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VEGETATIVE PROPAGATION OF *MILICIA EXCELSA* BY LEAFY STEM CUTTINGS: EFFECTS OF MATURATION, COPPICING, CUTTING LENGTH AND POSITION ON ROOTING ABILITY

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OFORI, D., NEWTON, A.C., LEAKEY, R.R.B. & GRACE, J. 1997. Vegetative propagation of *Milicia excelsa* by leafy stem cuttings: effects of maturation, coppicing, cutting length and position on rooting ability. The effects of stockplant age, coppicing, cutting stem length and node position on the rooting ability of leafy stem cuttings of *Milicia excelsa* Welw. were investigated using a non-mist propagation system in Ghana. Four separate experiments tested respectively: (i) cuttings obtained from 1-, 2-, 10- and 20-year-old trees, (ii) cuttings from coppice shoots of 1-, 4- and 20-year-old trees, (iii) five length treatments: 3, 6, 9, 12 and 15 cm, and (iv) different node positions. In each experiment, cuttings were treated with IBA and leaf areas were reduced to 20 cm^2 prior to insertion. Rooting percentages of 65.0% and 11.7% were recorded in 1- and 2-year-old seedlings respectively, while 0% cuttings from 10- and 20-year-old trees rooted. Mortality of cuttings from mature trees was associated with leaf abscission, attributed to the onset of senescence. Rooting ability of mature trees was restored by coppicing, although rooting percentage of cuttings from coppice shoots was still negatively correlated with age of the ortet ($r = 0.93$, $p < 0.05$). No significant effect of cutting length on rooting percentage was recorded, although there was a marked positive correlation between length and shoot production

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(r = 0.92, p < 0.05). Cutting length was negatively correlated with foliar relative water content (RWC) (r = 0.94, p < 0.05). Rooting percentage declined basipetally as a result of increased leaf abscission and lower values of RWC at lower node positions. The practical implications of these findings are discussed.

Key words: Vegetative propagation - rooting physiology - IBA - propagation medium - leaf area

OFORI, D., NEWTON, A.C., LEAKEY, R.R.B. & GRACE, J. 1997. Pembiakan tampang *Milicia excelsa* melalui keratan batang berdaun lebat: kesan pematangan, pengkopisan, panjang dan kedudukan tebangan terhadap keupayaan pengakaran. Kajian mengenai kesan umur tanaman stok, pengkopisan, panjang keratan batang dan kedudukan buku terhadap keupayaan pengakaran keratan batang berdaun lebat *Milicia excelsa* Welw. menggunakan sistem pembiakan tidak berkabus di Ghana. Ujian dijalankan secara berasingan iaitu: (i) keratan pokok berumur 1-, 2-, 10- dan 20 tahun, (ii) keratan pucuk kopis pokok berumur 1-, 4- dan 20 tahun, (iii) rawatan panjang bagi: 3, 6, 9, 12 dan 15 cm, dan (iv) kedudukan buku yang berbeza. Keratan dalam setiap ujian dirawat dengan IBA dan luas daun dikurangkan kepada 20 cm^2 yang disisip terlebih dahulu. Peratus pengakaran 65.0% dan 11.7% dicatatkan dalam biji benih berumur 1- dan 2- tahun, masing-masing manakala 0% keratan dari pokok berumur 10- dan 20 tahun didapati mengakar. Kematian keratan dari pokok matang berkaitan dengan absis daun akibat daripada permulaan proses penuaan. Keupayaan pengakaran keratan pucuk kopis berkaitan secara negatif dengan umur ortet (r=0.93, p<0.05). Tiada kesan penting dicatatkan mengenai panjang keratan ke atas peratus pengakaran walaupun terdapat perkaitan positif antara panjang dan pengeluaran pucuk (r = 0.92, p < 0.05). Panjang keratan berkaitan secara negatif dengan relatif kandungan air daun (RWC) (r = 0.94, p< 0.05). Peratus pengakaran merosot disebabkan oleh pertambahan absis daun dan kejatuhan nilai RWC pada posisi buku yang lebih rendah. Implikasi praktikal penemuan ini dibincangkan.

Introduction

Milicia excelsa [formerly known as *Chlorophora excelsa* (Welw.) Benth. & Hook.; trade name Iroko] is a commercially important timber species of West, Central and East Africa. At present, timber of this species is largely obtained from natural forest as few commercial plantations have been established. The main factor restricting cultivation of this species is its susceptibility to the gall forming insect *Phytolyma data* Walker, which deforms the shoot apex and stunts the growth of the tree. Studies at the Forestry Research Institute of Ghana have indicated that some resistance to the pest exists within natural populations of the species (Cobbinah 1990). To exploit this genetic variation and develop pest-resistant cultivars, the development of vegetative propagation techniques is required. Although *M. excelsa* has previously been successfully propagated vegetatively (Leakey *et al.* 1982), no information is currently available on the factors influencing rooting ability in this species.

