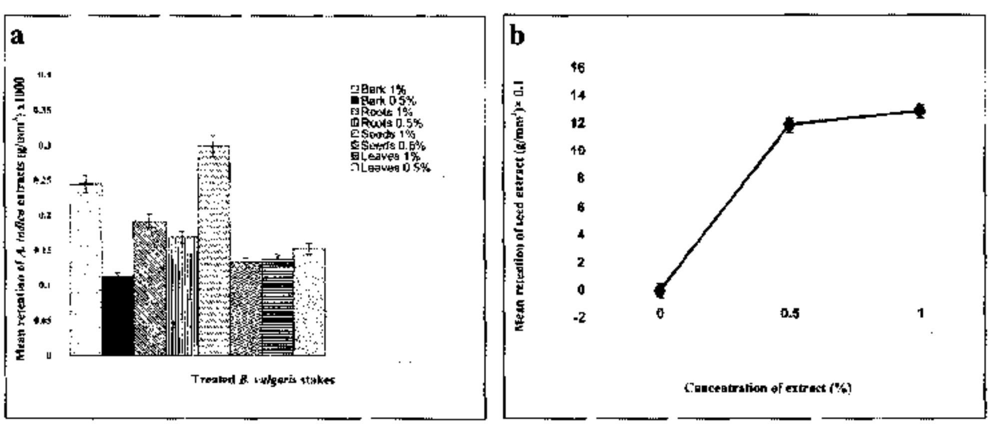

Figure 2. a: Retention of *A. indica* extracts in *B. vulgaris* stakes after pressure impregnation. b: Retention of seed extract at different concentrations.

Data showed that the untreated control bamboo stakes recorded higher percentage mass losses (*i.e.*, less durable) than all their treated counterparts. For the latter, those treated with seed extracts (1% and 0.5%) recorded the lowest mean percentage mass losses (*i.e.*, most durable). They were followed by stakes treated with 1 per cent root, 1 per cent bark as well as 1 and 0.5 per cent leaf extracts. In all, stakes impregnated with higher concentrations of extract (1%) recorded lower mean percentage mass losses than their counterparts treated with similar extract of lower concentration (0.5%). Apart from stakes treated with seed extracts (1% and 0.5%), the differences between those treated with each of the *A. indica* extracts were not significant ($P < 0.05$). The difference was significant ($P < 0.05$) only for stakes treated with seed extracts (Fig. 3a). It was observed that the higher the concentration, the lower the mean percentage mass loss (Fig. 3b).

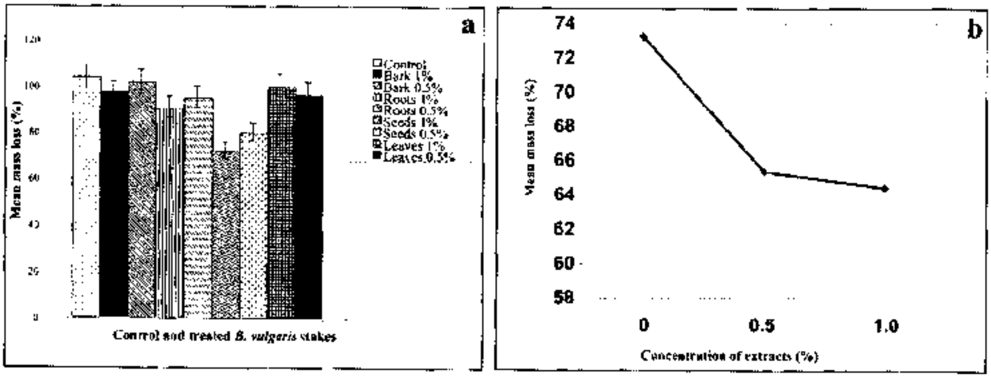

Figure 3. a: Mean percentage mass losses for untreated (control) and treated *B. vulgaris* stakes after field exposure; **b**: stakes treated with *A. indica* extracts at different concentrations.

Hardness loss of treated and untreated *B. vulgaris* stakes after field exposure

Figure 4a shows the depths of penetration of Pilodyn into treated and untreated bamboo stakes (*i.e.*, their hardness losses) after field exposure. As for mass loss, the controls recorded the greatest loss in hardness, while 1 per cent seed extract treated stakes commonly performed best (*i.e.*, hardest) followed by those treated with 1 per cent bark and 1 per cent root extracts. All stakes treated with 0.5 per cent *A. indica* extracts performed poorly, especially for the root and bark. The differences in hardness losses of the treated stakes with each extract were significant ($P < 0.05$) except between 1 per cent and 0.5 per cent leaf extracts. *B. vulgaris* stakes treated with various extracts at different concentrations also showed variation in hardness loss (Fig. 4a). All samples treated with 1 per cent extracts were harder than those impregnated with 0.5 per cent extracts (Fig. 4b).

