LOW-TECHNOLOGY TECHNIQUES FOR THE VEGETATIVE PROPAGATION OF TROPICAL TREES

By LEAKEY, R.R.B.*, MESÉN, J.F.†, TCHOUNDJEU, Z.‡, LONGMAN, K.A.*, DICK, J. McP.*, NEWTON, A*, MATIN, A.§, GRACE, J.§, MUNRO, R.C.| and MUTHOKA, P.N.|

SUMMARY

Stem cuttings of five tree species from dry and semi-arid woodlands (*Acacia tortilis, Prosopis juliflora, Terminalia spinosa, Terminalia brownii* and *Albizia guachapele*) and seven species from moist tropical forests (*Cordia alliodora, Vochysia hondurensis, Nauclea diderrichii, Ricinodendron heudelotii, Lovoa trichiliodes, Gmelina arborea, Eucalyptus deglupta*) have been easily rooted in improved low-technology, high humidity polythene propagators in Kenya, Cameroon, Costa Rica and Britain. These propagators, which are cheap to construct, are very effective and have no essential requirements for either piped water or an electricity supply. Experiments have tested different rooting media, auxin applications and compared mist *versus* non-mist propagation.

Assessments of the physical and gaseous environment of the propagators has indicated ways of improving the rooting environment through an understanding of the sensitivity of the relative humidity to radiant energy and to opening the propagator for short periods (eg 2-3 minutes).

RÉSUMÉ

Des boutures de tige de cinq essences forestières de forêt claire aride et semi-aride (*Acacia tortilis, Prosopis juliflora, Terminalia spinosa, Terminalia brownii* et *Albizia guachapele*) et sept essences de forêt dense humide tropicale (*Cordia alliodora, Vochysia hondurensis, Nauclea diderrichii, Ricinodendron heudelotii, Lovoa trichiliodes, Gmelina arborea, Eucalyptus deglupta*) ont été enracinées facilement dans des propagateurs polyéthylène à humidité élevée de technologie de base au Kenya, au Cameroun, au Costa Rica et en Grande-Bretagne. Ces propagateurs, qui ne sont pas chers à confectionner, sont très efficaces et n'ont pas d'exigences essentielles ou pour de l'eau canalisée ou pour une alimentation en électricité. Des expériences ont testé des milieux d'enracinement et des applications d'auxine différents et ont comparé la propagation sous brumisation avec la propagation sans brumisation.

Des évaluations de l'environnement physique et gazeux des propagateurs ont indiqué des moyens d'améliorer l'environnement d'enracinement par une compréhension de la sensibilité de l'humidité relative à l'énergie radiante et à l'ouverture du propagateur pour des périodes courtes (par exemple 2 – 3 minutes).

* Institute of Terrestrial Ecology. Bush Estate. Penicuik Midlothian, EH26 OQB, Scotland.

† ITE/CATIE Link Project Centro Agronómico Tropical de Investigación y Ensenanza, 7170 Turrialba, Costa Rica.

‡ ITE Forestry Project Office National de Regénération des Forêts, BP 163, Mbalmayo, Cameroon.

| ITE Agroforestry and Mycorrhizas in Semi-arid Lands Project, National Museums of Kenya, PO Box 40658, Nairobi, Kenya.

§ Department of Forestry and Natural Resources, University of Edinburgh, Kings Buildings, Mayfield Road, Edinburgh, EH9 3JU. Scotland.

RESUMEN

En estudios en Kenia, Cameron, Costa Rica y Gran Bretana utilizando propagadores mejorados de baja tecnología, se enraizaron fácilmente estacas de tallos de cinco especies arbóreas de zonas áridas y semi-áridas (*Acacia tortilis, Prosopis juliflora, Terminalia spinosa, Terminalia brownii* y *Albizia quachapele*) y siete especies de bosque húmedo tropical (*Cordia alliodora, Vochysia hondurensis, Nauclea diderrichii, Ricinodendron heudelotii, Lovoa trichiliodes, Gmelina arborea, Eucalyptus deglupta*). Estos propagadores son baratos de construir, muy efectivos y sin requirimientos imprescindibles de agua de canería ni de electricidad. Los ensayos han probado diferentes medios de enraizamiento, aplicación de auxinas y la comparación de propagación con y sin nebulización.

La evaluación del ambiente físico y gaseoso de los propagadores ha indicado maneras de mejorar el ambiente de enraizamiento entendiendo que la humedad relative es sensible a la energía radiante y la apertura del propagador por períodos cortos (ej. 2 – 3 minutos).

