Impregnability of *Grevillea robusta* using the sap displacement method

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To improve the durability of *Grevillea robusta* timber and thereby promote its use in the construction sector, we have studied its impregnability by sap displacement method using conventional copper, chromium and arsenic mixture. Recommendations are made to obtain a high degree of protection under different conditions, including uses in contact with the soil or immersion in fresh or marine water.

Grevillea robusta trees planted in a hedge for harvesting as timber.
Photo F. Mburu.

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RÉSUMÉ

IMPRÉGNABILITÉ DE *GREVILLEA ROBUSTA* PAR LA MÉTHODE DU DÉPLACEMENT DE SÈVE

L'utilisation du bois dans la construction peut être facilitée par le recours à des traitements de préservation peu coûteux permettant de limiter les frais de remplacement et de conserver les ressources naturelles. Le déplacement de sève est une méthode simple à mettre en œuvre facilement utilisable en milieu rural. Une étude a été réalisée pour évaluer l'efficacité de cette technique afin de promouvoir l'utilisation d'une essence peu durable du Kenya, *Grevillea robusta*. Des échantillons préalablement écorcés ou non ont été traités avec un mélange de cuivre, chrome et arsenic, dilué à 2, 4 ou 6 %. Les taux de rétention ont été mesurés et comparés avec les valeurs théoriques recommandées pour ce type de traitement. La pénétration et le taux de rétention du produit de préservation augmentent avec la quantité de produit de préservation utilisée. Les échantillons écorcés présentent généralement une meilleure imprégnabilité que leurs homologues avec écorces et les taux de rétention sont, dans tous les cas, supérieurs aux valeurs recommandées par la Fao.

Mots-clés : *Grevillea robusta,* déplacement de sève, mélange cuivre-chrome-arsenic, rétention, pénétration.

ABSTRACT

IMPREGNABILITY OF *GREVILLEA ROBUSTA* USING THE SAP DISPLACEMENT METHOD

The utility of construction timber can be improved through low-cost treatment methods that reduce the cost of replacing structural timbers replacement and thus help to conserve forests. The sap displacement method is simple and easily applied in rural areas. A study was carried out to investigate the effectiveness of this technique with *Grevillea robusta* with a view to promoting this non- durable Kenyan species. Specimens with and without bark were treated with a mixture of copper, chromium and arsenic in concentrations of 2, 4 and 6%. Retention was determined and compared with the recommended values. Retention and penetration of the preservatives increased significantly with increased concentrations. Retention in debarked specimens was significantly higher than in un-debarked specimens, but in both cases, retention was higher than the recommended FAO values for various uses. These results suggest that the sap displacement method can be used locally as an effective treatment for *Grevillea robusta* timber for end uses such as fencing poles.

Keywords: *Grevillea robusta,* sap displacement, copper-chromium-arsenic mixture, retention, penetration.

RESUMEN

IMPREGNABILIDAD DE *GREVILLEA ROBUSTA* POR EL MÉTODO DE DESPLAZAMIENTO DE LA SAVIA

El uso de la madera en la construcción puede verse facilitado mediante el empleo de tratamientos de protección asequibles que permiten limitar los costos de reemplazo y conservar los recursos naturales. El desplazamiento de savia es un método de aplicación simple, fácilmente utilizable en el medio rural. Se realizó un estudio para evaluar la eficacia de este procedimiento para fomentar el uso de una especie poco duradera de Kenia, *Grevillea robusta*. Algunas muestras, previamente descortezadas o no, se trataron con una mezcla de cobre, cromo y arsénico diluida al 2, 4 ó 6 %. Se midieron las tasas de retención y se compararon con los valores teóricos recomendados para este tipo de tratamiento. La penetración y la tasa de retención del producto de protección aumentan con la cantidad de producto de protección utilizada. Las muestras descortezadas suelen tener una mejor impregnabilidad que cuando tienen corteza y las tasas de retención son, en todos los casos, superiores a los valores recomendados por la FAO.

Palabras clave: *Grevillea robusta,* desplazamiento de savia, mezcla de cobre-cromo-arsénico, retención, penetración.

The context

Wood is widely used for construction because of its physical characteristics and engineering properties, associated with ready availability (Eaton, Hale, 1993; Aston, 1985). As the technology advances, more diverse and complex uses of wood have been developed. Despite its versatility as a construction material, modern technology has brought alternatives, such as metal and plastics, some of whose qualities have superseded those of wood .

The natural durability of timber is fairly often a disadvantage compared to other competing construction materials. Durability is mainly dependent on the wood structure of individual species and the chemical composition of extractives (Fengel, Wegener, 1983). The heartwood is generally described as more resistant than sapwood to fungi and insect attacks.