Visual durability ratings

Visual durability ratings for the bamboo stakes indicate that the controls recorded the maximum bio-degradable symptoms (including stake discolouration, softening, fungal

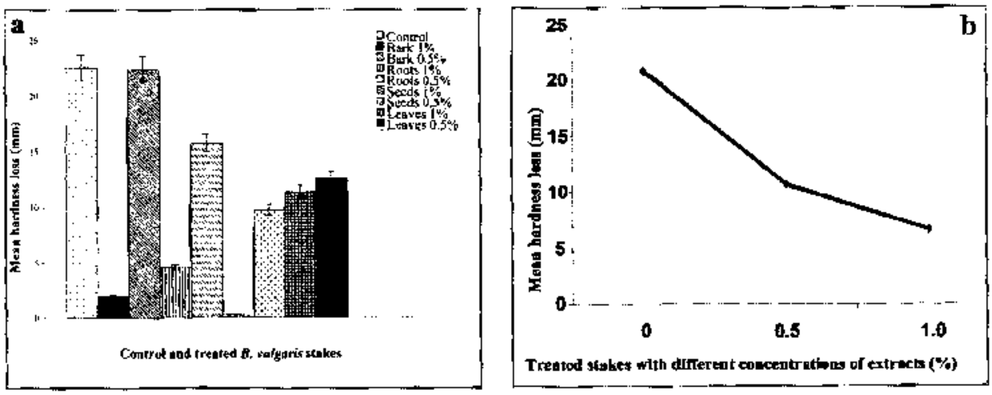

Figure 4. a: Mean hardness losses for untreated (control) and treated *B. vulgaris* stakes after field exposure; b: stakes treated with *A. indica* extracts at different concentrations.

fructification, infestation of parts). Stakes impregnated with 1 per cent seed extracts resisted the attack of bio-degraders and showed the lowest durability ratings followed by those treated with 1 per cent bark and root extracts (Fig. 5a). Significant differences ($P < 0.05$) never existed between 1 per cent bark and 1 per cent root, 1 per cent leaf and 0.5 per cent root as well as 0.5 per cent leaf and seed extracts impregnated stakes. Treated bamboo stakes with 1 per cent extracts recorded lower durability ratings compared to their counterparts treated with 0.5 per cent, as their visual durability rating variations were significant ($P < 0.05$) (Fig.5b). Figure 6 shows *B. vulgaris* stakes showing no signs of attack before field exposure, while Figure 6b shows the stakes with typical signs of attack including severe damage by termites. Incidence of damage was severe at the lower buried portions.

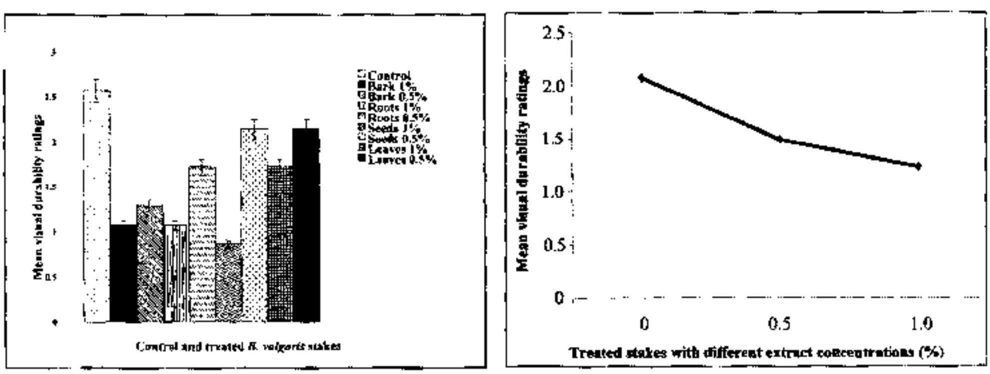

Figure 5. a: Mean visual durability ratings for untreated (control) and treated *B. vulgaris* stakes after field exposure; b: stakes treated with *A. indica* extracts at different concentrations.

DISCUSSION

The ability to retain natural preservatives is important in wood treatment, since the toxic chemicals could confer greater durability on wood and wood products against termites and fungi. The fact that *A. indica* extracts (1%) from the different parts of the

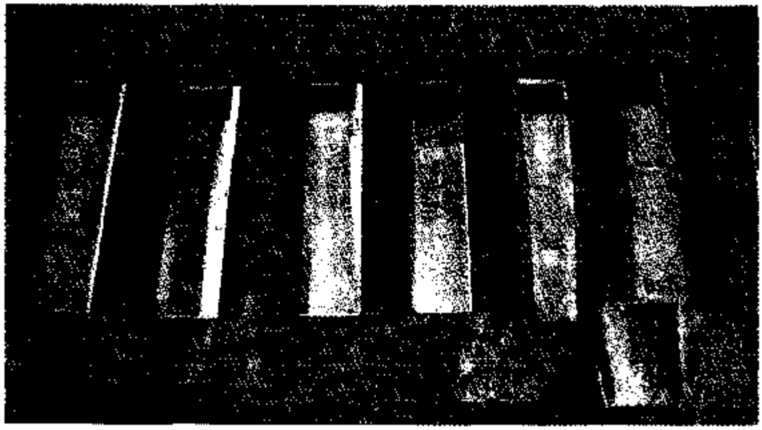

Figure 6a. *B. vulgaris* stakes before insertion in the field showing no signs of attack by bio-degraders.

