

Rationale for developing intensive teak clonal plantations, with special reference to Sabah

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Suitably selected and wisely deployed teak clones,

combined with intensive silvicultural practices, are the best option for large scale monospecific plantations as well as for agroforestry systems. Practical references are made to the Innoprise Corporation Sdn Bhd, ICSB, teak project in Sabah, Malaysia.



Tissue culture issued mass clonal propagation of teak clones in nursery (Sabah, Malaysia).
Photo O. Monteuis.

RÉSUMÉ

ARGUMENTS EN FAVEUR DES PLANTATIONS CLONALES INTENSIVES DE TECK, EN SE RÉFÉRANT À L'EXPÉRIENCE DU SABAH

Bien que très prisé, le bois de teck ne représente aujourd'hui que 1 % du volume total de bois d'œuvre utilisé dans le monde. La demande internationale croissante pour du bois de teck de bonne qualité est responsable d'une diminution alarmante des ressources provenant des peuplements naturels ou des plantations. Par ailleurs, le teck est de plus en plus protégé par la mise en place d'une réglementation stricte pour préserver la biodiversité *in situ* de l'espèce. Cette situation a entraîné récemment un changement radical de la façon de concevoir les nouvelles plantations de tecks. En effet, les teckeraies traditionnelles, gérées la plupart du temps par des organismes publics pour être exploitées à l'issue de rotations de 60 à 80 ans, voire plus, ne sont plus adaptées au contexte actuel, qui doit tenir compte de la pression démographique croissante et ses conséquences sur l'occupation des sols. La tendance actuelle tend à privilégier les investisseurs privés, paysans inclus, désireux de réaliser le meilleur retour sur investissement dans les plus brefs délais. Les plantations rationnelles de clones de tecks adaptés aux différents contextes, que ce soit à une échelle industrielle sous forme de blocs monospécifiques ou intégrés au sein de divers systèmes agroforestiers, semblent l'option la plus prometteuse à cette fin. Ces aspects sont développés dans le présent article, en prenant comme référence le projet ICSB teck du Sabah, en Malaisie orientale.

Mots-clés : agroforesterie, clone, intensification, plantation industrielle, productivité, sylviculture, *Tectona grandis*.

ABSTRACT

RATIONALE FOR DEVELOPING INTENSIVE TEAK CLONAL PLANTATIONS, WITH SPECIAL REFERENCE TO SABAH

Today, teak wood supplies account for only 1 % of the total volume of high value timber used worldwide, despite being the most prized wood. International demand, which is getting stronger and stronger for good quality teak, has resulted in an ever-increasing depletion of both natural and plantation teak resources. These latter are more and more protected by strict conservation policies aiming at preserving *in situ* biodiversity. This situation has been responsible lately for a basic change of teak plantation concept. Traditional teak plantations, most of which being managed by public organizations on rotations of 60 to 80 years or even more, are no longer adapted to the current context, with increasing population pressure and its heavy incidence on land tenure. The emerging trend is characterized by a stronger involvement of private investors, including farmers, who are looking for the best return on investment with the shortest delays. Suitably selected and wisely deployed teak clones combined with intensive practices seem to be the best option to meet this goal, for large scale monospecific plantations as well as for various agroforestry systems. This paper focuses on this particular topic with practical references to the ICSB teak project in Sabah, Malaysia.

Keywords: agroforestry, clone, intensification, large scale plantation, productivity, silviculture, *Tectona grandis*.