Introduction

It is now widely realized that vegetative propagation and clonal selection offer a means to greatly enhance the yield and quality of forest products from commercial plantings in the tropics (Leakey, 1987). However, there is a need to simplify the technology so that vegetative propagation can be achieved in the absence of mains electricity and a piped water supply. In addition, in many tropical countries, the high capital and running costs of currently available mist propagation systems makes them inappropriate, except for research or large-scale commercial projects.

The environmental requirements for root initiation in leafy stem cuttings are those that minimise physiological stress in the cutting. In general terms this means using shade to lower the air temperature and, by providing a high humidity, to reduce transpiration losses. By the latter, the vapour pressure of the atmosphere surrounding the cutting is maintained close to that in the intercellular spaces of its leaf.

There are numerous propagation systems used in commercial horticulture. These are usually based either on spraying mist, fogging or enclosing the cuttings in polythene. The advantages of polythene systems have been known for many years (Loach, 1977) and they have been used to propagate tropical hardwoods with good success, particularly at the Forest Research Institute of Nigeria, Ibadan (Howland, 1975).

Recent work by the Institute of Terrestrial Ecology (ITE) and its overseas collaborators has applied and improved the design of non-mist propagators for use with a wide range of timber and multi-purpose tree species from both tropical moist forests and semi-arid areas (Leakey and Longman, 1988). Recent studies with *Triplochiton scleroxylon* cuttings under intermittent mist have indicated that rooting ability is related to the production of reflux-soluble carbohydrates, apparently derived from current photosynthesis while the cuttings are in the propagation unit (Leakey and Storeton-West, in preparation). Furthermore, it seems that the ability to produce these carbohydrates is related to the pre-severance light environment and nutrient status of the cuttings while on the stockplants. Both the total irradiance and the light quality (red:far-red ratio) are important components of the pre-severance light environment, and these factors interact with nutrient availability to influence the rates of net photosynthesis and rooting. These variables to a large extent account for the variation in the rooting ability of cuttings of *T. scleroxylon* taken from different shoots of variously-treated stockplants (Leakey, 1983).

Materials and Methods

General

Juvenile shoots of twelve tree species (Table 1) have been used as leafy stem cuttings. The studies presented here were done in either glasshouses in the UK or under nursery conditions in Costa Rica, Kenya and Cameroon. In all instances, however, the propagator temperature was between 22 – 27°C, and the cuttings were prepared as described below and set in randomized blocks. The numbers of replicate cuttings per treatment were between 24 and 117. Standard errors for percentage rooting were calculated using the procedures of Bailey (1959) for data with binomial distributions.

Table 1 Tropical tree species vegetatively propagated using simple, low-tech propagators in Costa Rica, Cameroon, Kenya and Great Britain.

Species	*Family*	*Range*	*Uses*
Gmelina arborea Roxb.	Verbenaceae	Indo-Burma region, and S.E. Asia, a Pan-tropical exotic	Timber
Eucalyptus deglupta Bl.	Myrtaceae	Tropical Australasia, a Pan-tropical exotic	Timber
Nauclea diderrichii (DeWild & Th Dur.) Merr.	Rubiceae	W. and C. Africa	Timber
Lovoa trichilioides Harms	Meliaceae	W. and C. Africa	Timber
Ricinodendron heudelotii (Baill.) Pierre ex Pax	Euphorbiaceae	W. and C. Africa	Fruit
Cordia alliodora (Ruiz & Pav.) Oken	Ehretiaceae	C. America	Timber
Vochysia hondurensis Sprague	Vochysiaceae	C. America	Timber
Albizia guachapele (Kunth) Dug.	Mimosaceae	C. America	Timber
Prosopis juliflora (Swartz) D.C.	Mimosaceae	C. Amercia	Multipurpose
Acacia tortilis (Forsk.) Hayne	Mimosaceae	W. and E. Africa	Multipurpose
Terminalia spinosa Engl.	Combretaceae	E. Africa	Multipurpose
Terminalia brownii Fresen	Combretaceae	E. Africa	Multipurpose

Preparation of cuttings

Cuttings were harvested from seedlings, managed juvenile stockplants or coppice shoots. Depending on the species, 1- to 4-node cuttings were used. These were usually about 50-60mm long and with a leaf area of about 50cm^2 (Leakey, 1985). In large leaved species, leaf areas were reduced by trimming prior to severance. The basal end of cuttings were dipped briefly in indole-3yl-butyric acid solutions (0.2-0.4% IBA in industrial methylated spirit) to a depth of about 2-5mm, and the alcohol then rapidly evaporated off in a stream of cold air from a fan (Leakey *et al.* 1982, Leakey, 1989). To minimise stress, the cuttings were inserted in the propagator as soon as they were dry. Alternatively, commercial auxin-based rooting powders "Strike" and "Seradix 2" (May & Baker Ltd) were used.