Several studies have demonstrated that the ease of adventitious root formation in stem cuttings declines with the age of the ortet (Hartmann *et al.* 1990). This is an important problem because desirable phenotypic characteristics are generally not expressed until a plant has reached a considerable size or maturity. The loss of rooting ability with age potentially may be overcome by coppicing or regular pruning, since cuttings from coppice shoots generally root more readily than cuttings from mature trees (Leakey *et al.* 1982, Leakey 1983).

In propagation studies with a range of tree species, rooting has been found to be positively correlated with cutting length (Leakey 1983, Leakey & Mohammed 1985). This has been attributed to the fact that longer cuttings have larger reserves of carbohydrates and mineral nutrients, which are required for root development (Hoad & Leakey 1992). It has also been shown that in many plant species, cuttings taken from different positions within a shoot differ in their rooting ability (Hartmann *et al.* 1990). For example, cuttings originating from the upper portions of shoots of *Triplochiton scleroxylon* (Leakey 1983) and *Lovoa trichilioides* (Tchoundjeu 1989) displayed higher rooting abilities than those from lower positions, while the reverse was observed in *Khaya ivorensis* (Tchoundjeu 1989).

This paper describes four separate experiments which were undertaken with leafy stem cuttings of *M. excelsa*. The aims were (i) to define whether or not the age of the ortet has any influence on rooting, (ii) to compare the rooting ability of cuttings from coppice shoots from trees of different age, (iii) to determine the optimum cutting length for rooting, and (iv) to assess the influence of cutting position within the shoot on rooting ability. These experiments were also designed to test the suitability of a low technology non-mist system (Leakey *et al.* 1990) for the propagation of this species.

Materials and methods

Low technology non-mist propagators were constructed following the design described by Leakey *et al.* (1990), at the Mesawam Research Centre of the Forestry Research Institute of Ghana (FORIG), Kumasi (annual rainfall 1520 mm, altitude 300 m). The propagators were constructed from a wooden frame enclosed in clear polythene so that the base was watertight and were filled with water to a depth of 5 cm below the surface of the rooting medium. The dimensions of the propagators used in this investigation were 212 × 110 × 50 cm (length × width × height). The propagators were positioned under a shade screen (85% light interception). Whenever the propagators were opened, the cuttings were sprayed with a fine jet of water from a knapsack sprayer.

The rooting medium used in Experiments I and 2 was coarse sand (approximately 2-3 mm diameter), obtained by sieving river sand. The medium was treated three days prior to the beginning of the experiment with fungicide (Dithane M.45, Rohm and Haas, France S.A.) at a concentration of 25 g in 10 litres of water, and insecticide (Cymbush 10 EC, Imperial Chemical Industries Plc, Plant Protection Division, Fernhurst, Haslemers, Surrey, UK), at a concentration of 5.79 ml in 10 litres of water. In Experiments 3 and 4, the rooting medium used was sawdust (composted for six years), treated in the same way.

A mercury thermometer was inserted into the rooting medium to a depth of 1-2 cm to measure the propagator bed temperature. Air temperature and humidity within the propagators were also measured using a portable thermohygrometer (HYT-705-010G, Gallenkamp Express, Loughborough, UK). All measurements were taken daily between 1230 h and 1400 h throughout the experiments.

Experiment 1. Effect of age of the ortet on rooting ability

Cuttings were obtained from the dominant shoots of 1-y-old seedlings and from the crowns of trees of 2, 10 and 20 years of age, grown at the Mesawam nursery, Kumasi, Ghana. All plant materials were of local origin. The selected shoots were cut between 0600 h and 0700 h, misted with water from a knapsack sprayer and stored in polythene bags for not more than 20 min prior to propagation. The shoots were severed into cuttings of 6 cm length, and foliage was removed, leaving only one fully expanded leaf at the uppermost node. This leaf was then trimmed to an area of approximately 20 cm^2 using a paper template measured with a leaf area meter (Delta-T Devices, Burwell, Cambridgeshire, UK). The stem bases of the cuttings were dipped into a rooting powder ('Seradix No.2' with 0.8% IBA, May and Baker Ltd. Dagenham, UK) prior to insertion in the non-mist propagator.

A total of 240 cuttings (60 cuttings per treatment) were taken, and inserted in 6 randomised blocks, with 10 cuttings per treatment per block. Cuttings were assessed weekly for the presence of roots (> 2 mm length), number of roots (> 2 mm length), cutting mortality, leaf shedding and production of new shoots. Five cuttings per treatment were randomly sampled from the propagation bed at week 2 for the determination of foliar relative water content (RWC), determined as (F-D) / (T-D) x 100%, where F = fresh mass, D = dry mass (taken after drying in an oven at 80 °C for 48 h), T = turgid mass (taken after floating the leaf on water for 24 h). The mass of the samples was determined using an electronic balance (Precision standard electronic balance, TS120S, Ohaus Europe Ltd. UK).