RESUMEN

ARGUMENTOS A FAVOR DE LAS PLANTACIONES CLONALES INTENSIVAS DE TECA, REFIRIÉNDOSE A LA EXPERIENCIA DE SABAH

A pesar de ser muy apreciada, actualmente la madera de teca sólo representa un 1% del volumen total de la madera de construcción utilizada en el mundo. La creciente demanda internacional de madera de teca de buena calidad es responsable de una alarmante reducción de los recursos procedente de masas naturales o de plantaciones. Por otra parte, la protección de la teca es cada vez mayor al estar sujeta a una estricta normativa legal para proteger la biodiversidad *in situ* de la especie. Esta situación produjo recientemente un cambio radical en la manera de concebir las nuevas plantaciones de tecas. En efecto, las plantaciones tradicionales, gestionadas casi siempre por organismos públicos para su aprovechamiento después de rotaciones de 60 a 80 años, o incluso más, ya no están adaptadas al contexto actual, que debe contar con el incremento de la presión demográfica y sus consecuencias en el uso de la tierra. La tendencia actual tiende a favorecer a los inversores privados, campesinos incluidos, que desean realizar el mejor retorno sobre inversión lo más rápidamente posible. Las plantaciones racionales de clones de tecas adaptados a los distintos contextos, a escala industrial en forma de bloques monoespecíficos o integrados en distintos sistemas agroforestales, parecen la mejor opción. Estos aspectos se desarrollan en este artículo, tomando como referencia el proyecto ICSB teck de Sabah, en Malasia oriental.

Palabras clave: agroforestería, clon, intensificación, plantación industrial, productividad, sylvicultura, *Tectona grandis*.

Teak planting: time for a change

Tectona grandis, commonly known as teak, originates from India, Laos, Myanmar (ex-Burma) and Thailand. Despite being the most prized timber species, teak wood supplies currently represent only 1 % of the total volume of high value timber used worldwide (BEHAGHEL, 1999). Increased international demand for good quality teak has resulted in an ever-increasing depletion of natural resources which are more and more protected by strict conservation policies aimed at preserving *in situ* biodiversity. Old plantations, too, are in heavy demand.

This situation has resulted lately in a basic change in the concept of teak plantation. It seems that traditional teak plantations, managed mostly by state organizations to be harvested not before 60 or 80 years (BALL *et al.*, 2000), are no longer

adapted to the current global context. There is now an increasing demographic pressure on land tenure accounting for an overall intensification of crop productivity (BALL *et al.*, 2000; NAIR, 2000).

The emerging trend is therefore characterized by a greater involvement of private investors looking for the shortest possible delays. Suitably selected and wisely deployed teak clones appear to be the best options to meet this goal (BEHAGHEL, MONTEUUIS, 1999).

Since the early 1990s, CIRAD Forestry Department and Innoprise Corporation Sdn Bhd, ICSB for short, have actively invested along this line by developing operational strategies and techniques (GOH, MONTEUUIS, 1997), as reported in this paper.

Base population and observation plots

Efficient techniques for mass producing teak clones from plus trees of any age were developed in Sabah in the early 1990s within the framework of a collaboration between CIRAD Forestry Department and ICSB (GOH, MONTEUUIS, 1997).

Initially, the selection of candidate plus trees – the so-called CPT – for cloning has been mainly based on phenotypic criteria and more specifically on:

- Growth rate – an annual height increment of 4 m during the first years is not unusual in Sabah conditions!
- Clear bole length, 10 m minimum without any fork and with reduced lateral branching. Actually, most of the CPTs selected produce only large leaves, up to a height of 8 to 10 m, in the absence of any lateral branches which are produced at a higher level.
- Bole straightness and basal circularity, with an absence of buttresses or flutes.
- Crown development.



The oldest monoclonal block (clone MBo) planted under the ICSB project, 1 year (left) and 7 years after planting, with a dbh of 30cm at this age.
Photos O. Monteuis.

Table I.
List of the various seedlots obtained, germinated and planted within ICSB teak project.

Provenances	India Chandrapur Maharashtra
	India Sakrebail Karnataka – 2 batches
	India Virnoli Vir. Karnatakan – 2 batches
	India Karadibetta Karnataka
	India Gilalegundi Karnataka
	India Maukal Karnataka – 7 batches
	Thailand Mae Huat Lampang (natural stand)
	Thailand Mae Huat Lampang (planted stand)
Seed sources	Bulu Kumba, Indonesia
	Papua New Guinea ex-Brown River – presumably from Myanmar (Burma) (Cameron 1966, White, personal communication)
	Solomon Island Arara - presumably introduced from Myanmar if not from India or Thailand, via Papua New Guinea (White, personal communication)
	Solomon Island Viru – presumably introduced from Myanmar if not from India or Thailand, via Papua New Guinea (White, personal communication)
	Perlis, Peninsular Malaysia – from Forest Research Institute Malaysia, presumably from Thailand
	Kota Marudu, Sabah – introduced by the Dutch Tobacco Company, presumably from India
Total: 22 seedlots	

Table II.
List of families obtained from the Ivory Coast Clonal Seed Orchard and planted within ICSB teak project.

