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Maintaining Biological Diversity of Threatened Multipurpose Species in Central America by Vegetative Propagation

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EXECUTIVE SUMMARY

1. Three hundred and sixty-six trees in 29 provenances were selected of *A. guachapele, A. acuminata, B. quinata, C. alliodora,* and *V. guatemalensis* in Costa Rica, Colombia, Honduras, and Guatemala by CAMCORE and CATIE researchers. These activities represented the first time seed collections had been made on an individual plus tree basis for *A. guachapele, A. acuminata* and *V. guatemalensis.*

2. Twenty-nine hectares of provenance/progeny and *ex situ* gene conservation banks tests were established by CAMCORE members with seeds from these collections in Colombia, Costa Rica and Venezuela. Three year results from the oldest of these studies suggested that introduced selections may be superior to local selections, when the local genetic base was small and degraded. These initial trends support the premise that there is much to gain from continued individual tree selections and exchange of genetic material.

3. With the assistance of researchers from the Institute of Tropical Ecology, Edinburgh, Scotland, CATIE developed low-cost, non-mist propagation chambers to vegetatively propagate the species under study. The growth chambers consisted of a metal frames enclosed in polythene and were of the type that could be easily afforded by small forestry cooperatives or landowners in Central America.

4. Cutting from each species were initially harvested from seedlings grown in the CATIE nursery and were then established in clonal gardens as stockplants.

5. Different concentrations of IBA (0, 0.05, 0.2, 0.4 and 0.8 and 1.6%) were tested to determine optimum concentrations to promote maximum rooting for each species. The concentration of 0.2% achieved the best balance between rooting percentage and root quality.

6. Rooting percentage for all species ranged between 60 and 100%.

7. Initial results from the provenance/progeny tests, and the subsequent vegetative propagation activities have been presented in shortcourses to forester from Central America at CATIE. Included in the courses, were instructions on how to build the growth chambers. Furthermore, seven publication have been written describing project activities and results. The Costa Rican collaborator, Mr. F. Mesen, has used the results generated from the project as part of his Ph. D. work at the University of Edinburgh, Scotland.

8. Future work includes more intensive collections of these species to ensure that organizations possess as broad of genetic base as possible.

RESEARCH OBJECTIVES

The aim of the project was to conserve threatened populations of economically important multipurpose species in Central America through seed collections and to develop techniques to vegetatively propagate the best cultivars at a cost that was affordable to small and medium scale farmers and industrialists. The project was divided into two components jointly funded by the Central America and Mexico Coniferous Resources Cooperative (CAMCORE), Center for Tropical Agricultural Research and Education (CATIE) and the Office of the Science Advisor, Agency for International Development (AID). The **first component** included exploration in isolated regions of Guatemala, Honduras, and Costa Rica to collect research quantities of seeds of threatened populations of commercially important multipurpose species: *Albizia guachapele, Alnus acuminata, Bombacopsis quinata, Cordia alliodora, Sterculia apetala* and *Vochysia hondurensis* (recently renamed Vochysia guatemalensis). For *B. quinata* and *S. apetala*, explorations were expanded to include Colombia and Venezuela. No range-wide gene conservation efforts or genotypic evaluation had been conducted for these species before, with exception of *C. alliodora* at the provenance level.

With the seeds collected, gene conservation banks and provenance/progeny tests were to be established to preserve endangered gene pools, identify the most productive genotypes and produce new and useful genetic combinations for distribution by the CAMCORE and CATIE networks.

To maintain the biological diversity of populations in their native environment, the **second component** emphasized the development of rooted cutting techniques for the species

being studied in cutting chambers at CATIE. The growth chambers were to be designed and the vegetative propagation techniques developed with the assistance of scientists at the Institute of Terrestrial Ecology (ITE), Scotland, and the Overseas Development Administration (ODA), Great Britain. Genetic tests to compare the productivity of cuttings versus seedlings were to be established on several sites in Costa Rica to provide the factual data to quantify gains using both approaches.