The non-mist propagator

The propagator design currently in use is based on that of Howland (1975), modified by Leakey and Longman (1988) and now further modified so that it does not require daily watering (Fig. 1). Basically, a wooden or metal frame is enclosed in clear polythene so that the base is water-tight (Leakey, 1989). The frame also provides support for the enclosed volume of water. The polythene base of the propagator is covered in a thin

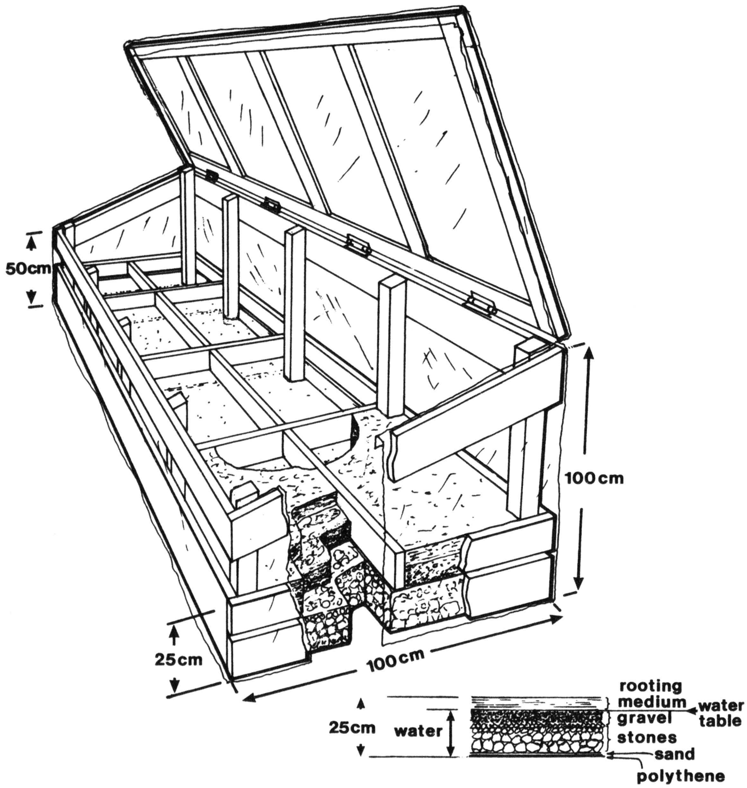


Figure 1. The design of ITE's improved non-mist propagator.

layer of sand to prevent the polythene from being punctured by the large stones (6 – 10 cm) which are placed on it to a depth of 10-15 cm. These stones are then covered by successive layers of small stones (3 – 6 cm) and gravel (0.5 – 1.0 cm) to a total depth of 20 cm. The gravel provides support for the rooting medium which is the uppermost layer, while the spaces between the stones are filled with water. A length of hollow bamboo provides an open cylinder inserted into the medium and stones which is used both to observe the water level and to add water if necessary. The rest of the frame is covered tightly with a single piece of clear polythene, and a closely-fitting lid is attached. Internal supports to the frame at the level of rooting medium also provide subdivisions allowing the independent use of different rooting media (Fig. 1). As a result of the studies reported here, further refinements to the design of non-mist propagators are discussed later. A similar frame to that of the non-mist propagator, with roll-up polythene sides, can be used, as in Costa Rica, as a weaning area.

Results

The propagator environment

In tests run in ITE glasshouses, in which air temperatures were maintained at about 20°C, temperatures in non-mist propagators rose to a mid-day peak of about 34°C during bright, sunny, mid-summer weather (eg 28th July). This rise in temperature was associated with a decrease in relative humidity from about 95% to about 75% (Fig. 2).