Experiment 2. Comparison of the rooting ability of coppice shoots from trees of different ages

Fifteen 1-y-old seedlings and ten 4-y-old saplings were pruned to stumps of 10 cm height. At the same time, six mature trees (20-y-old) were felled for the production of coppice shoots, leaving stumps of 40 cm height. The shoots were allowed to grow for nine weeks before harvesting for propagation. The cuttings were prepared as described in Experiment 1. A total of 134 cuttings were taken, of which 43 were derived from 1-y-old seedlings, 41 from coppice shoots of 4-y-old saplings, and 50 from coppice shoots of 20-y-old trees. The cuttings were then inserted in six randomised blocks in the non-mist propagator and assessed as described in Experiment 1, although root number was not assessed in this experiment.

Experiment 3. Effect of cutting length on rooting ability

Four weeks after germination, seedlings from four seedlots were potted into black polythene bags (10 cm height x 8 cm width) containing sandy loam collected from underneath a 20-y-old stand of *M. excelsa* at Mesawam, Kumasi. The seedlings were cut back to stumps of 5 cm height at one year of age, and repotted into larger black polythene bags (30 cm height x 25 cm width) containing soil from the same site. The plants were then transferred to a nearby nursery area and maintained under shade (35 - 45% full sunlight) provided by green palm fronds, placed at a height of 2.5 m above the ground. The plants received natural rainfall, supplemented by daily watering to field capacity when there was no rain for two days, and received weekly applications of foliar fertiliser (11.25 g of Grofol; 8.1N: 1.3P: 2.5K in 10 litres of water; Agrofarma Mexicana, S. A. de C. V. Mexico), applied in place of normal watering. The stockplants were repeatedly cut back to 5 cm stumps and a maximum of three shoots were allowed to grow on each stump.

Shoots were harvested 10 weeks after sprouting, from stockplants which had been watered to field capacity the previous evening. Shoots were cut between 0600 h and 0700 h, misted and stored as described in Experiment 1. Shoots from each of the four seedlots were randomly allocated to each of five length treatments: 3, 6, 9, 12 and 15 cm. The apical 2-3 cm portion of each stem was discarded, as a preliminary experiment had indicated that such material rapidly died during propagation. Leaf area of each cutting was reduced to 20 cm^2 as described in Experiment 1. Immediately prior to insertion, 10 µl of a solution of 0.2% IBA in industrial methylated spirit (IMS) was applied to the base of each cutting using a micropipette, then dried off by placing the cutting base in a stream of air from a fan (following Leakey *et al.* 1982). A total of 270 cuttings, 54 cuttings per treatment, were inserted in 9 randomised blocks, each block containing 30 cuttings (5 treatments x 6 cuttings). Cuttings were assessed weekly as described in Experiment 1. Besides the 270 cuttings used for the rooting assessments, 5 cuttings per treatment were inserted separately and removed from the propagator at week 2, for the determination of RWC as described above.

Experiment 4. Effect of cutting position within a shoot on rooting ability

Eighteen-month-old seedlings, planted out at the Mesawam nursery (1 × 1 m spacing) were cut back to 10 cm stump heights, and a maximum of three shoots were allowed to grow on each stump. The coppice shoots were harvested for propagation after nine weeks regrowth. Cuttings of 6 cm length were taken sequentially along each shoot, discarding the terminal softwood portions, and the position of each cutting in the shoot was noted. Three to five cuttings were obtained from each shoot, depending upon their lengths, giving a total of 516 cuttings. Varying numbers of cuttings were obtained from the different cutting positions, which were labelled 1 (apical) to 5 (basal). The cuttings were prepared as described in Experiment 3, and arranged in 10 randomised blocks. Weekly rooting assessments were carried out as described in Experiment 1. Five cuttings were sampled from each treatment at time of insertion, and ten days afterwards, for the determination of RWC.

Data in each experiment were analysed by calculating standard errors and confidence limits following Snedecor and Cochran (1980). In addition, rooting percentages were arcsin transformed prior to analysis of variance using SAS (1980). Normally distributed data were analysed using *t*-tests or analysis of variance where appropriate (Snedecor & Cochran 1980). Cuttings were defined as 'dead' when either shrivelled or severely rotted. Percentage leaf abscission and rooting were calculated on the original number of cuttings.

