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PRESERVATION OF ROUNDWOOD POLES BY THE SAP REPLACEMENT METHOD WITHOUT PRESSURE APPLICATION

Francis Ng'ang'a

Forest Department, P.O. Box 52715, Nairobi, Kenya

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NG'ANG'A, F. 1994. Preservation of roundwood poles by the sap replacement method without pressure application. A number of preliminary trials with poles of *Eucalyptus saligna* helped to establish an appropriate sap replacement treatment process. Factors studied included solution strength, bark removal influence, pole length limitations, tolerable pre-treatment delay and preservative retention uniformity. Treatment success was assumed achieved if the pole absorbed a pre-determined quantity of preservative. Relating to the treatment by the full-cell pressure method, treatability responses of poles belonging to eight wood species commonly grown in Kenya plantations were compared. As preservative retention built up towards the pole absorption end, the treatment gave poor results compared with the full-cell process. Retention was also largely confined to the outer sapwood. Despite these drawbacks and the additional risk of exposure of the untreated wood by splitting on drying, the method has scope in preservation of certain classes of wood products, such as fence posts and building poles.

Key words: Roundwood poles - preservation - sap replacement - preservative retention

NG'ANG'A, F. 1994. Pengawetan kayu tiang menggunakan kaedah penggantian sap tanpa tekanan. Beberapa percubaan awal dengan kayu tiang pokok *Eucalyptus saligna* telah mewujudkan proses rawatan penggantian sap yang sesuai. Faktor-faktor yang telah dikaji termasuk kekuatan larutan, pengaruh pembuangan kulit, batasan panjang kayu bulat, penangguhan prarawatan yang boleh ditahan dan kesamaan penahanan pengawet. Rawatan dianggap berjaya jika kayu bulat menyerap jumlah pengawet yang telah ditetapkan. Respons kayu bulat dari lapan spesies kayu yang biasa ditanam di ladang Kenya terhadap rawatan telah dibandingkan dengan kaedah tekanan sel penuh. Penahanan pengawetan yang meningkat ke arah penghujung penyerapan kayu tiang menyebabkan hasil yang lemah berbanding dengan proses sel penuh. Penahanan juga terbatas terutamanya pada bahagian luar kayu gubal. Kaedah penggantian sap tanpa tekanan mempunyai skop dalam pengawetan kelas-kelas tertentu keluaran kayu seperti tiang pagar dan tiang bangunan, walaupun terdapat kelemahan-kelemahan yang telah disebutkan serta risiko kerekahan apabila dikeringkan yang disebabkan oleh pendedahan kayu yang tidak dirawat.

Introduction

A stem, and indeed any plant part, freshly cut and with its butt end dipped immediately in an aqueous solution continues for awhile to draw in the solution to replenish evaporation losses. This phenomenon offers a low-cost means of introducing a preservative into the wood interior.

Among the common water soluble preservatives available commercially only the copper-chrome-arsenic (CCA) formulations are not moisture leachable once fixed in the wood, an important requirement for wood to be used in contact with the ground. Using these preservatives a series of trials were undertaken to establish feasibility of treating roundwood poles by this non-pressure method of sap replacement. The trials were carried out in two stages. The initial stage sought to reveal the appropriate process control factors. Such factors include suitable conditions of exposure, treatment solution concentration, bark removal influence, pole length limitations if any and pre-treatment delay tolerance. The results helped in adoption, during the second stage, of a standardised treatment process by which treatability of some eight wood species commonly grown in Kenya would be compared.

The preservation process offers a low-cost option for on-farm application where the trees are grown and the poles can also be used. Unlike pressure methods of preservation, it does not require specialized impregnation equipment and the preservative solution preparation costs are minimal.

Effectiveness of the treatment method was compared with matched poles treated by the conventional pressure impregnation method. Both qualitative and quantitative analytical techniques were employed in assessing treatment effectiveness. The former involved visual examination, with the aid of colour indicator, of the wood colour changes. For quantitative analyses, sawdust samples from the treated wood were liquid extracted to a form suitable for atomic absorption spectrophotometry (AAS).

A third preservation treatment by the full-cell process using creosote served to compare treatability of the different wood species with aqueous and oil-based preservatives.