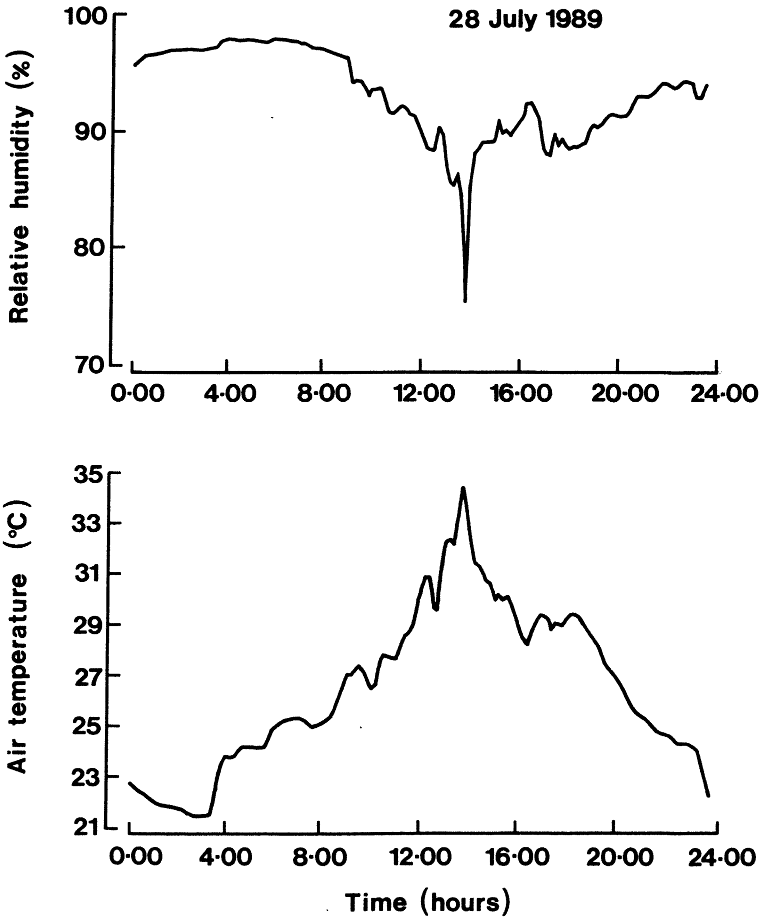


Figure 2. Effects of a rise in air temperature on the relative humidity inside a non-mist propagator.

This represents a substantial increase in the saturation vapour pressure deficit (SVPD) of the air from 0.02 kPa to 1.37 kPa. An important decrease in relative humidity also occurred when the propagator was opened for five minutes at midday (Fig. 3). In this instance, relative humidity decreased by about 40 – 50% to glasshouse ambient within two minutes,representing an increase in evaporation rate of approximately x 4.5 (SVPD = 0.45 kPa to 2.08 kPa). Relative humidity increased rapidly again following closure of the lid. Decreases in air temperature to ambient were also associated with this period of opening. Subsequent gains in the temperature resulted from closing the propagator, but the response time for temperature was considerably slower than for relative humidity.

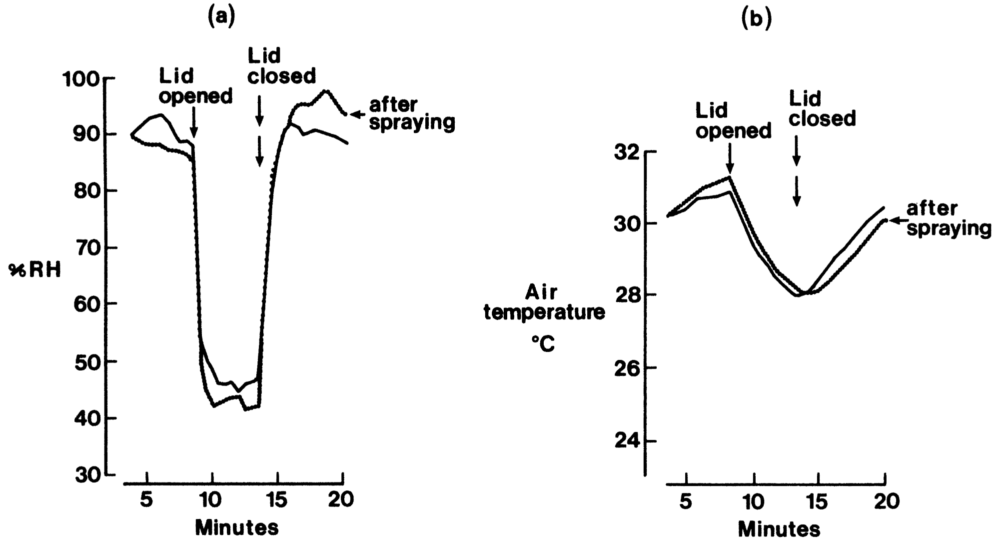


Figure 3. Effects of opening the lid of a non-mist propagator on its: a) relative humidity and b) air temperature.

When the easy-to-root species *Nauclea diderrichii* (Leakey, in press) was used for physiological studies in a non-mist propagator at Edinburgh University (Matin, 1989), it was found that cuttings had maximum rates of photosynthesis that were typical of intact plants, up to 6μ mol CO_2 m^{-2} s^{-1} at an irradiance of 1000μ mol m^{-2} s^{-1}. However, the photosynthetic capacity of these cuttings was influenced by changes in the CO_2 concentration inside the propagator. In the middle of the day, the CO_2 concentration fell to 150μ mol mol^{-1}, while by midnight it rose to 550μ mol mol^{-1}, reflecting daytime assimilation and night-time respiration, respectively.