In Kenya, state forest plantations cover about 1 405 000 ha, or 2.4% of the total land area. These forests are made up of 31% pine, 45% cypress, 10% eucalyptus and 14% of other species. Private forests cover about 70 000 ha and consist mainly of acacia species and *Grevillea robusta*, the latter accounting for about 75% of the total area (Kfmp, 1994). Acacia is used to extract tannin while Grevillea provides multipurpose timber from agroforestry. The use of *Grevillea* for fencing and construction purposes has been necessitated by a timber deficit in Kenya that appeared in 2000 due to industrial development and a ban on logging in government forests in 2001. Increasing population pressure has caused depletion of natural forests, leading to shortages in industrial raw material. As a result of this and the current ban on logging in Kenya, consumers have sought alternative sources and species for manufacturing and construction, including *Grevillea robusta*. *Grevillea robusta* is a fast growing agro-forestry tree species distributed in most parts of Kenya's Central and Rift Valley provinces (Kfmp, 1994). Most fast growing trees have a high ratio of sapwood to heartwood, and therefore have lower natural durability than selected slow-growing trees extracted from natural forests.

Various preservatives are used in Kenya to suit different end uses. These include chromated copper arsenate (CCA), pentachlorophenol (PCP) and creosote oil. Pressure treatment of *Eucalyptus saligna* using tar oil is mainly used to achieve high rates of retention (160-400 kg/m^3) as recommended for high hazard areas against termites and in marine waters. *Eucalyptus saligna* transmission poles have also been treated with CCA using the full cell pressure method. However, premature failures have been reported for some poles in service due to low preservative fixation associated with the anatomical characteristics of eucalyptus (Okwara, 2000; Venkatasamy, 1997). Cheap preservation treatments including brushing, immersion or sap displacement can be investigated to improve the durability of Grevillea wood. The effectiveness of these treatments depends not only on the method used but also on the preservative employed. It is generally accepted that sap displacement enables sapwood to be treated effectively by allowing uniform penetration of the active ingredients used for preservation. This is a cheap method that can be used to treat *Grevillea robusta* for local construction uses in Kenya. The choice of preservative depends on the level of risk of biological attack on the wood during its service life. Because of the extent of decay and termite degradation, CCA was retained as the most effective low-cost preservative to improve the durability and performance of *Grevillea robusta* as construction timber.

The sap-displacement method may be applied to freshly felled green hardwood or softwood and uses the principle of hydrostatic pressure to force the preservative from the butt end of the round timber to the top. Some impermeable species like *Picea* spp. can take a long time to season adequately. Fowlie and Sheard reported successful treatment of *Picea abies*, *Picea sitchensis* and *Pinus nigra* in 20-30 hours, using pressurized sap displacement (Fowlie, Sheard, 1983). The method produces a greater concentration of the preservative at the butt end and this is welcome, especially in the case of poles driven into the ground, which are more vulnerable to decay. This method is also economically advantageous in remote areas with no facilities for timber impregnation and where labour costs are not too high (Findley, 1985; Goodell *et al*., 1991).

The aim of this study is to investigate the impregnability of *Grevillea robusta* using sap-displacement to enhance its uses, reduce replacement costs and provide a relatively durable construction material, especially in rural areas where it is mostly grown in agro-forestry systems.

Tree *G. robusta* poles used for a gate.
Photo F. Mburu.

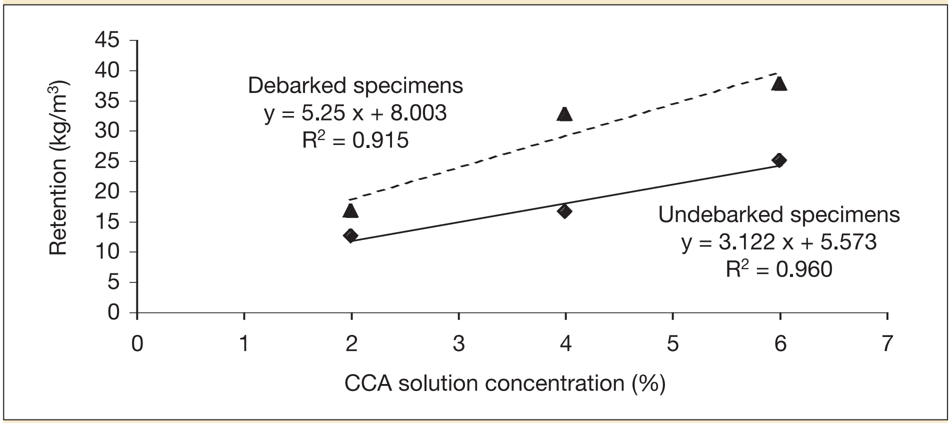


Figure 1.
Relationships between retention and concentrations of chromated copper arsenate (CCA) solutions.