Materials and methods

Preservatives

Only the two internationally traded CCA brands are commercially available in Kenya, "Tanalith C" in a dry powder form and "Celcure P" as a soggy paste. Either brand was used according to availability and relative cost at the time of procurement.

In the case of the paste preservative, the whole content of the package, a 100 kg drum, was made up into a concentrated bulk solution. From the bulk solution appropriate portions were drawn and diluted to the required treatment solution. For the preservative in powder form, treatment solutions were directly obtained by dissolving exactly weighed amounts.

Wood samples

Roundwood poles were obtained initially in whole tree lengths. The wood species included *Acacia mearnsii, Casuarina equisetifolia* , *Eucalyptus camaldulensis* , *E.globulus* , *E. regnans* , *E.saligna, Pinus caribaea* and *P.patula.* They are all exotic or naturalized trees important in Kenya plantation forestry and rural afforestation. The selected trees had diameter of around 120 mm at breast height.

In the initial stages the pole specimens treated measured 1.5 m long. Later the length was increased to 2.0 m except for the trials on the effect of length in which the specimens were 6.0 m long. Each wood species was represented by at least sixty trees. Table 8 gives a summary of the various trials carried out.Whereas ideally treatment should commence immediately after tree felling, in practice some delay is inevitable especially when treatment is centralized. In this work all the treatment took place at Karura Forest Station, Nairobi. The various forest sources were located between 2 and 600 km away. Delivery period thus varied from less than one hour to two days. As a standard practice therefore, precautions were taken to hinder,if not stop, any moisture loss from the wood prior to commencement of treatment.

Immediately after felling and lopping the branches, each end of the stem was tightly sealed in a piece of moisture impervious sheet, either polythene or rubber. Whenever treatment could not commence on the day the trees had been felled, the whole of the fresh poles consignment was covered under tarpaulin.

Just prior to commencement of treatment, the bark was carefully stripped off, avoiding any bruising of the wood underneath, except in the particular trial purposely retaining the bark. Then fresh end surfaces were obtained by cutting off an end piece 0.5 m long. From some of the trees a 2 cm disk for density and moisture content determinations was cut adjacent to the fresh surface so produced. Basic density, calculated from oven dry mass and green volume, was measured by the water displacement method.

Sap replacement process control variables

Several trials were run to elucidate influence of the various factors described below. Except for the trials to compare solutions of different concentrations, all the experiments employed treatment solutions of four per cent solid preservative equivalent by weight.

Treatment solution concentration

This trial made use of preservative solutions at five different concentrations, between 2 and 10 per cent. The exact volume of solution to give gross preservative retention in the pole specimen equivalent to 12 kg m^{-3} was put in a 20-litre bucket.

Pole specimens from 20 trees per wood species were each placed standing upright on their butt ends in individual buckets. As only 10 buckets were available and every tree provided two poles, each run of the trial could have not more than five trees represented. To prevent solution losses by spurious evaporation, a polythene sheet covered the top of each bucket throughout the duration of the treatment.

The first run took place in an enclosed laboratory room where ventilation was available intermittently only during working days. This constrained exposure to evaporation proved inappropriate. In all subsequent treatments therefore the poles were treated while exposed to the open air.

Observation of the poles under treatment continued on daily basis until each pole had sucked up all the solution in the respective bucket. Some poles took up part of the solution before suction ceased. Such poles were regarded as untreatable. In calculating the average treatment time, the untreatable specimens were disregarded.

Bark influence

Two runs of the above experiment were carried out with an uniform solution but with half the number of poles having their bark still on. Each of the ten trees provided one specimen with bark and another without bark.

Pole length limitation and effect of turning over

Pole specimens 6.0 m long were stood upright in the treatment solution for a period of ten days. Twenty trees provided one pole each. While half the number of the poles remained undisturbed over the whole treatment period, the other half was turned upside-down on the seventh day. The latter poles were thus treated from both ends.

Pre-treatment delay

This trial served to show the effect of delay in commencing preservation treatment after the tree is felled. Fifteen trees provided three poles 2.0 m long each, one of which was treated immediately while the others were stored with their bark intact and suitably covered to minimize moisture loss. Treatment of the stored poles commenced at one week intervals. Distribution of the poles from the same tree to the three periods was random.