As regards rooting media, the water-holding capacity of a fine-gravel (2 – 3mm diameter) medium was considerably increased, at the expense of the volume of the air spaces (Fig. 4), by the addition of rotted sawdust (50% by volume).

Rooting tests

In Costa Rica, studies using five tree species investigated the effects of four different rooting media (i) gravel, (ii) 50:50 gravel with sawdust, (iii) fine sand and (iv) 50:50 fine sand and sawdust. Each medium was tested with cuttings dipped in a range of IBA concentrations (0, 0.05, 0.1, 0.2, 0.4 and 0.8%). There were, however, substantial differences between species with regard to rooting success on the different media. Single-node juvenile cuttings of all five species rooted well (70 – 95%) on their best medium (Fig. 5). *Cordia alliodora* rooted best in fine sand, with or without sawdust,

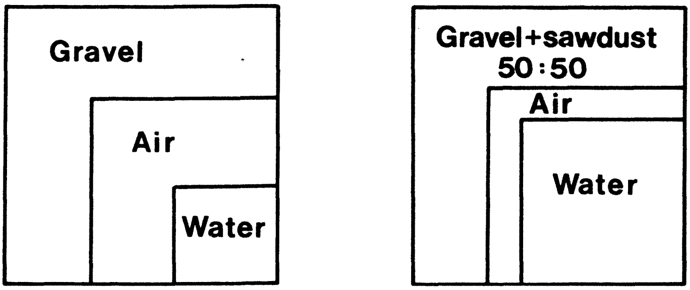
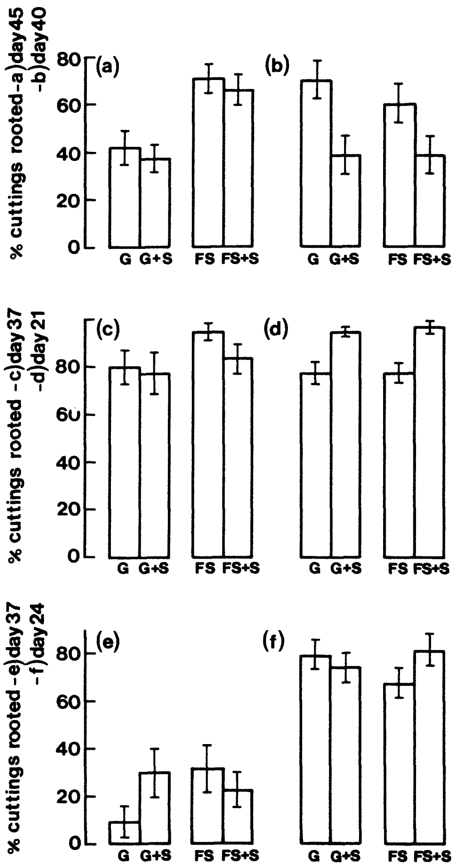


Figure 4. Relative composition by volume of a gravel rooting medium with and without sawdust.



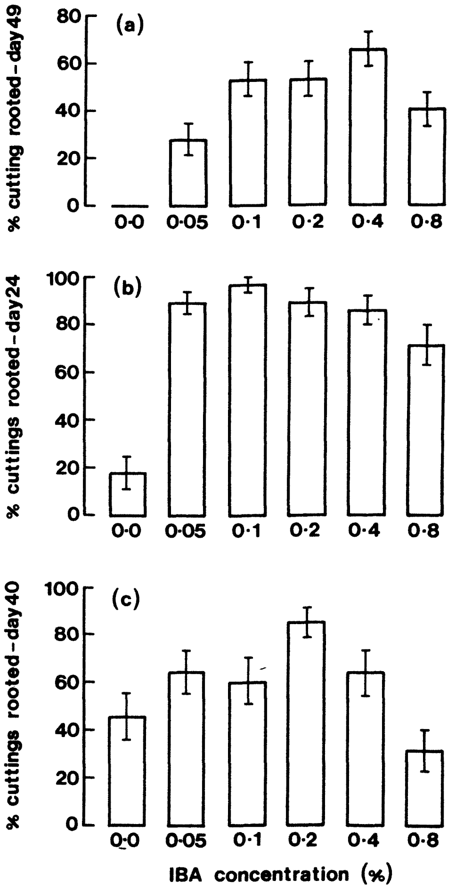


Figure 5. Effects of rooting medium (G = gravel, FS = fine sand and S = sawdust) on the rooting of leafy stem cuttings of (a) *Cordia alliodora*, (b) *Vochysia hondurensis*, (c) *Gmelina arborea* (juvenile), (d) *Eucalyptus deglupta*, (e) *Gmelina arborea* (mature), and (f) *Albizia guachapele*.