METHODS AND RESULTS[1]

Explorations and Seed Collections

Explorations were carried out in Colombia, Costa Rica, Guatemala, and Honduras to locate populations of the species and select phenotypically superior trees. This was by far the most labor intensive and time-consuming part of the project because trees tend to be widely separated and frequently located in areas that are not easily assessable. No more than about five phenotypically superior trees were selected per week of constant searching, while seeds were collected from one to three trees per day, with two to five visits to each tree during the seed collecting season being necessary in order to obtain the quantities required for the tests. Seed collections of *Sterculia apetala* were attempted in two different years with little success because the fruits and seeds were destroyed by heavy insect attack while still immature. For this reason it was not possible to include this species in either the genetic testing program or the vegetative propagation research. In total, 366 superior trees were identified in 29 provenances of the six species. The selection of phenotypically superior trees

[1] The Results and Method Section was taken in part from Mesén & Dvorak, 1992 (see literature cited).

was completed by the end of the first year of the project; during the second year, seed collections were carried out from trees which produced little or no seed in the first year. Table 1 summarizes the results of the seed collections.

Table 1. Summary of the phenotypically superior trees selected by the project.

Species	Number of Provenances		Number of Trees	
	Costa Rica	Other Countries	Costa Rica	Other Countries
A. guachapele	2	1 (Honduras)	40	14
A. acuminata	4	1 (Guatemala)	37	15
B. quinata	5	2 (Honduras, Colombia)	97	20
C. alliodora	5	1 (Honduras)	61	12
S. apetala	1	0	9	0
V. guatemalensis	5	2 (Guatemala, Honduras)	26	35
TOTAL	22	7	270	96

Establishment of the Provenance/Progeny Tests

Following the intensive seed collections during the first year of the project, a large amount of open pollinated families were available for trials during the second and third year. Twenty-nine hectares of provenance progeny trials were established in Colombia, Costa Rica and Venezuela with the seed collected by CAMCORE/CATIE researchers (Table 2). In Colombia and Venezuela, the tests were established by the CAMCORE network of private industries on land owned by each respective organization. In Costa Rica, the genetic tests were established under cooperative agreements with farmers involved in reforestation under the Costa Rican General Forestry Directorate (DGF) incentive scheme or land owned by research institutions, thus facilitating the proper maintenance of the trials in the future. In

all three countries, the standard design recommended by CAMCORE for the international provenance/progeny tests was used, i. e. randomized complete blocks with nine replications and line plots of six trees per family, keeping together the families of the same provenance. Tests are measured at one year for survival, and three, five and eight years for growth and quality traits.

Table 2. Details of the trials established by CAMCORE members in Colombia, Costa Rica and Venezuela.

Species	Location	Number of families	Area (ha)
A. guachapele	Lourdes, Guanacaste, Costa Rica	41	2.0
A. guachapele	Huacas, Guanacaste, Costa Rica	20	0.6
A. guachapele	El Hierro, Venezuela*	23	0.7
A. guachapele	Zambrano, Colombia**	11	0.6
A. guachapele	Zambrano, Colombia**	34	1.2
A. acuminata	Santa Cruz, Turrialba, Costa Rica	45	3.0
B. quinata	Nandayure, Guanacaste, Costa Rica	62	3.0
B. quinata	El Hierro, Venezuela*	39	1.9
B. quinata	El Hierro, Venezuela*	62	1.8
B. quinata	Zambrano, Colombia**	62	1.6
C. alliodora	Upala, Alajuela, Costa Rica	69	3.0
C. alliodora	El Toco, Venezuela*	15	0.7
V. guatemalensis	OTS, Sarapiquí, Costa Rica	48	3.0
V. guatemalensis	DGF, Sarapiquí, Costa Rica	47	3.0
V. guatemalensis	CATIE, Turrialba, Costa Rica	47	3.0

* Test established by Smurfit-Cartón de Venezuela
** Test established by Pizano/Monterrey Forestal

Three year results are available only for three *B. quinata* tests at this time (Table 3). In Venezuela, the local *B. quinata* material performed poorly in height growth relative to the introductions from Costa Rica (Dvorak & Donahue, 1992). In Colombia, the growth of the local material was not statistically different in height from the Venezuelan selections (Table 3). Provenance variation accounted for 1% to 7% of the total variation in the test.

Preliminary results suggests that there is much to gain by incorporating new material from other countries into local *B. quinata* breeding programs and making family and within family selections.