Standardised sap replacement process

Based on findings from the above trials, the final treatment process adopted lay within the following limits:-

i. Immediately after tree felling the poles had both ends suitably covered to limit moisture loss. For the same reason, the whole batch was wrapped in tarpaulin whenever treatment could not start on the same day.

ii. The poles were debarked just prior to starting the treatment.
iii. A fresh end surface was obtained by cutting away a short piece from each end at the commencement of the treatment process.
iv. Treatment solution of four per cent solids preservative concentration was contained in a purpose built tank with provision for poles to stand upright. The tank allowed immersion depth of up to 0.4 m.
v. During treatment the poles were fully exposed to the open air, but under shed to ward off rain water.
vi. The poles stood in the solution on butt ends for seven days, then they were turned to stand on their top ends for three additional days.

From each of the trees represented, another specimen was debarked and air-dried under an open-air shed for later treatment by pressure impregnation. Procurement of the poles and treatment by the sap replacement process continued over a period of more than one year.

Comparative treatments by pressure impregnation

The dried poles were divided into two equal lots to be treated with either creosote or CCA preservatives. The prolonged drying period gave rise to infection of the susceptible eucalypts by powderpost borers. As a result some of the trees, including the whole lot of *E. globulus*, had to be discarded to avoid misleading results.

In CCA treatment the process started with a vacuum of 0.15 MPa in the pressure tank, already filled with treatment solution, for 15 minutes. Then followed a positive pressure of 1.6 MPa for half an hour. After draining off the solution, a final vacuum same in magnitude and duration as the first completed the process.

The creosote treatment process employed a vacuum of 0.14 MPa for an hour prior to filling the pressure tank, followed by a positive pressure of 1.4 MPa for half an hour after filling the tank with the treatment solution at 63 ^{0}C. A final vacuum same in magnitude as the first for twenty minutes in the drained tank concluded the treatment.

All the wood species were included in each of the treatment charges so that they were all subjected to exactly the same impregnation conditions. Although pre-treatment drying periods varied according to the time of tree felling, all the poles had attained equilibrium moisture content.

Analyses

Both qualitative and quantitative methods were used to evaluate results of the different trials.

Qualitative analysis

Visual inspection of individual treated poles gave indication of the relative amounts of preservative absorbed. The inspection was made on surfaces made by cutting sections to expose internal wood. Such sections revealed the depth and uniformity of the preservative penetration. In the case of CCA preservation, a colour indicator (chrome azurol S) which turns blue in the presence of copper was applied to the cut surfaces. An arbitrary ranking scale based on depth of penetration and apparent uniformity of preservative distribution, extending between the extremes of very good and very poor, served to assess the comparative level of treatment effectiveness obtained in the wood.

Quantitative analyses

Retention, or the amount of preservative absorbed, was directly obtained in the case of creosote as the weight difference of individual poles measured immediately before and again after treatment. While the same method could conceivably be employed to assess retention of CCA preservatives in poles treated by pressure impregnation, it cannot serve for wood treated by the sap replacement method.

Retentions of CCA preservatives were measured by a lengthy process in which comminuted wood samples are subjected to solution extraction followed by determination of individual element concentration in the extract. A series of peripheral saw-cuts to a depth not more than 20 mm with a fine-toothed tenon saw produced the fine particles needed for extraction. Details of the sawdust extraction are explained by Williams (1970). Determination of the individual metal concentration in the resulting solution with AAS instrument was done as specified by the British Standards Institution (Anonymous 1974).

The sawdust samples were obtained from within 50 mm of nominal sampling distance along each pole. The most common region of sampling was the groundline, here taken as the distance equal to one fifth the pole length from its butt end.

Individual sawdust specimen from each sampling region on a treated pole supplied corresponding analytical solution extracts. After suitable dilution of the extract, concentrations of copper and chromium were read on an atomic absorption spectrophotometer. The AAS instrument available was not equipped to measure arsenic.

Due to the high expense the analysis entailed, sawdust samples were limited to a maximum of 20 poles for any one trial.

Results and discussion

Figures 1 and 2 show cross-sections of poles treated by sap-replacement and pressure impregnation. Some of the results reported below are in fair agreement with those by Plumptre (1964) on treatment of *Eucalyptus saligna*.