Origin of seed lots	Number of seedlots
India Nellicutha	13
India Nilambur	10
India Vernolirge	3
India Va	2
India Purunakote	3
Ivory Coast Bamoro	2
Ivory Coast Kokondekro	1
Laos Paklay	2
Senegal Djibelor	1
Tanzania Kihuhwi	3
Tanzania Mt	3
Tanzania Bigwa	3
Thailand Huoi-Nam-Oon	3
Thailand Maasale Valley	2
Thailand Pong Salee	2
Thailand Ban Pha Lay	2
Thailand Ban Cham Pui	1
Total: 17 origins	Total: 56 seedlots

Recently, availability of non-destructive wood analysis methods such as core sampling (BAILLÈRES, DURAND, 2000), and molecular marker technology will undoubtedly provide valuable additional criteria to those mentioned above for refining the initial phenotypic selection.

Efficient and economically viable nursery (MONTEUUIS, 1995) or tissue culture (MONTEUUIS *et al.*, 1998) techniques have been developed, which can be used in a variety of different situations. The respective advantages and limitations of the nursery versus *in vitro* systems have been highlighted elsewhere (MONTEUUIS, 2000).

Since 1994, teak trees clonally or bulk-produced from cuttings and microcuttings have been established and assessed on ICSB's research areas and various locations within Malaysia, as well as in countries such as Australia, and in Africa and South America.



A teak tree from meristem (100 μ m) culture at 18 months (left) and 7 years (girth: 55 cm; height: 25 m) after planting. Note the long, clear bole and reduced lateral branching resulting from the phenotypic selection from the ortet from which the meristems were collected.
Photos O. Monteuis.

The first monoclonal block was established in 1997 with a spacing of 3 x 3 m on a 1.2 ha plot from micro-cuttings. As far as we are aware, this is the oldest and largest monoclonal plot for teak established from micro-cuttings and not from grafts. Records and pictures have been taken at regular time intervals in order to note the evolution of this plot during the course of time, and to assess any intra-clonal variation with regard to different criteria such as growth, form, flowering onset and more recently, wood characteristics.

Concomitantly, two provenance-cum-progeny trials were set up in 1997 in the form of partially balanced incomplete block designs in two different locations, one in a lowland (Taliwas, Lahad Datu) and another in a hilly area (the Luasong

Forestry Center). These trials encompass 41 and 42 seedlots respectively, 26 being common to both areas. These provenance and progeny trials were designed in such a way that the plots can be easily converted into seed production areas for supplying genetically improved quality seeds without risks of inbreeding.

Additional plots for demonstration have been set up in the ICSB's concession from seeds obtained from various natural provenances and seed-sources.

All these constitute a very diverse collection of teak origins, detailed in Tables I and II, from which further candidate plus tree selection can be made for the production of clones from various provenances likely to adapt a wide range of ecological conditions.



A 37 year-old candidate plus tree (CPT) for cloning.
Photo O. Monteuis.

The seed-derived strategies

The numerous plots established from seeds of various origins can be considered as *ex situ* biodiversity conservation sites.

The main intention, however, is to use the broad genetic diversity of the teak germplasm introduced as base populations for further genetic improvement. Different options can be considered, but efficiency and short term benefits remain our main concerns.

The seed stand option

The two provenance-progeny trials can be easily converted into seed stands by culling the inferior trees and also half-sibs in close vicinity in order to favor the intermating of superior individuals that are not genetically related. Seven years after planting, some trees exhibit impressive height, averaging 22-23 m, and a good height/diameter ratio (80 to 100 on average), in addition to attractive phenotypic features. In the absence of sufficiently detailed information on genetic origin, resorting to molecular biology techniques can

help in the determination of the genetic relatedness among individuals planted within the same neighborhood. Further testing of the selected seed producers of the stand based on the performance of their progeny will indicate their combining ability that can then be used for refined or more advanced selection and culling activities, such as those highlighted by KJÆR and FOSTER (1996). A final density of 120 to 180 seed producers per hectare of seed stand is expected at the end of these selection and roguing activities (Figure 1).