Two *Grevillea robusta* trees.
Photo F. Mburu.

Materials and methods

Sampling

Specimens from freshly cut 1m lengths of roundwood from twenty year-old *Grevillea robusta* A. Cunn ex. R. Br. with a top diameter of 140-180 mm were cut following the procedure of Harwood and Booth (1992). Sixty specimens were prepared: thirty were debarked and thirty undebarked but with a small debarked portion to allow preservative uptake. The debarked portion is dipped into the CCA container to avoid direct absorption of the chemical by the bark. The uptake of CCA from the container was expected to be mainly by suction created through sap displacement.

Sap-displacement treatment

Industrial-quality CCA was used during this study (Tanalith-C, Arch Timber). Aqueous solutions of CCA were prepared at different concentrations (2, 4 or 6% in mass) and used to impregnate the specimens. The butt end of each specimen was placed in a plastic container filled with CCA solution (five litres for debarked and four litres for undebarked poles). The container was firmly attached to the butt end and supported in a slanting position. The treatment was continued until the chemical oozed out from the top end of the posts or when all the preservative in the container was absorbed. At the end of the treatment the containers were removed and the specimens were left in the same position for 7 days to leach out unfixed preservative. Retention (kg/m^3) was determined for both debarked and un-debarked specimens and compared with the recommended average retention for timber under various exposure conditions according to the formula (i):

Table I.
Mean chromated copper arsenate (CCA) retention values measured and possible uses according to FAO standards.

Concentration of treatment solution (%)	Debarked specimens		Undebarked specimens	
	CCA Retention (kg/m³)	Possible use t according to FAO	CCA Retention (kg/m³)	Possible use according to FAO
2	16.66 ± 1.70	Permanently immersed in fresh water	12.55 ± 1.73	Timber in contact with the ground
4	32.69 ± 2.97*	Permanently immersed in sea water	16.60 ± 1.68	Permanently immersed in fresh water
6	37.66 ± 5.60*	Permanently immersed in sea water	25.04 ± 3.26	Permanently immersed in sea water

* Significantly different values at 5% level of significance.

Impregnability

Retention = $(m_2 - m_1) \times c / v$ . . . (i)

where m_1 is the mass of the fresh untreated sample (kg), m_2 is the weight of the impregnated sample measured immediately after the CCA solution had oozed out from the top of the pole (kg), c is the CCA solution concentration (%) and v the sample volume (m^3).

Penetration was measured in percentage along the height of samples according to the formula (ii):

Penetration = $(1 - [r - r_1]/r) \times 100$ . . . (ii)

where r_1 is the depth of preservative penetration (cm) and r the radius of the sample (cm) for a given position from the butt end.

G. robusta posts and runners forming a fence.
Photo F. Mburu.

Retention

The Food and Agriculture Organisation (FAO), recommends a CCA retention value of 6 kg/m³ for interior timbers not in contact with the ground, such as trusses or rafters, and of 8 kg/m³ for exterior timbers not in contact with the ground, such as doors and windows. The recommended value for timber in contact with the ground, such as fence posts, railway sleepers or bridge timbers, is 12 kg/m³. Timber permanently immersed in fresh water requires a retention value of 16 kg/m³ and timber immersed in seawater (e.g. groynes, jetties or boat building timber) requires 24 kg/m³ (Fao, 1986).

Table I shows mean CCA retention values obtained for debarked and undebarked specimens and their possible uses according to FAO recommendations.

Debarked specimens had significantly higher retention than the undebarked specimens for the same solution strength. In both debarked and undebarked specimens, retention increased with the strength of the solution.

Comparisons between the experimental mean retention values and the FAO recommended values indicated that the impregnation of *G. robusta* using the sap displacement method is sufficient to reach the value of 12 kg/m³ required for uses in contact with the ground. For the 2% solution, debarked specimens did not have a significantly different value from the value recommended for immersion in fresh water. This implies that *G. robusta* meets the minimum requirements set for timbers to be permanently immersed in fresh water. However, the values obtained with the 4 and 6% solutions were significantly higher than the recommended values. These are suitable for all environmental hazards but they are uneconomical because of the high retention obtained.