Results

The relative humidity inside the propagators ranged from 72.4 to 100%, with mean values generally over 90%. However, values in Experiment 3 were relatively low, probably resulting from the relatively high propagator air temperatures recorded during this experiment (Table 1). Mean temperature of the propagation medium was more than 2 °C lower in Experiment 1 than in the other three experiments, and was associated with relatively low air temperatures recorded both inside and outside the propagators. Mean irradiance varied markedly between experiments, ranging from 778 to1788 lux (Experiments 3 and 2 respectively) inside the propagators (Table 1), although this variation was apparently not related to differences in temperature and humidity between experiments.

Experiment 1

Cuttings taken from the 1-y-old stockplants rooted more rapidly and reached a higher rooting percentage than those from the 2-y-old stockplants. At the end of the experiment, 65.0% and 11.7% of cuttings had rooted from the 1- and 2-y-old seedlings respectively, while none of those from the 10- and 20-y-old trees had rooted (Figure 1a). The effect of treatment on final rooting percentage was highly significant overall ($p < 0.001$, ANOVA). The mean number of roots per rooted cutting was also significantly ($p < 0.05$) higher in cuttings from 1-y-old than 2-y-old stockplants (Figure 1c). Mortality of cuttings obtained from 10- and 20-y-old trees reached 100% by the third week after propagation, while those of 1 and 2-y-old stockplants were 33.3% and 88.3% respectively at the end of the experiment (Figure 1b). All the leaves of cuttings obtained from 10- and 20-y-old trees had abscised by the end of the third week, while those from 1- and 2-y-old stockplants abscised 48.3% and 88.3% of their leaves respectively by the end of the experiment. No significant treatment differences in RWC were recorded (Table 2).

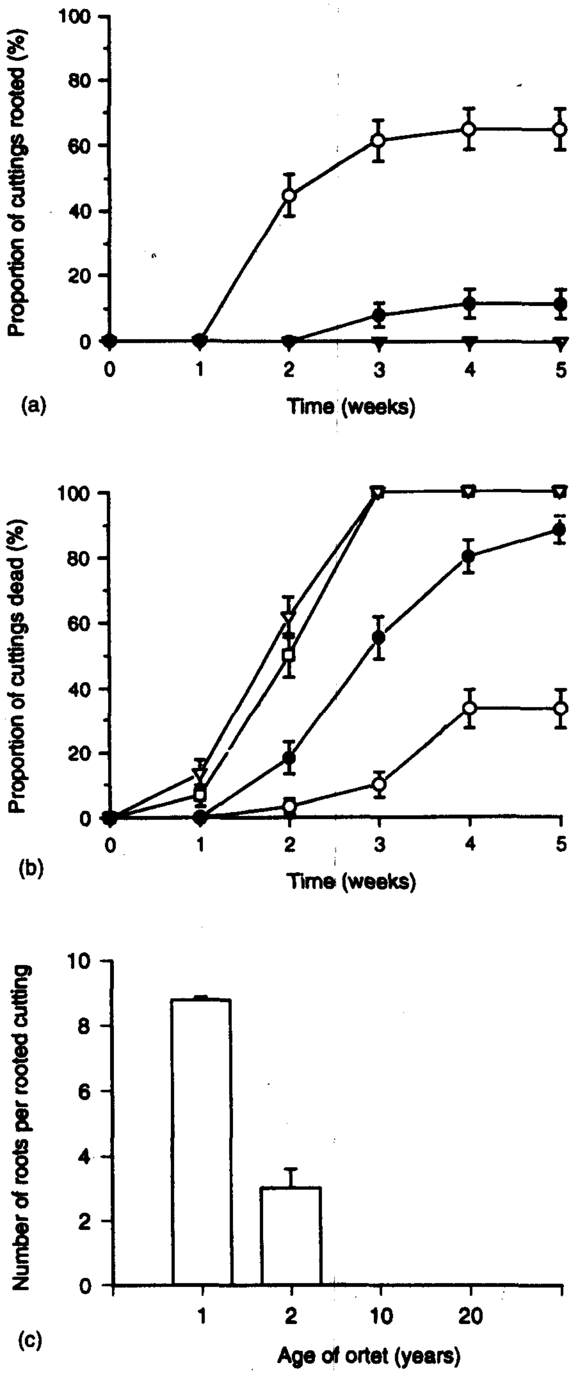

Figure 1. Effect of age of ortet on (a) percentage rooting, (b) percentage mortality and (c) number of roots of *Milicia excelsa* cuttings in a non-mist propagation system o : 1-y-old; stockplant; ●: 2-y-old ; ▽ : 10-y-old; □ : 20-y-old). Values presented are means (n = 60) + SE. Untransformed mean and error values are given although percentages were arcsin transformed for separate ANOVA analysis to assess treatment differences (see text).