Improved quality seed production strategy

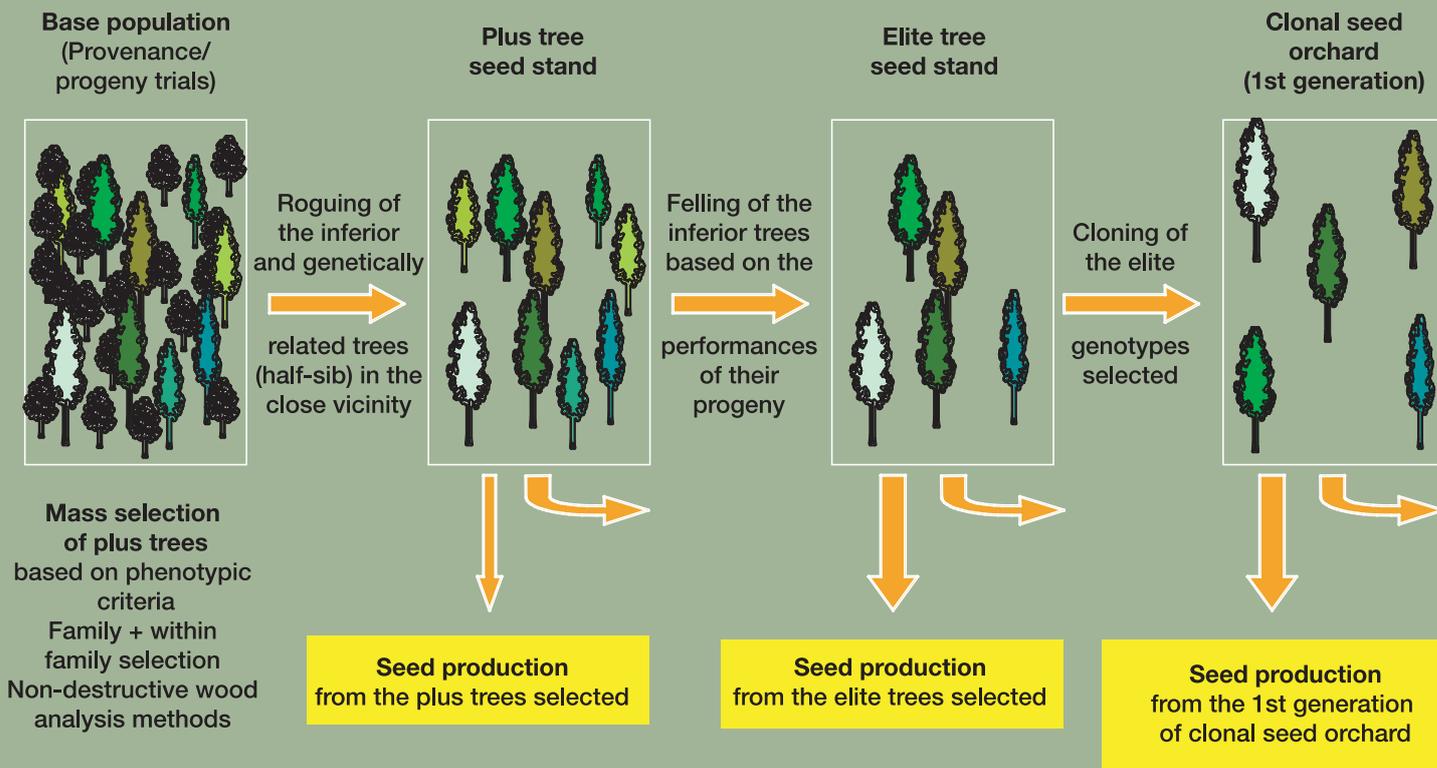


Figure 1.

Illustration of the ICSB-CIRAD Forestry Department strategy for producing improved-quality seeds in the shortest delay, starting from genetically-rich base populations. Advanced generations of clonal seed orchards can be envisaged for the long term.