Figure 6. Effects of IBA concentrations on the rooting of leafy stem cuttings of (a) *Cordia alliodora* (b) *Albizia guachapele* and (c) *Vochysia hondurensis* in a non-mist propagator.

while rooting of *Vochysia hondurensis* cuttings was detrimentally affected by the incorporation of sawdust into both gravel and fine sand. On the other hand, sawdust enhanced the rooting of *Eucalyptus deglupta* cuttings in both gravel and sand, while *Gmelina arborea* and *Albizia guachapele* rooted well in all media. Unlike these juvenile cuttings, mature cuttings from vigorous shoots in a heavily pruned crown of *G. arborea* rooted much less well (Fig. 5e) especially in pure gravel. In juvenile *G. arborea*, a comparison between cuttings set in fine sand under an intermittent mist propagator and the non-mist propagator, showed better rooting in the non-mist propagator.

C. alliodora, *A. guachapele* and *V. hondurensis* differed in their responses to the range of IBA concentrations (0 to 0.8%). Optimal concentrations would appear to be 0.4, 0.1 and 0.2% IBA respectively for the three species (Fig. 6). In addition *C. alliodora* did not root at all without applied auxins, while rooting in untreated *V. hondurensis* cuttings exceeded 40%. Cuttings of *A. guachapele* were very responsive to all auxin treatments.

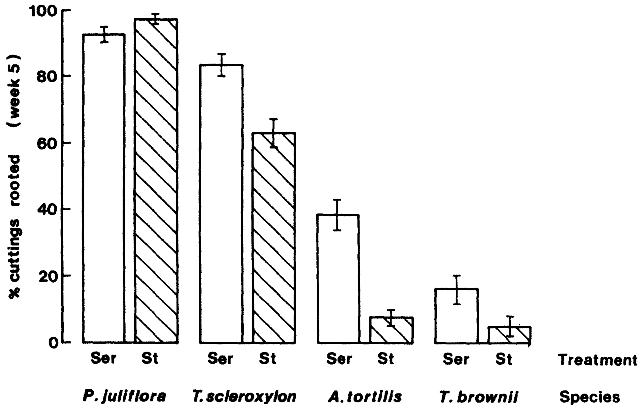


Figure 7. **Percentage of cuttings of *Prosopis juliflora*, *Terminalia spinosa* *Acacia tortilis*** and *Terminalia brownii* rooted in a non-mist propagator when treated with commercial rooting powders (Ser = "Seradix 2", St = "Strike").

Studies using non-mist propagators in Edinburgh and in Kenya, with tree species from semi-arid areas, investigated the relative merits of two commercially available rooting powders: (i) "Strike" = 0.25% NAA, and (ii) "Seradix 2" = 0.8% IBA. Seradix-treated cuttings of *Acacia tortilis*, *Terminalia spinosa* and *Terminalia brownii*, rooted better than those treated with Strike, while for *Prosopis juliflora*, rooting percentages were above 90% with both treatments (Fig. 7).

Two-node cuttings of *P. juliflora* also rooted relatively easily without applied auxins, although IBA solutions (0.4-0.8%) did hasten rooting and increase the numbers of roots formed. Long cuttings tended to root better than short ones, although there was no relationship between cutting length and its position of origin on the stockplant. Cuttings from lower on a stem generally rooted better than apical ones. An experiment comparing rooting under mist, with rooting in a non-mist propagator, clearly demonstrated the advantages of conditions without mist (Fig. 8). A third treatment in which a mist propagator was enclosed in polythene, resulted in even less rooting and higher mortalities due to rotting. When non-mist propagators have been used in Kenya to produce clonal material of *P. juliflora* for field experiments, the success rate was greater than 75%.

Like those of *P. juliflora*, cuttings of *A. tortilis* and *T. spinosa* are also much more easily rooted in the high humidity conditions of a non-mist propagator. There is, however, very considerable clonal variation in rooting ability in these species, and cuttings of *T. brownii* have so far only been rooted with a low rate of success.