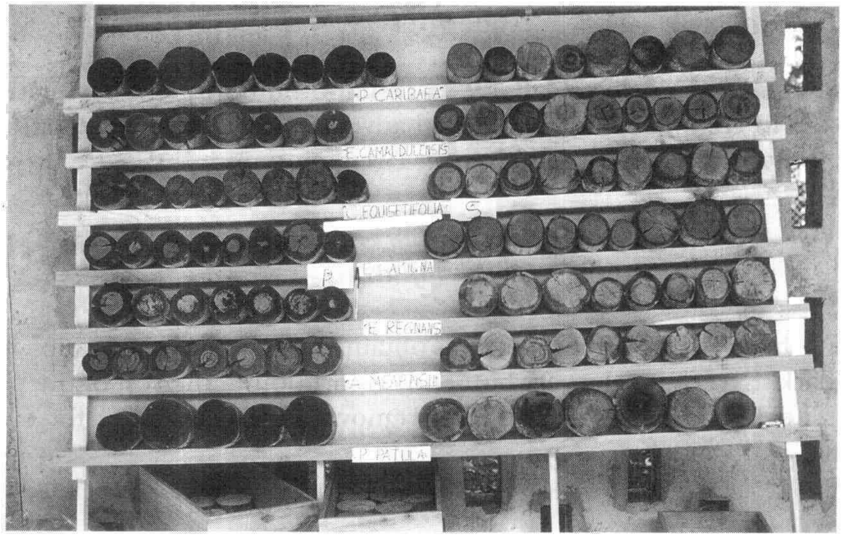

Figure 1. Cross-sections of poles treated by sap-replacement (right) and pressure impregnation (left). Near the middle of each row (species) is the best treated specimen of either method, followed immediately by the worst and so on paired

Figure 2. Close-up of the middle cross-section in Figure 1

Weather influence

Treatment in the enclosed laboratory room with intermittent ventilation took three weeks to complete. This compared adversely with a period of nine days in open air under shed. Exposure to free air circulation must therefore be regarded as essential.

Bark influence

Table 1 shows preservative retentions obtained in tree-matched poles, with and without bark. Except for the very butt-end, absorption in the rest of the pole with bark was negligible. So evidently bark removal is also essential for successful treatment.

Table 1. Effect of removing bark on treatability by sap replacement, average of 10 poles

Wood species	Height from butt (m)	Retention % weight			
		With bark		Without bark	
		Copper	Chromium	Copper	Chromium
Eucalyptus saligna	0.4	0.01	0.19	0.34	1.13
	1.0	0.00	0.02	0.14	0.30
Acacia mearnsii	0.4	0.02	0.11	0.15	0.68
	1.0	0.00	0.03	0.07	0.48

Treatment solution concentration

Tables 2 and 3 summarize the results of treatment with preservative solutions at different concentrations.

According to Table 2 it appears that, except for duration of treatment, the various solution strengths gave more or less equally good results. Results of qualitative analysis, as given in Table 3, however, reveal that dilute solutions tend to give more uniform preservative penetration and distribution. Combined results in Tables 2 and 3 lead to the conclusion that optimum concentration lies somewhere above 2 but below 10%. But many more trials would be needed to narrow down this range.

Table 2. Preservative retentions at ground-line and near top end of poles treated with solutions of different concentrations

Solution concentration (%)	Treatment time (days)	Copper retention (% weight)		Chromium retention (% weight)	
		Ground-line	Top-end	Ground-line	Top-end
2	17	1.1	0.07	1.6	0.34
3	9	1.0	0.11	1.4	0.16
4	9	1.1	0.09	1.6	0.17
6	5	1.2	0.13	1.9	0.19
10	3	1.0	0.07	1.9	0.19

Table 3. Treatment effectiveness as determined by visual assessment of preservative penetration and distribution

Solution concentration	Sample treatability rank distribution %							
	At Ground-line				At Top-end			
%	Very good	Good	Poor	Very poor	Very good	Good	Poor	Very poor
2	100	0	0	0	0	0	100	0
3	67	33	0	0	0	0	75	25
4	75	17	8	0	0	8	50	42
6	67	33	0	0	8	8	75	8
10	27	73	0	0	0	9	45	45

Pre-treatment delay

As shown in Table 4 the measures taken to limit moisture loss prior to treatment proved quite effective. In the first week the average moisture content, measured by oven dry method, dropped from 96 to 89% and remained virtually constant for the whole of the second week. Clearly a delay of one week, despite the small loss of moisture, had very little effect on treatability.