The seed orchard option

The best combining genotypes or “combiners” can be asexually propagated or duplicated to be mixed according to a well-suited planting design within a vegetative seed orchard consisting of clones from different families and provenances, as illustrated in Figure 1.

These clones will be produced on their own root systems by rooted cuttings or microcuttings in order to prevent grafting incompatibility problems and the consequential production of “illegitimates”. These are likely to depreciate the genetic quality of the seeds produced, first, when col-

lected directly from such unexpected “mothers”, since illegitimates are most of the time hard to distinguish from the grafts as they look similar, and second, since these will pollute the genetic quality of the seeds produced by the “legitimates” around.

However, the numerous question marks and uncertainties associated with the real benefits that can be expected from such clonal orchards have to be seriously pondered (KJAER, FOSTER, 1996; KASOA-ARD *et al.*, 1998; WHITE, GAVINLERTVATANA, 1999; KJAER *et al.*, 2000). The implementation of this strategy is therefore only to be considered for the long term.

The clonal option

The clonal option has been viewed from the beginning as the most efficient strategy for generating uniform teak planting material of superior quality in the shortest feasible time, as has been discussed at length by MONTEUUIS and GOH (1999). This is the basis of the strategy illustrated in Figure 2, which takes into account all the efforts made along this line, starting first with the development of adapted propagation techniques