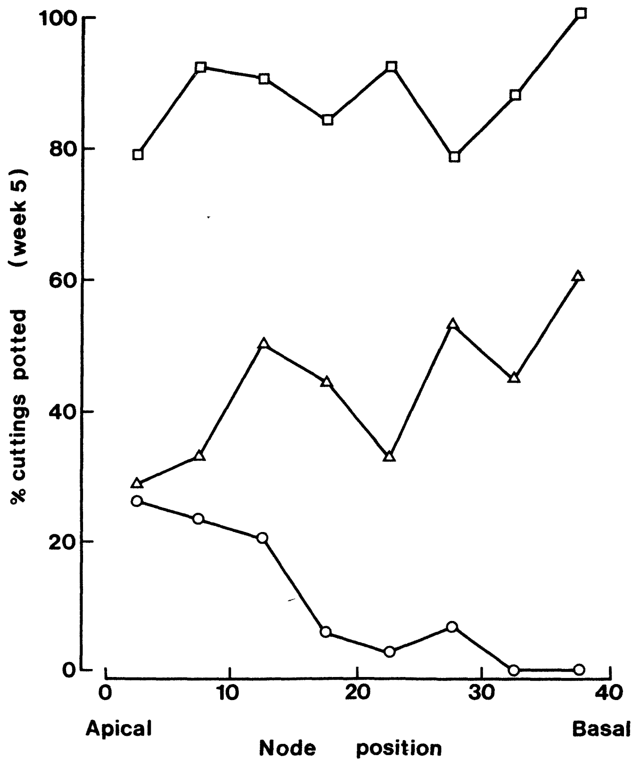


Figure 8. Effects of node position on the percentage of 2-node *Prosopis juliflora* cuttings rooted under three propagation environments (□ = non mist, ○ = enclosed mist, ▲ = open mist).

In Cameroon, the percentage rooting of cuttings of *Lovoa trichiloides* was relatively poor (c. 40-50%), and, in addition, the results were frequently unexpected. For example, no beneficial effects on rooting were found following the application of NAA or a range of IBA concentrations (0-200 μg/cutting), either in terms of the percentage of cuttings rooted or the of roots per cutting. Furthermore, the optimum leaf area seemed to be very high at about 200 cm^2 per cutting (Tchoundjeu, 1989).

When the rooting of cuttings of *Ricinodendron heudelotii* was tested both under mist and in non-mist propagators with 'Seradix 2', rooting by day 21 was best without mist (75% *v* 50% under mist).

Discussion

While there are reports of cuttings of *Prosopis, Gmelina* and *Eucalyptus* species being rooted (Felker and Clark, 1981; Sim and Jones, 1987; Delwaulle, 1983; Delwaulle *et al*, 1983), there are apparently none on the other species tested here. *Terminalia spinosa, Terminalia brownii, Vochysia hondurensis, Albizia guachapele* and *Ricinodendron heudelotii* may not have been previously tested, while for example, a number of previous attempts to root *Cordia alliodora* have failed (Dyson, 1981). *Acacia* spp. of semi-arid/arid areas of Africa also have the reputation of being difficult-to-root (Roche *et al.* 1989). The 'low-tech', non-mist propagators described here therefore seem to provide a very practical solution to the problem of how a wide range of tropical tree species can be propagated vegetatively. The advantage of these propagators seems to be particularly great for the dry-zone species which can be very susceptible to rotting under mist. While it is clear that the environment within the non-mist propagator fluctuates considerably over the day in response to variations in ambient temperature and incident radiation, it is also clear that, by being enclosed and continuously moist, the cuttings are not subjected to the extremes of saturation and water stress that can occur when misting frequency is poorly matched to changes in the weather.

An improvement which might further stabilise relative humidity in the non-mist propagator would be to construct the lid in several sections. Then the whole propagator would not have to be opened to access the cuttings. Ideally, the propagators are opened as little as possible and especially not during the heat of the day. When propagators are opened the cuttings should be sprayed frequently with a fine spray of water from a hand-held or knapsack sprayer. During bright sunny weather, shading is essential and spraying is highly desirable to prevent low relative humidity developing at mid-day (see Fig. 2). Attention to these points of detail are likely to be particularly important when propagators are used in hot, sunny and dry areas.

The reasons why the rooting of cuttings of different species have slightly different requirements with respect to propagation media, and auxin concentration, is unknown. Studies are in progress at the Institute of Terrestrial Ecology and are aimed at the identification of fundamental principles determining rooting ability in a range of tropical tree species. In this regard it appears that stockplant light/nutrient interactions prior to severance are important (Leakey and Coutts, 1989; Leakey and Storeton-West, in preparation) affecting the subsequent capacity of unrooted cuttings to photosynthesise. This photosynthesis could also be limited to low daytime CO_2 concentrations in the propagator. Thus it may be necessary in future to enhance CO_2 diffusion into the propagators.

REFERENCES

BAILEY, N.T.J. (1959). *Statistical Methods in Biology*, English Universities Press, London, p24.