Experiment 2

Cuttings from the 1-y-old seedlings displayed the highest rate and final percentage of rooting (Figure 2a). Rooting ability tended to decline with increasing age of the ortet: a negative correlation (r = - 0.93) was observed between age of the donor tree and rooting percentage. The effect of treatment on final rooting percentage was highly significant overall (p = 0.036), although no significant differences in rooting were observed between cuttings from the 4-y-old and those of 1- and 20-y-old stockplants (Figure 2a). Mortality of the cuttings taken from the 1-y-old seedlings was significantly lower than in the other treatments from week 2 onwards (Figure 2b). In addition, a higher proportion of cuttings obtained from 4- and 20-y-old stockplants abscised their leaves than those from 1-y-old stockplants (53.6% and 74.0% versus 37.2% respectively), although this difference was not significant (p > 0.05).

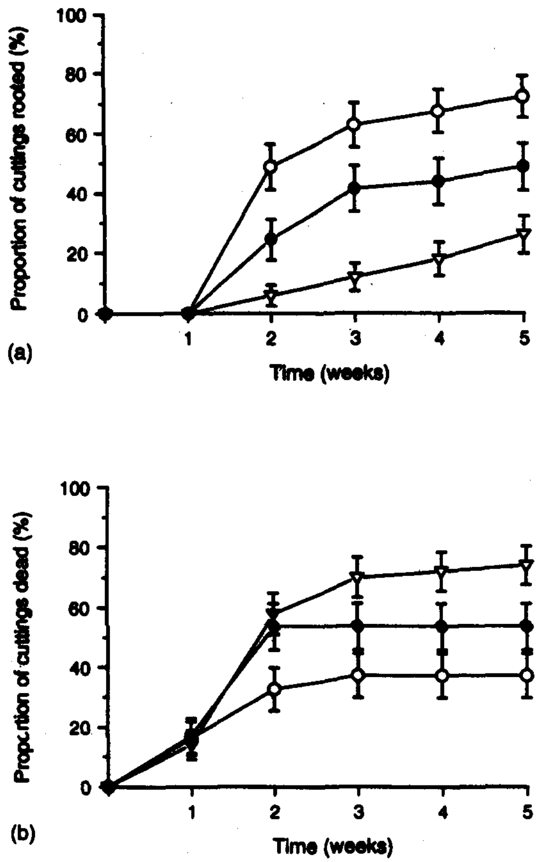

Figure 2. Effect of coppicing trees of different age on (a) percentage rooting, and (b) percentage mortality of *M. excelsa* cuttings. (o : 1-y-old stockplant, ● : 4-y-old, ▽: 20-y-old). Values presented are means (n_1, = 43, n_4 = 41, n_{20} = 50) + SE (see caption to Figure 1).

Table 1. Microclimate of non-mist propagation system, during four propagation experiments with *Milicia excelsa*

	Experiment 1		Experiment 2		Experiment 3		Experiment 4	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Relative humidity (%)								
Inside propagator	95.7	91.4 - 100	91.7	89.7 - 98.2	85.9	72.4 - 93.5	92.4	84.2 - 100
Outside propagator	78.1	65.6 - 87.5	76.9	64.8 - 87.3	51.9	36.8 - 72.4	68.5	56.6 - 78.6
Air temperature (°C)								
Inside propagator	26.7	24.0 - 27.8	29.7	26.0 - 30.6	31.7	29.5 - 34.0	30.7	28.4 - 32.7
Outside propagator	26.4	24.5 - 28.9	28.5	28.2 - 30.5	30.0	27.9 - 33.6	27.4	25.5 - 31.5
Temperature (°C) of medium	24.9	23.5 - 27.0	27.8	27.0 - 29.0	27.8	25.0 - 30.0	27.0	25.0 - 29.0
Irradiance (lux)								
Inside propagator	1238	300 - 2500	1788	550 - 2645	778	300 - 2500	893	570 - 1600
Outside propagator	5213	3600 - 5800	5304	3589 - 5824	5213	3600 - 5800	5600	5215 - 5900

Table 2. Effect of propagation treatment on foliar relative water content (RWC)

Experiment 1		Experiment 3		Experiment 4	
Tree age (y)	RWC (%)	Cutting lengths (cm)	RWC (%)	Cutting position	RWC (%)
1	91.1a	3	90.0a	1	72.5a
2	92.3a	6	88.0ab	2	72.0a
10	91.5a	9	88.0ab	3	70.4ab
20	94.5a	12	86.4ab	4	62.0b
		15	82.3b		

Means in a column grouped by the same letters are not significantly different ($p \geq 0.05$). Experiments 1 and 3, values obtained 14 days after insertion; Experiment 4, values obtained 10 days after insertion; cutting position 1 = apex, 5 = base. No values obtained in Experiment 2, $n \geq = 5$ in each case.