Table 3. Provenance mean height (m) for **Bombacopsis quinata** assessed at three years of age in Venezuela and Colombia

Test Code: Site Code:	Cartón de Venezuela 24-03-02A 21	Cartón de Venezuela 24-03-02D 21	Pizano Colombia 24-09-01D 30
Provenance:			
Guanacaste	4.3 a	3.1 a	--
Atlantico	3.8 b	3.0 a	2.9 a
Zambrano	--	--	3.1 a
Barinas	3.7 b	2.8 a	--
Choluteca	--	--	2.8 a

Means in a column with the same letter are not significantly different.

Vegetative Propagation

It is now widely realized that vegetative propagation and clonal selection offer a means to greatly enhance the yield and quality of forest products (Leakey, 1987). The tremendous improvements in productivity and form of clonal eucalypts in Brazil, for example, are well known by foresters. Similar genetic gains may be possible with native broadleaved species.

There are numerous systems used commercially for the propagation of forest species, usually based on mist spraying. However, in all Central American countries, the high capital and running costs of currently available mist propagation systems makes them inappropriate

(Leakey, 1987). Therefore, the project concentrated on the development of lower cost, simpler techniques for the propagation of the species involved. Preliminary results favored the non-mist propagators, developed by ITE for the propagation of West African hardwoods (Leakey and Longman, 1988). The propagator is based on that of Howland (1975), modified by Leakey and Longman (1988) and now further amended based on experiences at CATIE (Leakey et al., 1990).

The non-mist propagator

The non-mist propagator or metal frame enclosed in polythene so that the base is water tight. The polythene base is covered in a thin 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 a layer of smaller stones or gravel to a total depth of 20 cm. The gravel provides support for the rooting medium which is the uppermost layer. Water is added to the propagator up to the base of the rooting medium, which is kept humid by capillary motion. The rest of the frame is covered tightly with a single piece of clear polythene, and a closely-fitting lid is attached. Preferably, the lid should be constructed in several sections, so that the whole propagator does not have to be opened to access the cuttings. Further details on the design and use of the propagator are given in Leakey et al. (1990) and Mesén et al., (in press).

The propagator environment

Numerous factors, anatomical, physiological and environmental, affect root initiation in leafy stem cutting (Hartman and Kester, 1968), and all must be optimized for successful rooting (Leakey and Mesén, 1991). However, the minimization of water stress is considered the key point in the process (Loach, 1988). The effectiveness of the non-mist propagator seems to lay in its capacity to minimize water stress, protecting the cuttings from the strong environmental variations experienced under normal tropical conditions. While external relative humidity may vary between 75 and 100% in a typical bright day, the relative humidity inside the propagator varies between 85 and 100% for the same period (Mesén et al., in press). Maintenance of a high relative humidity within the propagator is critical, especially during the first 2-3 weeks, when the cuttings lack roots and can not compensate the water lost by transpiration. In leafy stem cuttings of *C. alliodora*, for example, the relative water content of the leaves varied between 75 and 95% during a six week period in the propagator, which permitted rooting percentages above 80% at the end of this period (Mesén, 1991).

Relative humidity and irradiance are negatively correlated. In Turrialba, irradiance can easily reach values of 2000 umol m^{-2} s^{-1} or more in a bright day, which can cause an unwanted decrease in relative humidity inside the propagator. Therefore, the use of shade is usually necessary to lower irradiance and reduce transpiration losses. Shade can be provided by using palm leaves or layers of black plastic netting. A single layer of plastic netting reduced irradiance from 2000 umol m^{-2} s^{-1} to values below 600 umol m^{-2} s^{-1},

considered appropriate for rooting (Mesén et al., in press). The reduction in irradiance should not be excessive, however, since rooting of leafy stem cuttings is usually enhanced by photosynthates formed during the propagation period (Davis, 1988; Leakey and Storeton-West, in prep.). The use of a single layer of plastic netting seems to achieve an appropriate balance, since, again in *C. alliodora*, high rates of net photosynthesis (4-5 umol CO_2 m^{-2} s^{-1}) were recorded at irradiances of around 300 umol m^{-2} s^{-1} (Mesén et al., in press; Ramos and Grace, 1990).