DELWAULLE, J.C. (1983). Création et multiplication végétative par bouturage d'*Eucalyptus* hybrids en Republique Populaire du Congo, *Silvicultura*, **8**: 775–778.

DELWAULLE, J.C., LAPLACE, Y. & QUILLET, G. (1983). Production massive de boutures d'*Eucalyptus* en Republique Populaire du Congo, *Silvicultura*, **8**: 779–781.

DYSON, W.G. (1981). *Report (1980) to ODA of the UK Government*, London, 16pp.

FELKER, P. & CLARK, P.R. (1981). Rooting of Mesquite (*Prosopis*) cuttings, *Journal of Range Management*, **34**: 466–468.

HOWLAND, P. (1975). Vegetative propagation methods for *Triplochiton scleroxylon* K. Schum., *Proceedings of the Symposium on Variation and Breeding Systems of Triplochiton scleroxylon K. Schum.*, Federal Department of Forest Research,Ibadan, Nigeria, 21–28 April 1975, 99–109.

LEAKEY, R.R.B. (1983). Stockplant factors affecting root initiation in cuttings of *Triplochiton scleroxylon* K. Schum., an indigenous hardwood of West Africa, *Journal of Horticultural Science*, **58**: 277 – 290.

LEAKEY, R.R.B. (1985). The capacity for vegetative propagation in trees. In: *Attributes of Trees as Crop Plants*, Eds. Cannell, M.G.R. and Jackson, J.E., 110 – 133, Institute of Terrestrial Ecology, Abbots Ripton, Huntingdon, England.

LEAKEY, R.R.B. (1987). Clonal forestry in the tropics — a review of developments, strategies and opportunities, *Commonwealth Forestry Review*, **66**: 61 – 75.

LEAKEY, R.R.B. (1989). Vegetative propagation methods for tropical trees: rooting leafy softwood cuttings, In: *Agroforestry and Mycorrhizal Research for Semi-arid lands of East Africa Workshop*, National Museums of Kenya, Sept. 1989, 26 – 64, Institute of Terrestrial Ecology, Bush Estate, Penicuik, EH26 0QB, Scotland, UK.

LEAKEY, R.R.B. (In press). *Nauclea diderrichii*: rooting stem cuttings, clonal variation in shoot dominance and branch plagiotropism, *Trees*: LEAKEY, R.R.B. and LONGMAN, K.A. (1988). Low-tech cloning of tropical trees, *Appropriate Technology*, **15**: 6.

LEAKEY, R.R.B. and COUTTS, M.P. (1989). The dynamics of rooting in *Triplochiton scleroxylon* K. Schum. cuttings - their relationship to leaf area, node position, dry weight accumulation, leaf water potential and carbohydrate composition. *Tree Physiology*, **5**: 135 – 146.

LEAKEY, R.R.B. and STORETON-WEST, R. (In prep). Stockplant illumination, photosynthesis and the rooting ability of *Triplochiton scleroxylon* K. Schum. cuttings: the effects of irradiance, light quality and their interactions with nutrients, *Tree Physiology*.

LEAKEY, R.R.B., CHAPMAN, V.R. and LONGMAN, K.A. (1982). Physiological studies for tropical tree improvement and conservation. Some factors affecting root initiation in cuttings of *Triplochiton scleroxylon* K. Schum., *Forest Ecology and Management*, **4**: 53 – 66.

LOACH, K. (1977). Leaf water potential and the rooting of cuttings under mist and polythene. *Physiologia Plantarum*, **40**: 191 – 197.

MATIN, M.A. (1989). Carbon economy during rooting of cutting of *Nauclea diderrichii* (De Wild & Th. Dur.) Merill. M.Phil Thesis, University of Edinburgh, pp 123.

ROCHE, L.A., WYN JONES, R.G. and RETALLICK, S.J. (1989). A comparative study in Africa of agroforestry trees on vertisolic soils under low rainfall. *Annual Progress Report to ODA 1988-89, Project R4181*, University College of North Wales, 13pp.

SIM, B.L. & JONES, N. (1985). Improvement of *Gmelina arborea* in "Sabah Softwoods" plantations. In: *Provenance and Genetic Improvement Strategies in Tropical Forest Trees*. (Eds: R.D. Barnes & G.L. Gibson), Commonwealth Forestry Institute, Oxford, UK and Forest Research Centre, Harare, Zimbabwe, 604 – 609.

TCHOUNDJEU, Z. (1989). Vegetative propagation of the tropical hardwoods *Khaya ivorensis* A. Chev. and *Lovoa trichiloides* Harms., *Ph.D. thesis*, *University of Edinburgh*, 270pp.