Experiment 3

No significant differences ($p > 0.05$, ANOVA) in percentage rooting were observed among the different cutting lengths at week 5, although rooting percentage tended to decline with increasing cutting length (Figure 3a). The mean number of roots per rooted cutting followed the same trend, with a significantly lower number of roots formed in cuttings of 15 cm than 3 cm length (Figure 3c). Cutting mortality tended to increase with increasing cutting length, even though no statistical differences ($p > 0.05$) were observed between the various treatments (Figure 3b). The percentage leaf abscission of 12 cm cuttings was significantly higher than those of 6 cm and 9 cm length (53.1% versus 18.4% and 22.5% respectively), but was not different from those of 3 cm and 15 cm (30.6% and 30.0% respectively). The percentage of cuttings which produced shoots during propagation showed a strong positive correlation with length ($r = 0.92$, $p < 0.05$) at week 5. Values from the 9 cm, 12 cm and 15 cm cuttings were significantly higher than the 3 cm and 6 cm treatments (64.8%, 73.6% and 69.8% versus 10.2% and 31.4% respectively). The percentage sprouting at week 4 was negatively correlated with percentage rooting on the same date ($r = 0.90$, $p < 0.05$). A strong negative correlation ($r = 0.94$, $p < 0.05$) was observed between cutting length and foliar RWC determined at week 2 (Figure 4), the value from the 3 cm treatment being significantly higher than the 15 cm treatment (90.0% versus 82.3% respectively, $p < 0.05$) (Table 2).

Experiment 4

The position of origin of the cuttings had a substantial effect on rooting ability, with the highest rooting percentage occurring in cuttings from apical positions 1 and 2, and the lowest in cuttings from basal position 5 (Figure 5a). Although the mean number of roots per rooted cutting tended to increase basipetally, ranging from 23.9 ± 1.5 (position 1) to 32.6 ± 4.0 (position 5) at the end of the experiment, no significant differences between treatments were recorded (Figure 5c). Similarly, the mean root dry mass did not differ significantly between treatments, values ranging from 0.01 to 0.02 g at week 4. Percentage mortality of cuttings from position 5 was significantly ($p < 0.05$) higher than those of positions 1 and 2, reaching a maximum of 38.7% after four weeks, but did not differ significantly from those of positions 3 and 4 (Figure 5b). The percentage leaf abscission was significantly ($p < 0.05$) influenced by the position of the cuttings within the shoot, values decreasing acropetally, such that cuttings from positions 1 and 2 (16.5% in both cases) were significantly lower than values from positions 4 and 5 (33.3% and 48.4% respectively). No statistical differences ($p > 0.05$) in foliar RWC were recorded between the treatments at day 0 (Table 2). However, the mean RWC of cuttings from position 4 was significantly ($p < 0.05$) lower than those from positions 1 and 2 at day 10 (62.0% versus 72.5% and 72.0% respectively).