In Turrialba, the non-mist propagator aiso maintains air and substrate temperatures within the range recommended for the propagation of tropical species, i.e. 20-35°C, respectively (Mesén et al. in press).

Relative humidity within the propagator decreases rapidly to values of around 40-50% if the lid is opened at midday, even for short periods (Leakey et al., 1990). Therefore, handling of cuttings should be avoided during the brightest hours of the day, to avoid stress to the cuttings.

There are also substantial differences between species with regard to rooting medium. The reasons for these 'preferences' are not well understood, but seem to be related with the relative composition (solids: air: water) of the rooting medium. Table 4 shows the rooting medium most appropriate for each species. In this regard, local and easily available substrates were preferred, following the same principles of simplicity and economy of the propagator.

Table 4. Summary of results on substrate requirements for the rooting of leafy stem cuttings of the project species.

Species	Rooting medium	Average rooting percentage
A. guachapele	Gravel, gravel + sawdust*	80-90%
A. acuminata	Sand	60-80%
B. quinata	Sand, sawdust	70-80%
C. alliodora	Sand, sand + sawdust*	60-90%
V. guatemalensis	Sand, sand + sawdust*, gravel + sawdust*	80-90%

*50/50 by volume

Preparation of cuttings

One of the main constraints of clonal silviculture is the difficulty of propagating trees mature enough to show their phenotypic worth. Various practices have been used to overcome this problem, for example: i) to fell the tree and utilize the coppice rising from the stump, ii) to stimulate sprouting from the base of standing trees, and iii) serial grafting on to a juvenile rootstock to rejuvenate to adult scion (Leakey, 1988). The latter method has serious technical problems, as it may take a long time to develop truly juvenile material and, in many species, it may be difficult to know when 'true juvenility' has been achieved. The former methods present practical problems, since the trees are scattered in small private farms, sometimes of difficult access, all over the region. Felling the best trees is unlikely to be accepted by farmers. Therefore, for the clonal work it was decided to start cloning from seedlings. Two other arguments put forward in favor of this approach were: i) it would be easier for participating countries to exchange seed rather than vegetative material, and ii) the use of seed would capture the full range of genetic variation from the undoubtedly dysgenic Central American populations of the species. This method starts with material of

unknown phenotypic potential, but early selection test can be developed, as has been done for other hardwood species (Leakey et al., 1982).

Cuttings were initially harvested from seedlings. Rooted cuttings were then established in clonal gardens and managed as stockplants, with frequent harvests, fertilization and watering as required, to stimulate the production of a large number of vigorous, orthotopic shoots. Usually, shoots were harvested every three months, each one providing 6-10 single-node, leafy stem cuttings. These were usually 5-6 cm long, with the leaf area trimmed to around 30 cm^2. Shoots were harvested during the coolest time of the day and transported to the propagation area in containers with water. Once in the propagation room, the cuttings were kept moist and under shade to avoid water stress, and inserted in the propagator as quickly as possible after treatment.

Auxin concentration

Applied auxins have been shown not only to increase the percentage of cuttings which form roots, but also to hasten root initiation, to increase the number and quality of roots produced per cutting and to increase uniformity of rooting (Hartman and Kester, 1968; Blazich, 1988). It seems that there is no simple relationship between auxin levels in cuttings and rooting, and, to date, the exact role of auxins in stimulating adventitious root formation remains unclear. Besides the well known effects of auxins on cell division and growth, the beneficial effects of auxins on rooting have been associated with an increased transport of carbohydrates and leaf cofactors to the base of the cutting, where they enhance root primordium initiation and development (Haissig, 1974). It is also well established that

metabolites and other growth factors are actually translocated to auxin-treated regions of the stem (Phillips, 1969; 1975). Under conditions of low photosynthetic activity, auxin transport and/or synthesis may be reduced; thus, photosynthesis by the cuttings may also indirectly influence rooting, by affecting auxin supply to the base of the cutting (Davis, 1988). Exogenous auxins may also induce rooting by stimulating DNA synthesis in suitable cells (Gaspar and Hofinger, 1988). It is likely that the effect of auxins in stimulating adventitious root formation in cuttings is a result of a complex interaction of these and probably other processes.