Figure 6b. *B. vulgaris* samples after 4-months field exposure showing signs of termite attack.

plant generally retained more in the bamboo stakes than the extracts of lower concentration (0.5%) is consistent with the results obtained by Fougerousse (1985).

Apart from the greater retention in impregnated bamboo stakes with *A. indica* extracts of higher concentration, these stakes also recorded the lower mean percentage mass losses and visual durability ratings and hence performed better in the field than those treated with extracts of lower concentration (0.5%). Thus, it could be stated that, extracts of higher concentration generally imparted higher toxicity to the stakes, which contributed in resisting bio-deterioration, especially from termite attack, more than those treated with the extracts of lower concentration. The lowest mean percentage mass losses and visual durability ratings recorded both for stakes impregnated with seed extract could be attributed to the highest concentration of Azadirachtin (a bio-pesticide) reported to be contained mostly in *A. indica* seeds. As seed extract was retained most, coupled with the higher Azadirachtin concentration and pesticidal efficacy, stakes treated with 1 per cent seed extract had more Azadirachtin to repel termites and other bio-degraders. Intensive investigation on neem seeds has revealed Azadirachtin, is a highly oxygenated complex compound which is a very potent anti-feedant and growth disruptant to many insect pests and is also considered environmentally safe.

Woods offer resistance to indentation and penetration (Negi, 2004). However, one of the diagnostic features of wood deterioration is strength reduction (particularly hardness) due to the action of environmental factors (*e.g.*, moisture) and deteriorating agents, which often cause wood softening. The Pilodyn was used as a measure of stake hardness (Brunner and Grüsser, 2006) before and after treatment as well as after field exposure. Once again, bamboo stakes treated with 1 per cent *A. indica* seed extract had the lowest mean hardness loss and resisted degradation (through infestation by termites) best and thus showed the least strength reduction. Stakes treated with the lower concentration (0.5%) were a bit soft unlike the controls, which especially performed the worst in the field and were the softest at the end of the experiment.

CONCLUSION

The present study has revealed that *A. indica* extracts are effective in preserving bamboo, since all the three parameters (percentage mass and hardness losses, visual durability ratings) employed to determine the field performance of bamboo stakes showed comparable encouraging results. However, variation existed in the ability of extracts from different parts of *A. indica* to confer the durability on bamboo stakes and the concentration employed. Thus, seed extract at 1 per cent concentration was more effective than the lower concentration (0.5%). Therefore, for more effective and commercial exploitation as natural wood preservative, the neem seed extract concentration should be increased (*i.e.*, >1%).

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REFERENCES

Anonymous 1989. BS EN 252 (BS EN 7282:1990) – Field Test Method for Determining the Relative Effectiveness of a Wood Preservative in Ground Contact.

Anonymous 1997. Methods of Tests for Bamboo. A Review. International Network for Bamboo and Rattan (INBAR): 10-28.

Antwi-Boasiako, C. 2004. Assessment of Anatomy, Durability and Treatability of Two Tropical Lesser-Utilized Species and Two Related Primary Species from Ghana. Ph.D. Thesis. The School of Plant Sciences, The University of Reading, Reading, UK: 318p.

Brunner, M. and Grüsser, F. 2006. Investigations on lesser-used timber species for the construction of light bridges in Ghana.1st Interim Report 2005-06, DEZA/SNSF. Biel, Switzerland.

Dobriyal, P.B., Shukla, K.S., Dev, I. and Kumar, S. 1994. Bamboo Preservation Techniques: A Review. INBAR and ICFRE Publication, Dehradun, India: 1-31.

Fougerousse, M. 1985. Soft rot fungi occurring in the field tests in Ivory Coast and France. *Mat. Org.* 3(3): 21-34.

Grosser, D. and Liese, W. 1971. On the anatomy of Asian bamboos with special reference to their vascular bundles. *Wood Science and Technology* 5: 290-312.

Liese, W. 1987. Research on Bamboo. *Wood Science and Technology* 21:189-209.

Negi, S. S. 2004. Wood Science and Technology. Applied Forestry Series No. 2. International Book Distributors, Dehradun, India: 249p.

Onuorah, E.O. 2000. Short Communication: The wood preservative potential of heartwood extracts of *Milicia excelsa* and *Erythrophleum suaveolens*. *Bioresources Technology* 75:171-173.

Saxena, P and Dev, I. 2002. Preliminary studies on termite resistance of water soluble phenolics fraction of Western Red Cedar. *Can. J. Bot.* 32 (1): 308-309.

Swathi, D., Tripathi, S. and Dev, I. 2004. Preliminary screening of Neem (*Azadirachta indica*) leaf extractives against *Poria monticola* - A wood destroying fungus. *J. Ind. Acad. Wood Sci.*, (N.S.) 1(1&2): 103-112.