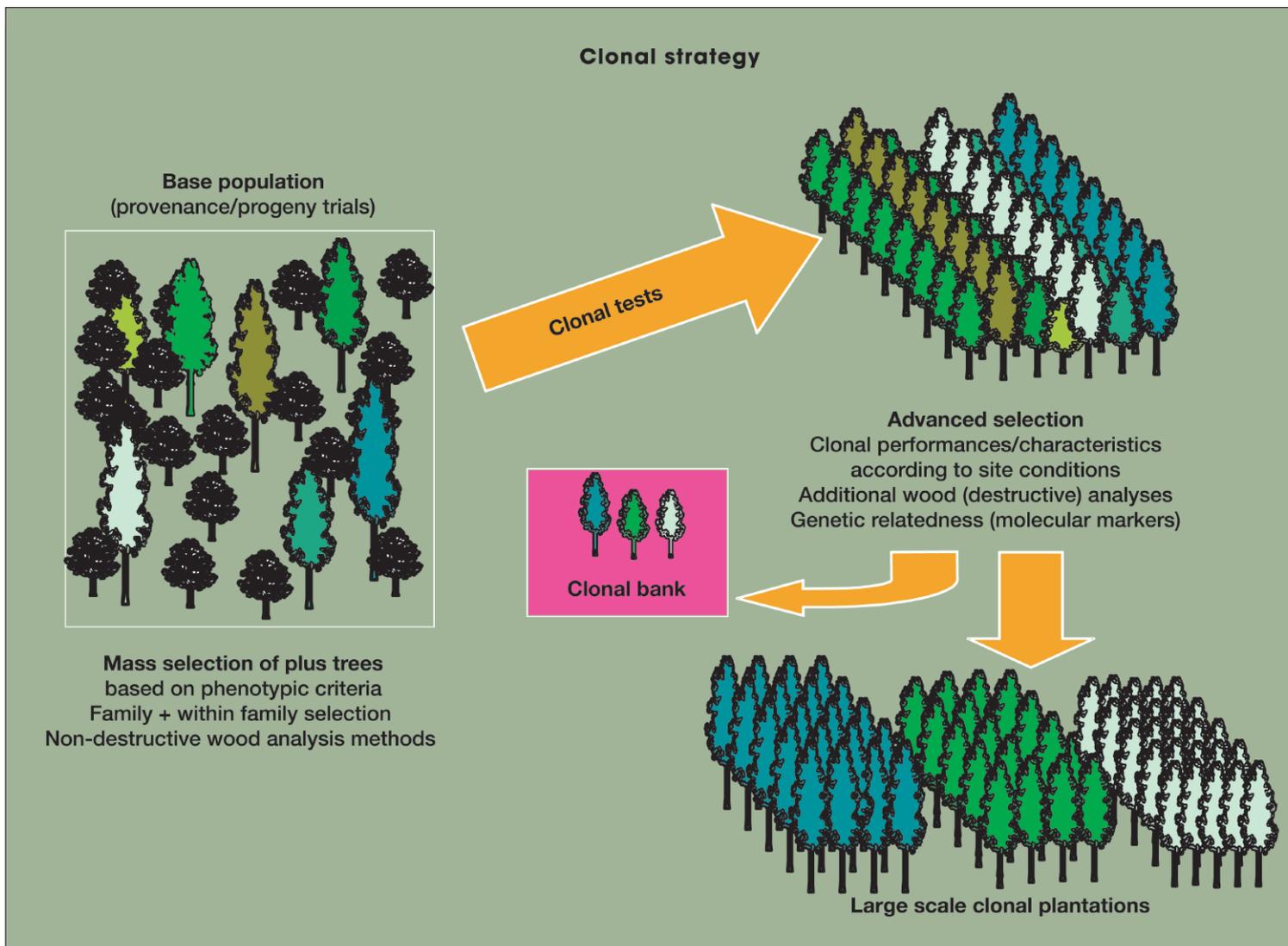


Figure 2.

Illustration of the project strategy for large-scale clonal teak plantations. Molecular markers can help to obtain pedigree information with a view to certification, and to determine genetic relatedness between the clones used for clonal deployment.



The main provenance-progeny trial of Taliwas set up under the ICSB project in 1997: quite a genetically-rich germplasm that can be profitably used for clone or seed production after proper selection of plus trees.

Photo O. Monteuis.

Clonal mass propagation techniques

In Sabah, where there is no distinct dry season, 450 to 500 rooted cuttings per square meter of properly managed and container-grown stock plants can be produced annually in suitable nursery conditions. Average rooting rates range from 70 to 80 % for mature selected genotypes – 60 year-old or more – once the rejuvenation process has been achieved (MONTEUUIS *et al.*, 1995). Applying this procedure, 250 000 cuttings have been produced since 1992 for various uses such as establishment of demonstration plots, clonal tests, commercial plantations and sale to local clients. All these have strongly demonstrated the total efficiency of the developed technology for the mass production of superior quality teak clones.

Nevertheless, comparative economic analyses have clearly shown that for the production of more than 100 000 cuttings per year, tissue culture procedures are more efficient (MONTEUUIS, 2000; GOH, MONTEUUIS, 2001). This is particularly true for exporting clones to various overseas clients in the absence of any phytosanitary restrictions, unlike for rooted cuttings (GOH, MONTEUUIS, 2001).

About 300 000 vitroplants have so far been produced by the Plant Biotechnology Laboratory – PBL for short – within the framework a joint project between ICSB and CIRAD Forestry Department. The PBL has operated on a pilot scale and has managed to deliver teak plantlets to different countries all around the world, including Australia, South America, Africa and within South East Asia.

Field behavior of the cuttings and microcuttings-derived teak trees

Contrary to many forest trees species, teak plants issued from cuttings and microcuttings have developed true-to-type, in the absence of any phenotypic abnormalities such as undesirable plagiotropic growth patterns which are affecting (micro)cuttings of many forest species – the so-called “C effects” (FRAMPTON, FOSTER, 1993). Growth rates have been impressive in the first few years, with 3 to 4 m of annual increment under Sabah conditions, during which large leaves and very few lateral branches are produced. The trees thereafter increase more in diameter with average annual increments of 2.5 to 3 cm.

Some of these cutting-derived trees have attained 28-30 m in height and 40 cm in diameter 10 years after planting, while measurements of 29 m in height and 36 cm in diameter were recorded 8 years after planting for microcutting-derived teak trees. In addition to this impressive growth, the cloned plants have developed noteworthy long clear boles devoid of forks and with very few lateral branches, even when planted at wide spacing. This attests the validity of the mass selection based on phenotypic criteria. More extensive information is expected from the data analyses of the various clonal tests set up since 1997.