Although indole-3-acetic acid (IAA) is the auxin naturally found in plants, a related synthetic compound, indole-3-butyric acid (IBA) has been found most reliable in stimulating adventitious root formation in cuttings. It is non-toxic over a wide range of concentrations and is effective in promoting rooting of a large number os species, It is also much more light-stable that IAA and, being insoluble in water, remains longer in the site of application and then maintains its activity over longer periods (Hartmann and Kester, 1968). In addition, plants possess several mechanisms which operate to reduce and/or mollify the effectiveness of IAA, by conjugating it with other compounds or destroying it (Blazich, 1988). Optimum auxin concentration varies greatly between species, due to variations in levels of endogenous auxins, rooting co-factors, inhibitors, anatomy, leaf retention and possibly, to interactions between these factors (Leakey, 1985).

Considering this, it was not surprising to find difference between species with regard to IBA concentration. In every case, IBA was applied to the clean cut base of the cuttings in 10 ul of methanol solution using a micrometer syringe. This allowed the application of

a standard quantity of solution to every cutting. The alcohol was quickly evaporated off in a stream of cold air from a fan before inserting the cuttings in the propagator bed (see Leakey et al., 1982). Usually, concentrations of 0, 0.05, 0.2, 0.4, 0.8 and 1.6% IBA were tested. Table 5 shows the optimum concentration for each species. Contrary to all other species, *V. guatemalensis* showed the highest rooting percentages when no auxin was applied. However, the number of roots per rooted cutting increased with successive increases in auxin concentration, from three roots per rooted cutting with 0% IBA to eight roots per rooted cutting with 0.8% IBA. The concentration of 0.2% achieved the best balance between rooting percentage and root system quality (Mesén et al., in press).

An IBA-based commercial rooting powder (Seradix) was also found effective in promoting rooting of most species, and could be used here supplies of pure IBA are not locally available.

The time for the beginning of root formation also varied between species, from three weeks for *A. guachapele* and *B. quinata* to around five for *V. guatemalensis*. For all the species, no further rooting occurred beyond eleven weeks.

Table 5. Summary of results on IBA requirements for the rooting of leafy stem cuttings of the project species.

Species	IBA concentration (%)	Average rooting percentage
A. guachapele	0.05-0.4	90-100
A. acuminata	0.2	60-80
B. quinata	0.2	60-80
C. alliodora	0.8-1.6	60-90
V. guatemalensis	0.2	80-90

IMPACT, RELEVANCE AND TECHNOLOGY TRANSFER

The provenance/progeny trials established under this project are the first of their kind for most of the species studied, with the exception of *C. alliodora*. This project represents the results of a pioneering coordinated effort between many countries and institutions and is the first documented work that explores the efficacy of placing selection pressure on these broadleaf species in natural stands through plus tree selection. Most trials are still too young to draw definite conclusions, but it appears that organizations can gain much in productivity by exchanging genetic material. This suggests that the more tree sampled in natural stands, the greater the chance for finding those genotypes that are well adapted to a specific set of climatic and environmental conditions. Such information is of great practical value to foresters for it means that explorations for new populations should continue followed by plus tree selection.

The design used for the tests is excellent for conversion to a seedling seed orchard after the evaluation period, by removing the worst trees and leaving only the best tress of the best families for seed production. CAMCORE has developed a selection index to facilitate the selection of the best genotypes in each test (Balocchi, 1990). The resulting seedling seed orchards will represent the first genetically proven seed sources for most species in Central America- a major step forward for the region.

The project, with close collaboration of ITE, has also demonstrated that clonal silviculture can be adopted by small scale rural development programs, by using low cost, simple propagation techniques. The project produced the first reports of successful rooting for *A. guachapele, A. acuminata, C. alliodora*, and *V. guatemalensis*, some of which had a

reputation of being difficult to root. The non-mist propagators described here and elsewhere (see Leaky et al., 1990) seem to provide a very practical solution for the rooting of a very wide range of tropical species.