A point to note at this stage is the treatability variation inherent between trees. Poles from one tree in this trial were consistently untreatable. The treatability of all the trees tended to decrease with time even when moisture content remained unchanged.

Table 4. Influence of delay in treating pole after tree felling on treatability of *Eucalyptus saligna*, average period of treatable poles only

Delay (weeks)	Moisture content (%)	Sample poles		Treatment period	
		Total number	Untreatable number	Average (days)	Range (days)
0	96	15	1	7	4 - 12
1	89	15	1	7	5 - 13
2	89	15	6	9	6 - 18

Influence of pole length

In all those poles treated from the butt end only, preservative absorption near the top end was invariably little irrespective of the pole length. Ground-line retentions of the 6.0 m poles, i.e. at 1.2 m height, compared favourably with ground-line retentions of the shorter poles at 0.4 m. This inference was drawn from examination of specimens, the analytical results of which are summarized in Tables 5, 6 and 7. The top halves of the long poles, however, had hardly any trace of the preservative.

Table 5. Preservative retention increase at the top end, 5.0 m from butt end, as a result of turning over the poles during treatment

Treatment	Average retention (% weight)	
	Copper	Chromium
Turned over	0.34	0.41
Upright only	0.03	0.16

Effect of pole turning over

As shown in Table 5 the poles which were treated from both ends acquired much higher preservative retentions at the pole tops. Like debarking, therefore, turning over the poles can be regarded as quite a necessary part of the treatment process. Obviously the region of minimum retention shifts then to somewhere near the mid-length of the pole.

Role of transpiration stream

There exists a general presumption that sap replacement treatment exploits the mechanism of transpiration previously operative in the living stem. On this basis solution absorption should be enhanced by retention of foliage, a practice not without its advocates but certainly of limited practicability.

If the transpiration forces were significantly at play, then there would be no difficulty in treating poles with their bark intact. On the contrary, as found earlier, such poles are just not treatable. The effective mechanism on which the treatment relies seems largely to be simple evaporation from the whole exposed wood surface.

Treatability of different wood species

Table 6 summarizes results of the various quantitative analyses of poles treated by both the sap replacement method and pressure impregnation, including

Table 6. Preservative retention obtained by sap replacement treatment compared with pressure impregnation, average of 20 poles

Wood species	Pole-tree overbark diameter (mm)	Green moisture content (%)	Basic density ($kg\ m^{-3}$)	Creosote gross retention ($kg\ m^{-3}$)	Ground-line retention (% weight)			
					Sap replacement		Presure process	
					Copper	Chromium	Copper	Chromium
Acacia mearnsii	112	52	530	32	0.13	0.53	0.11	0.67
Casuarina equisetifolia	118	65	670	66	0.23	0.31	0.13	0.66
Eucalyptus camaldulensis	124	96	550	151	0.26	0.31	0.20	0.93
E.globulus	125	78	630	-	0.39	1.90	-	-
E.regnans	127	168	390	10	0.80	0.86	0.36	1.86
E.saligna	126	121	440	121	0.28	0.68	0.27	1.34
Pinus caribaea	147	132	400	306	0.27	0.44	0.36	1.69
P.patula	146	142	390	296	0.21	0.85	0.32	1.54

impregnation with creosote-oil preservative. From the table the following conclusions can be drawn:

(i) Based on copper retentions at the ground-line, the hardwoods were as treatable by sap-replacement as by pressure impregnation. The pine poles treated by sap replacement gave poorer retentions than those treated by pressure impregnation.

(ii) Within each of the two poles categories, hardwood or softwood, sorting in order of preservative retention yields identical rank for either treatment, sap replacement or pressure impregnation.

(iii) At the ground-line, chromium retention remained invariably lower in sap replacement poles than in pressure impregnated ones. Although chromium is not among the toxic ingredients of the preservative, this observation reveals component disproportioning of the preservative along the treated pole and so corresponding variation in preservative effectiveness, quite apart from retention per se.