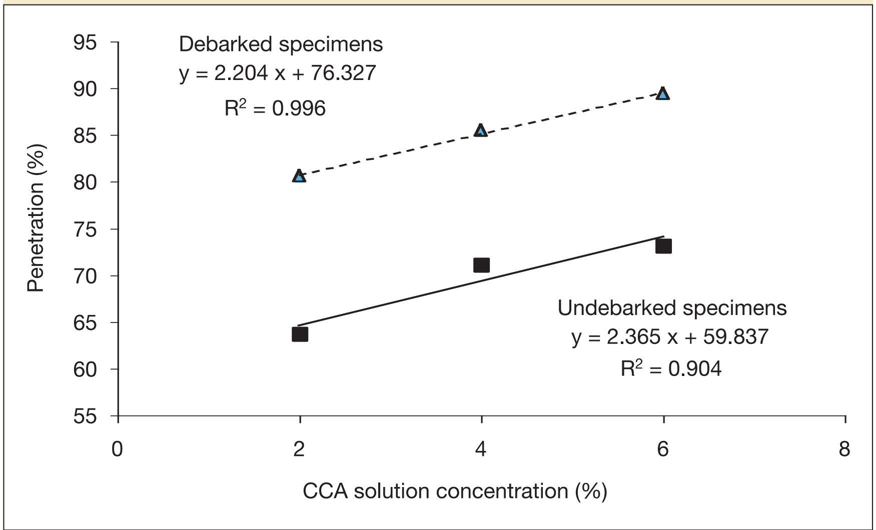


Figure 2.
Relationships between depth of penetration and chromated copper arsenate (CCA) concentration measured at a height of 500 mm.

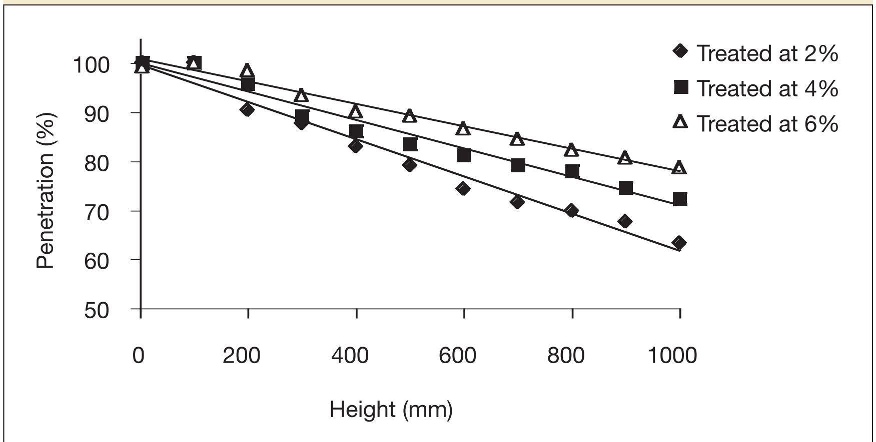


Figure 3.
Chromated copper arsenate (CCA) penetration according to extraction height for debarked specimens.

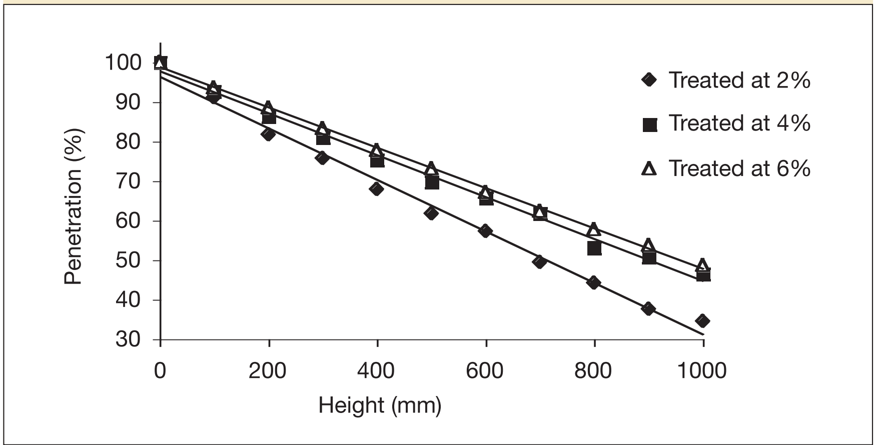


Figure 4.
Chromated copper arsenate (CCA) penetration according to extraction height for undebarked specimens.

Values obtained for undebarked specimens using the 2, 4 and 6% solutions were generally smaller than those obtained for debarked specimens. This may be because the larger surface area increased suction pressure and therefore absorption of the chemical. However, these values are in all cases higher than the 12 kg/m³ recommended by FAO. *G. robusta* treated with 2 and 4% solutions of CCA can meet the minimum retention requirements for uses in contact with the ground and immersion in fresh water, respectively. Values obtained for the 6 % CCA solution were slightly higher and allow uses where timbers are permanently immersed in sea water.