Farmers in Costa Rica have visited CATIE to learn more about the non-mist propagation chambers for replicating good genotypes for small scale planting programs. The technology is simple and inexpensive, and therefore, very practical at the local level. The techniques for vegetative propagation using the mist chambers, have also be described in the Tree Improvement short course held at CATIE, in 1992 (Leaky, 1991) and will again be presented in 1993. This course, which is held in Spanish, is attended primarily by young forest technicians from all over Central America and other parts of Latin America.

The success of the vegetative propagation program developed by this project coupled with the financial incentives offered by the Costa Rican government has spawned renewed interest in the value of gene conversation, tree selection and tree breeding, locally. The Costa Rican counter-part in this project, Mr. Francisco Mesén, has used preliminary data generated from the project for use in his Ph. D. work at Edinburgh, Scotland. Mr. Mesén will return to CATIE after his research work is completed at the end of 1992 to continue as Project Manager of CATIE's tree improvement section.

PROJECT ACTIVITIES AND OUTPUT

Meetings

At CATIE January 23-24 1989 to discuss the logistics of seed collections and trial design. In attendance, R. Camino, F. Mesen, E. Correa (CATIE), R. Kellison (CAMCORE, Raleigh), E. Gutierrez (CAMCORE, Guatemala), Oscar Ochoa (Honduras), Jesus Dorantes (University of Veracruz, Mexico), David Boshier (ODA),and M. Kane (Pizano/Monterrey-Colombia).

Publications:(that have included references to the project).

Dvorak, W. S. 1992. Forest Gene Conservation and Genetic Testing Efforts of the CAMCORE Cooperative. Presentation at the MPT-GRC Consultation meeting, ICRAF, Nairobi, Kenya. June 2-5. 5 p.

Dvorak, W. S. and J. K. Donahue. 1992. CAMCORE Cooperative Research Review, 1980-1992. College of Forest Resources, North Carolina State University. Raleigh. 93 p.

Dvorak, W. S, and J. K. Donahue. 1991. Programa de conservación y mejoramiento de Bombacopsis quinata (Jacq.) Dugand en Centro and Sur América de la Cooperativa CAMCORE. En: Noticiero Mejoramiento Genetico Y Semillas Forestales Para America Central. No. 6. pp. 22-25.

Kane, M. H. Urueña, W. Dvorak and C. Atehortúa. The potential of Bombacopsis quinata as a commercial plantation species. Forest Ecology and Management (in press).

Leaky, R. R. B and J. F. Mesén. 1991. Métodos de propagación vegetativa en árboles tropicales: enraizamiento de estacas juveniles. **In**: Manual sobre Mejoramiento Genético Forestal con Referencia Especial a America Central. Cornelius, J. P., Mésen, J. F and Corea, E. (Eds.). CATIE, Turrialba, Costa Rica. Capítulo 10. pp. 113-133.

Mesén, F and W. S. Dvorak. 1992. Seed collections and vegetative propagation of threatened multipurpose species in Central America. Networking/Workshop Meeting of the Board on Science and Technology for International Development, National Research Council. CATIE, Turrialba, Costa Rica, April 2-9, 1992. 10 p.

Mesén, J. F., R. R. B. Leaky, A. C. Newton. 1992. Hacia el desarollo de técnicas de silvicultura clonal para el pequeño finquero. El Chasqui, Costa Rica (in press).

PROJECT PRODUCTIVITY

The project accomplished all of its goals.

FUTURE WORK

Additional seed collections are planned for the most important of these species, particularly, *B. quinata, C. alliodora, V. guatemalensis* and *S. apetala*. To make seed collections and conservation, *ex situ*, more efficient, two areas of research must be addressed. First, the geographic ranges of these species are still not well known. Use of aerial photos or satellite imagery, might prove useful in locating additional populations of the species. If not, much time and expense will be needed to define the geographic range of the species through field explorations. Unfortunately, such tedious but important work is seldom funded because it is not considered innovative research. Second, better information is needed to define the genetic variation among populations of threatened broadleaf species before collections are initiated. Recent advances in utilization of RAPD markers should help define how genetic diversity is structured at the population level. Seed collection can be concentrated in those populations that are the most genetically diverse.

LITERATURE CITED

Balocchi, C. E. 1990. CAMCORE tree improvement program. CAMCORE Bulletin on Tropical Forestry. No. 7. College of Forest Resources, North Carolina State University. March. 37 p.