(iv) Neither wood density nor green moisture content seemed to correlate with treatability.

(v) Within the hardwood group, the relative retentions of creosote bear no direct relation with CCA retentions. The behaviour of *Eucalyptus regnans*, in particular, seems inexplicably odd, being the most treatable species with CCA but virtually untreatable with creosote oil.

Not discernible from Table 6, but quite visible in Figures 1 and 2, are the following additional results from both quantitative and qualitative analyses:-

(vi) Within a species, poles from different trees have different treatability. The variation gets more pronounced with sap replacement treatment and with overall species treatability. Thus while most poles of *Acacia mearnsii* treat very poorly, an occasional specimen treats quite well.

(vii) Even for the most treatable wood species by sap replacement, only the outer sapwood consistently showed presence of preservative. In all specimens the inner sapwood and the whole of heartwood had little or none. This peripheral migration tendency was observed by Baechler and Roth (1964) and also by Johnstone and Blau (1970) even when the treatment included pressure application. For the lesser treatable specimens, the band of treated outer sapwood was at some places quite thin or even discontinuous. Preservative distribution elsewhere in the pole was invariably patchy and erratic.

Effectiveness compared with pressure impregnation

As shown above, preservation by the sap replacement method does on the average result in preservative retentions comparable with treatment by pressure methods, at least up to the ground-line region. Variability of preservative absorption between trees and ditribution within a pole is such that the method is not an

Table 7. Preservative retention measured at different heights of poles treated from butt end only, average of 15 poles

Wood species	Height (m)	Preservative retention, % weight	
		Copper	Chromium
	1.2	0.48	0.65
Eucalyptus saligna	3.0	0.05	0.20
	5.0	0.01	0.06
	1.2	0.19	0.26
Acacia mearnsii	3.0	0.05	0.12
	5.0	0.01	0.01

Table 8. Summary of preservation trials carried out

Observation purpose	Wood species number	Pole length (m)	Poles analysed per species	Solution strength (%)	Height positions analysed (m)
Effect of solution concentration	1	1.5	59	2-10	0.3, 1.04
Influence of bark	2	2.0	10	4	0.4, 1.0
Effect of pole length	2	6.0	15	4	1.2, 3.0, 5.0
Effect of immersing other end	1	6.0	20	4	5.0
Effect of pre-treatment delay	1	2.0		4	
Treatability with CCA: by sap-replacement	8	2.0	20	4	0.4
Treatability with CCA: by full-cell process	7	2.0	20	4	0.4
Treatability with creosote: by full-cell process	7	2.0			

equal substitute. Furthermore there is always the likelihood of pole splitting in the course of subsequent drying, with concomitant risk of the untreated wood deeper than the treated peripheral crust becoming exposed.

Since preservative retention tails off from the absorption end, even where the pole is turned over there must be a maximum length beyond which retention at the middle would be inadequate. This length was not purposely determined but the results suggest it to lie bewteen 3 and 4 metres. Thus the method seems most suitable for such commodities like fence posts and short building poles.

As to service performance of the treated wood, fence posts of *Eucalyptus saligna* have been observed to remain serviceable beyond fifteen years under the same conditions that cause failure of all similar but untreated poles by the sixth year. The beneficial effects of the treatment can therefore not be doubted.

Conclusions

The sap replacement preservation process as described here works only with debarked poles exposed to circulating air suitable for extended evaporation from the wood surface.

Preservative retention diminishes with distance from the end immersed in solution so that immersion of the other end is a beneficial part of the treatment. This behaviour limits the length of pole which can adequately be treated.

Provided precautionary measures are taken to limit moisture loss from the wood, treatment can be delayed for up to about one week.

Successful treatment depends on the wood species but variation between trees is such that even with generally untreatable species, occasional trees treat quite well.

The method is less effective than pressure impregnation, because even with comparable retentions, preservative distribution within the wood is not as uniform, being largely confined to outer sapwood. There also results in disproportioning of the preservative components along the pole.

Comparative species treatability with CCA followed the same trend whether treatment was by sap replacement or pressure impregnation. This trend differed from that obtained when the wood was preserved with creosote.

Despite the risk of exposed untreated wood exposure as a result of splitting after treatment by sap replacement, service life of treated poles far exceeds that of comparable untreated poles.

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