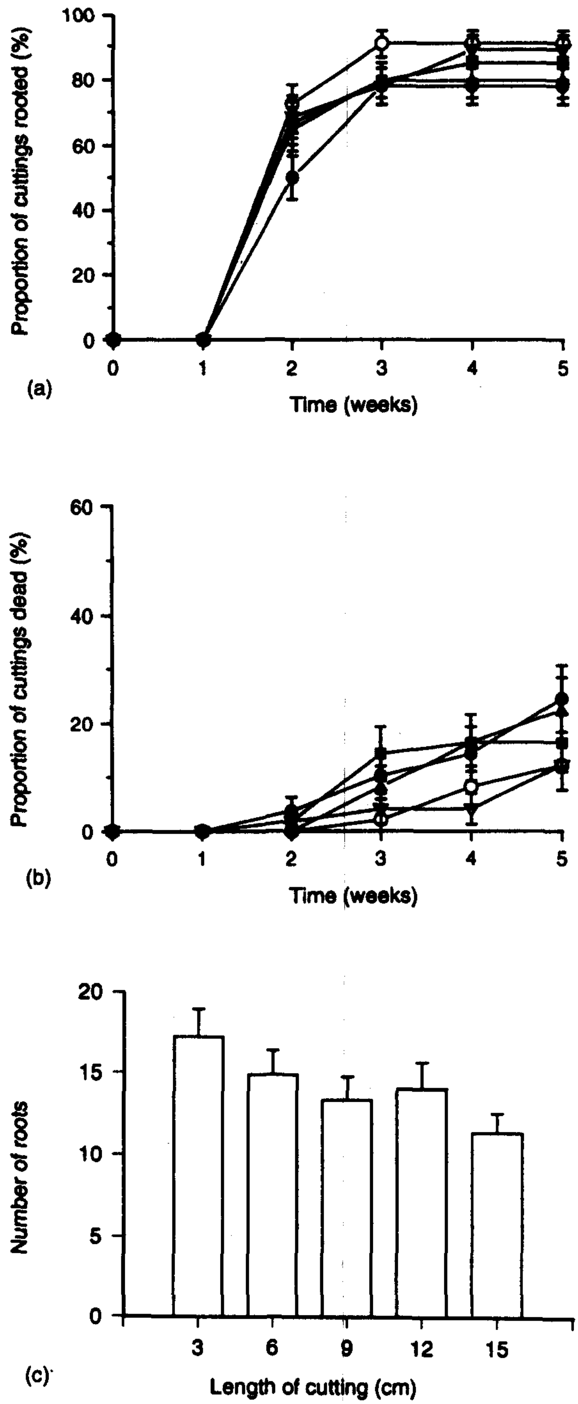

Figure 3. Effect of different cutting lengths on (a) percentage rooting, (b) percentage mortality and (c) number of roots of *M. excelsa* cuttings. (o : 3 cm, ∇: 6 cm, ■ : 9 cm, ▲ : 12 cm, ● : 15 cm). Values presented are means (n = 54) + SE (see caption to Figure 1).

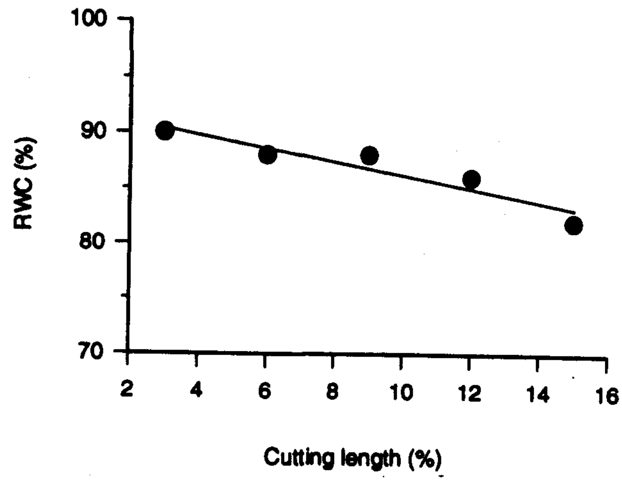

Figure 4. The relationship between cutting length and foliar relative water content (RWC%) at the fifth week after insertion ($y = 92.2 - 0.6 x$, $r = 0.94$, $p = 0.018$)

Discussion

Ease of adventitious root formation generally declines with the age of the ortet (Raviv *et al.* 1987). In this study, rooting of *M. excelsa* cuttings declined in terms of speed of rooting, rooting percentage and the number of roots per rooted cutting, as the donor trees became older and larger. This implies that by the time individuals which are genetically resistant to the *Phytolyma lata* gall attack can be identified, they may have lost their rooting ability. The reasons for the higher rooting ability of juvenile versus older material are not fully understood (Leakey *et al.* 1992). Contributory factors may be a reduction in the supply of endogenous auxin, carbohydrate or nitrogenous substances, or a decline in meristematic activity (Hartmann *et al.* 1990) with increasing tree age. Increasing sclerification as the tree ages may also be influential (Davies 1983). The higher percentage mortality recorded in the mature cuttings in this investigation was associated with higher percentage leaf abscission. As no effect of preharvest position in the parent shoot on RWC was observed, abscission was apparently a result of leaf senescence rather than water deficit.

A variety of techniques are employed to rejuvenate mature slockplants and improve rooting success. For example, the regular pruning of *Triplochiton scleroxylon* stock plants (Leakey 1983) has been shown to be effective in maintaining the rooting potential of cuttings taken from them. The results from this study indicate clearly that coppicing of *M. excelsa* enables cuttings from mature trees to be rooted. However, cuttings obtained from coppice shoots derived from mature trees displayed lower rooting percentages than those from saplings or seedlings, suggesting that the degree of reinvigoration obtained was dependent on the age of the mother plant.