Blazich, F. A. 1988. Chemicals and formulations used to promote adventitious rooting. IN: Adventitious Root Formation in Cuttings. T. D. Davis, B. E. Haissig and N. B. Sankhla (Eds). Disocorides Press, Portland, OR. Chap. 10. pp: 132-149.

Davis, T. 1988. Photosynthesis during adventitious rooting. IN: Adventitious Root Formation in Cuttings. T. D. Davis, B. E. Haissig and N. B. Sankhla (Eds). Disocorides Press, Portland, OR. Chap. 6. pp: 79-87.

Dvorak, W. S. and J. K. Donahue. 1992. CAMCORE Cooperative Research Review, 1980-1992. College of Forest Resources, North Carolina State University. Raleigh. 93 p.

Gaspar, T. and M. Hofinger. 1988. Auxin metabolism during adventitious rooting. **IN**: Adventitious Root Formation in Cuttings. T. D. Davis, B. E. Haissig and N. B. Sankhla (Eds). Disocorides Press, Portland, OR. Chap. 9. pp: 117-131.

Hartmann, H. T. and D. E. Kester. 1968. Plant propagation, principles and practices. 2nd ed. Englewood Cliffs, N. J. Prentice Hall. 702 p.

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. April. pp. 99-109.

Leaky, R. R. B. 1985. The capacity for vegetative propagation in trees. **IN**: Attributes of Trees as Crops Plants. M. G. R. Cannell and J. Jackson (Eds) Institute of Terrestrial Ecology, Monks Wood, Huntingdon, Eng. pp. 110-133.

Leaky, R. R. B. 1987. Clonal forestry in the tropics- a review of developments, strategies and opportunities. Commonw. Forestry Review. **66**: pp. 61-75.

Leaky, R. R. B. 1988. Vegetative propagation consultancy: CATIE, Costa Rica. Report to the Overseas Development Administration, ODA/NERC, contract No. OMC 527/093/003 A. Institute of Terrestrial Ecology, Bush Estate, Penicuik, Midlothian. 50 p. (Unpublished).

Leaky, R. R. B and K. A. Longman. 1988. Low-tech cloning of tropical trees. Appropriate technology. **15**:6.

Leaky, R. R. B., V. R. Chapman, K. A. Longman, 1982. Physiological studies for tropical tree improvement and conservation. Factors affecting root initiation in cuttings of Triplochiton scleroxylon K. Schum. Forest Ecology and Management

Leaky, R. R. B., J. F. Mesén, Z. Tchoundjeu, K. A. Longman, McP. J. Dick, A. C. Newton, A. Matin, J. Grace, R. C Munro, P. N Mutoka. 1990. Low-technology techniques for the vegetative propagation of tropical trees. Commonw. Forestry Review. **69**(3). pp: 247-257.

Leaky, R. R. B and J. F. Mesén. 1991. Métodos de propagación vegetativa en árboles tropicales: enraizamiento de estacas juveniles. **In**: Manual sobre Mejoramiento Genético Forestal con Referencia Especial a America Central. Cornelius, J. P., Mésen, J. F and Corea, E. (Eds.). CATIE, Turrialba, Costa Rica. Capítulo 10. pp. 113-133.

Mesén, F and W. S. Dvorak. 1992. Seed collections and vegetative propagation of threatened multipurpose species in Central America. Networking/Workshop Meeting of the Board on Science and Technology for International Development, National Research Council. CATIE, Turrialba, Costa Rica, April 2-9, 1992. 10 p.

Mesén, J. F., R. R. B. Leaky, A. C. Newton. 1992. Hacia el desarollo de técnicas de silvicultura clonal para el pequeño finquero. El Chasqui, Costa Rica (in press).

Phillips, I. D. J. 1969. Apical dominance. IN: Physiology of Plant Growth and Development. M. B. Wilkins (Ed). McGraw Hill-London. pp. 163-202.

Philips, I. D. J. 1975. Apical dominance. Annual Review of Plant Physiology. **26**. pp: 341-367.

Ramos, J. and J. Grace. 1990. The effects of shade on the gas exchange of seedlings of four tropical trees from Mexico. Functional Ecology. **4**: pp 667-677.