Investigations underway

Advanced analyses of wood characteristics will be used for refining the initial selection based so far on phenotypic criteria. Non-destructive core sampling will be preferably used for seed-issued CPT, whereas destructive board sampling, which is more informative, can be applied to some representatives of certain genotypes established through clonal plots. Such investigations are very innovative and are valuable for assessing, within the same clone, the extent to which possible tree to tree phenotypic differences such as growth rates can be correlated with variations of wood characteristics. Possible genotype x site effects can be similarly assessed. The networking established among the various buyer countries and on different continents in which the same clones have been introduced is already highly informative and useful in this respect, with obvious commercial implications.

Resorting to molecular biology for DNA profiling will allow a better identification of the genotypes and of their original provenances, in particular for the trees issued from various seed sources such as the Solomon Islands. This kind of information is useful in many respects, for instance in the assessment of teak adaptability according to its natural origin.



7 year-old CPT used in the Taliwas provenance-progeny trial: a long clear bole with minimal branching waiting for wood analysis results (non-destructive core sampling methods) which will refine the initial phenotypic selection. Photos O. Monteuis.

Information on the genetic relatedness of the selected trees is also expected from these DNA investigations, which will support wiser clonal deployment and better seed orchard design, thus preventing risks of inbreeding.

Another application related to DNA fingerprinting will be the genotypic characterization of the clones available for sale, in particular where property rights are concerned.

Needs for teak clonal plantations

The advantages of developing clonal plantations for teak have been advocated for a number of years (MONTEUUIS, GOH, 1999). Recent promising field results from cuttings or microcutting-produced teak plants, and the noticeable change of mentality as far as timber plantations and land use policy are concerned, have greatly reinforced this viewpoint. As far as we are aware, ICSB, with joint efforts from CIRAD Forestry Department, has been the pioneer in operational clonal propagation and plantations of teak, and as such has an unrivalled background especially in terms of propagation experience and field behavior of (micro)cutting issued clones.

Considering the tremendous demand for teak wood, which is far greater than the resources currently available worldwide, it is considered that there will continue to be excellent market prospects for the supply of superior quality teak wood.

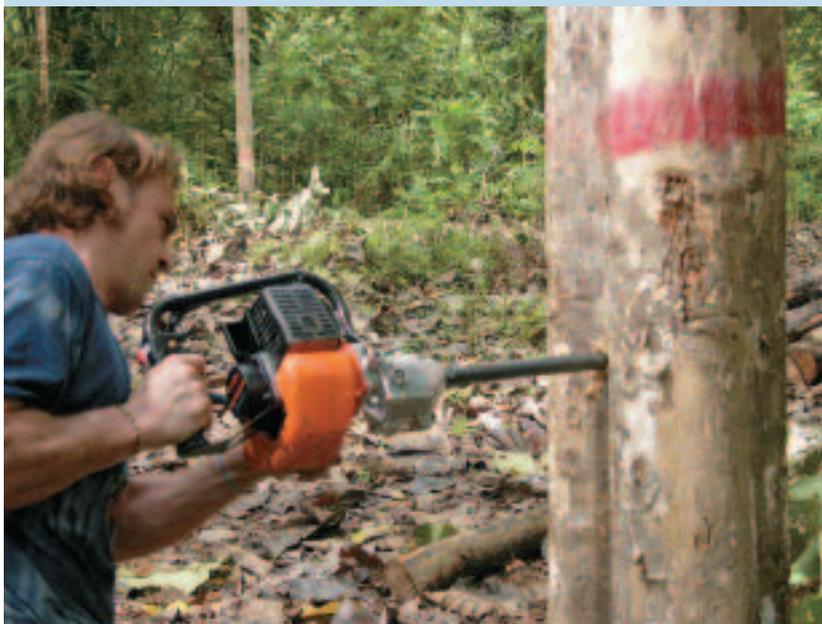
It is thus now possible to establish fast growing, uniform teak clonal stands, with enhanced yields, high wood quality and commercial value on short rotations. These are so many good reasons for investors and landowners to regard planting this highly prized timber species as an attractive proposition.

The fact that many natural teak areas have a 3 to 5 month long dry period does not necessarily mean that the species is not adapted to more humid conditions, characterized by high rainfall regime all over the year, as demonstrated by the teak trees introduced in Central Java some 4 or 5 centuries ago, and now as observed under Sabah conditions.