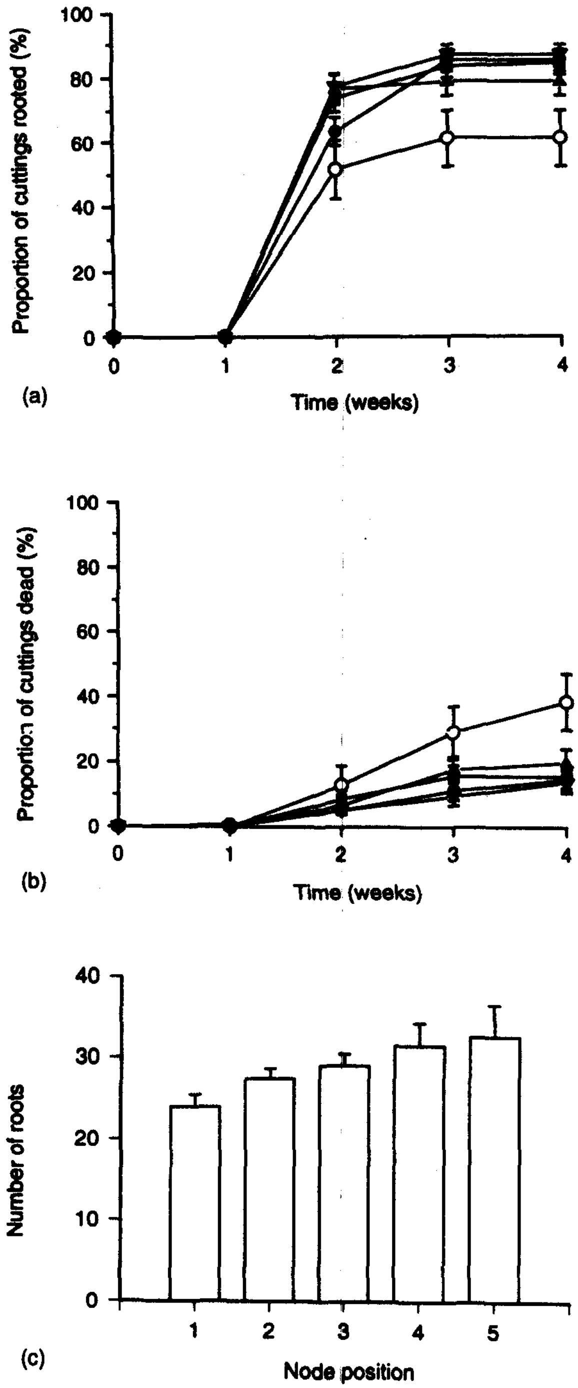

Figure 5. Effect of cutting position within a shoot (1 = apex, 5 = base) on (a) percentage rooting, (b) percentage mortality and (c) number of roots of *M. excelsa* cuttings (● : 1, ▽ : 2, ■ : 3, ▲ : 4, o : 5). Values presented are means (n_1 = 120, n_2 = 120, n_3 = 119, n_4, = 96, n_5 = 37) ± SE (see caption to Figure 1).

Much propagation research is directed towards optimising the number of cuttings per unit length of shoot, while achieving a consistently high rooting percentage. Investigations with many tree species have shown that rooting percentage is often positively correlated with cutting length (Geary & Harding 1984, Leakey & Mohammed 1985, Hoad & Leakey 1992). In contrast, no significant differences in rooting or mortality were observed between *M. excelsa* cuttings of different lengths. In this study, the number of shoots produced per cutting during propagation increased with successive increases in cutting length, which may have depleted the nutrient reserves available for rooting by acting as a competing sink. The longer cuttings were also more prone to drought, as indicated by the negative correlation recorded between cutting length and foliar RWC.

In many species, such as *Khaya ivorensis* (Tchoundjeu 1989), rooting ability has been found to increase from the apical to the basal part of the shoot. This has been attributed to accumulation of carbohydrates at the base of the shoot (Hartmann *et al.* 1990), probably as a result of greater stem volume of basal cuttings when a standard length of cuttings is taken (Leakey & Mohammed 1985). In contrast, the results of this experiment indicate that cuttings originating from the apical portions of shoots of *M. excelsa* displayed higher rooting percentages than those from the basal portions. Similar results have been reported for *Triplochiton scleroxylon* (Leakey 1983) and *Nauclea diderrichii* (Matin 1989). This trend could be ascribed to increasing lignification and secondary thickening from top to base or higher concentrations of endogenous root promoting substances present in the terminal sections of the shoot (Hartmann *et al.* 1990). The percentage leaf abscission of cuttings during propagation increased basipetally in this study, which may account for the higher percentage mortality of basal cuttings. This effect may be attributed to a lower photosynthetic capacity of the older leaves at the basal nodes (Leakey 1983). However, the basipetal decline in foliar RWC observed at day 10 indicates that cuttings from basal nodes also suffered greater water deficits.

The results of this investigation indicate clearly that *M. excelsa* can be rooted successfully using the low technology non-mist system. If pest-resistant individuals of *M. excelsa* can be identified and coppice shoots obtained, vegetative multiplication should be possible using the techniques described here. The results suggest that stem lengths of 3 - 6 cm would be appropriate for mass propagation of this species, although the precise treatment adopted would depend on the propagation conditions employed. In addition, the propagation environment should be managed to avoid water deficits in the cuttings (Newton & Jones 1993). A mean RWC of 62.0%, as recorded in the node position 4 treatment in Experiment 4, represents a severe water deficit, and may account for the lower rooting percentage observed.

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