Figure 1 shows the relationship between retention and solution strength for debarked and undebarked samples. The linear relationship is described by equations (iii) and (iv) and the corresponding correlation coefficients of $R^2 = 0.92$ and $R^2 = 0.96$ respectively:

Retention = 5.25 (solution strength) + 8.00 . . . . (iii)

Retention = 3.12 (solution strength) + 5.57 . . . . (iv)

Retention in undebarked specimens has a stronger linear relationship than in debarked specimens. These models can be used to determine levels of retention in both debarked and undebarked specimens using the sap displacement method.

The higher retention values measured in debarked samples may be due to the larger surface area creating increased suction pressures, which cause evaporation and higher chemical uptake.

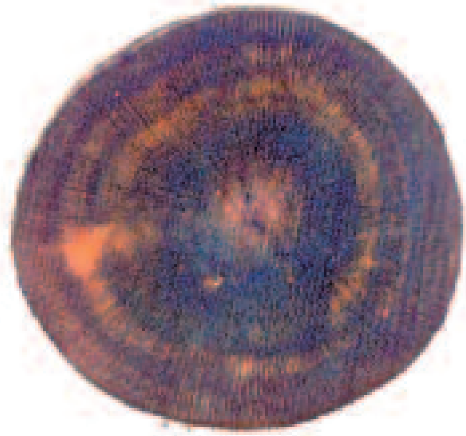
Penetration

Table II shows penetration in debarked and undebarked specimens using 2, 4 and 6% solutions.

With all three concentrations, penetration was higher in debarked specimens.

Table II.
Mean penetration for debarked and undebarked specimens.

Concentration of CCA solution (%)	Penetration (cm)	
	Debarked specimens	Undebarked specimens
2	80.6 ± 12.7	63.7 ± 21.7
4	85.6 ± 9.8	71.1 ± 17.6
6	89.4 ± 7.8	73.2 ± 6.9



Transverse section of a treated *G. robusta* pole.
Photo F. Mburu.

Figure 2 shows the variation in preservative penetration according to solution strength for debarked and undebarked samples. The linear relationship is described by equations (v) and (vi) and by the corresponding correlation coefficients of $R^2 = 0.97$ and $R^2 = 0.90$ respectively:

Penetration = 2.21 (solution strength) + 76.3 . . . . (v)
Penetration = 2.37 (solution strength) + 59.8 . . . . (vi)

There were significant differences in penetration between debarked and undebarked specimens. Preservative penetration increased with higher solution strengths. Debarked specimens showed higher penetration than undebarked specimens. Debarked samples have a higher surface area for evaporation, which creates a higher suction pressure than in barked samples, hence higher penetration. Even in treatments using the same solution strength, samples showed variation in penetration. This can be explained by differences in sapwood content, density and moisture content. There is a stronger linear relationship between penetration and solution strength for debarked than for undebarked specimens. The strong correlation between penetration and solution strength for the two groups of specimens indicates that the two models adequately predict the degree of preservative penetration.

Variations in the depth of penetration of the preservative according to the height of specimens are shown in Figures 3 and a 4 for debarked and undebarked samples respectively. In both cases, penetration decreased with the height of the specimen. The depth of penetration was also dependent on the concentration of the treatment solution, i.e. the stronger the concentration, the higher the penetration and consequently the retention.

Mature *G. robusta* trees showing orange flowers.
Photo F. Mburu.


Treatment of undebarked specimens.
Photo F. Mburu.


Mature 24 year-old *G. robusta* plantation, growing in the Uasin Gishu district of the Rift valley Province. Heavy rainfall area, high altitude plain.
Photo F. Mburu.

Conclusion

Our results show that *Grevillea robusta* can be adequately treated using the sap displacement method to retention levels that meet minimum requirements for various use conditions, including contact with the ground or permanent immersion in fresh and sea water. The positive linear relationship between retention, penetration and solution strength means that the desired retention and penetration of preservative can be achieved by varying the solution strength. Preservative penetration is dependent on the height of the pole and inversely proportional to the distance from the end dipped in preservative. Undebarked specimens tend to retain less preservative, while debarked ones yield greater penetration.

Debarked *G. robusta* poles can achieve the degree of retention required for wood permanently immersed in fresh water with a 2% solution and for marine water exposure with 4 and 6% solutions. Undebarked wood can be treated to achieve the retention levels required for ground contact using a 2% solution, and for fresh water and marine exposure using 4 and 6% solutions.


G. robusta trees ready for harvesting and use as fence posts.
Photo F. Mburu.

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