Wood quality of planted teak may not be as high as for natural teaks growing slower in dryer conditions, but the differences in quality may not be that obvious according to certain experts (BAILLÈRES, DURAND, 2000; BATH, 2000). The first board samples collected from 7 to 12 year-old fast growing teak trees in Sabah showed an unexpectedly high proportion of nicely veined heartwood.



Board samples taken from 7 year-old (micro) cuttings derived teak trees for in-depth wood analyses. Photo D. Goh.



Wood sample collection within the ICSB project in Sabah (Malaysia): non-destructive core-sampling (left); a core sample (middle) and board sampling.

Photos D. Goh.



Teak combined with other crops within agroforestry systems: with oil palm in Sabah, East Malaysia (left), with coffee in Nicaragua (right), illustrating the need for properly selected teak clones.

Photos O. Monteuis.



References

More in-depth analyses will reveal the properties of this heartwood, including its natural durability. Nonetheless, it has to be stressed here again that considering alternative solutions to depleting natural teak wood resources must be found soon, and the wood produced by fast growing teak clones will still be teak-wood.

Such superior quality and highly productive clonal plantations can be wisely developed as monocultures or as agroforestry systems, applying proper silvicultural practices yet to be defined on a case to case basis. For instance plant materials with narrow crowns will be preferable for agroforestry use, with the possibility of an early cash flow from associated crops such as cocoa, oil palm, and coffee, which could also be produced from clones. In the case of intercropping with legumes, these species can benefit teak trees by natural enrichment of the soil in nitrogen.

In view of all these arguments, and considering the serious limitations of seed-issued planting stock (MONTEUUIS, 2000; GOH, MONTEUUIS, 2001), the clonal option appears to be the best, and in many cases the only way to maximize the returns on investments with regard to the establishment of teak plantations, and from a more general standpoint, to land use.

BAILLÈRES H., DURAND P.Y., 2000. Non-destructive techniques for wood quality assessment of plantation-grown teak. *Bois et Forêts des Tropiques*, 263, 17-29.

BATH K.M., 2000. Timber quality of teak from managed plantations of the tropics. *Bois et Forêts des Tropiques*, 263, 6-16.

BALL J.B., PANDEY D., HIRAI S., 2000. Global overview of teak plantations. FORSPA Publication n° 24/2000, Teaknet Publication, n° 3, 11-33.

BEHAGHEL I., 1999. État des plantations de teck dans le monde. *Bois et Forêts des Tropiques*, 262, 6-18.

BEHAGHEL I., MONTEUUIS O., 1999. À propos du séminaire : *Site, technology and productivity of teak plantations*. Chiang Mai, Thaïlande, 26-29 janvier 1999. *Bois et Forêts des Tropiques*, 261, 70-79.

FRAMPTON JR L.J., FOSTER G.S., 1993. 9. Field testing vegetative propagules. *In: Clonal Forestry 1 Genetics and Biotechnology*. Ahuja and Libby ed., Springer-Verlag, Berlin, Heidelberg, New York, London, Paris, Tokyo, Hong Kong, Barcelona, Budapest, 110-134.

GOH D., MONTEUUIS O., 1997. Vegetative propagation of teak. *ITTO Tropical Forest Update*, 7 (2): 13.

GOH D., MONTEUUIS O., 2001. Production of tissue cultured teak: the plant biotechnology laboratory experience. *Proc. of the Third Regional Seminar on Teak*, 31 July- 4 August 2000, Yogyakarta, Indonesia, 237-247

KAOSA-ARD A., SUANGTHO V., KJAER E.D., 1998. Experience from tree improvement of teak (*Tectona grandis*) in Thailand. DANIDA technical note n° 50, 14 p.

KJAER E.D., FOSTER G.S., 1996. The economics of tree improvement of teak (*Tectona grandis* L.). Technical note n° 43, DANIDA Forest Seed Centre, Denmark, 23 p.

KJAER E.D., KAOSA-ARD A., SUANGTHO V., 2000. Domestication of teak through tree improvement. Options, possible gains and critical factors. *In: Site, technology and productivity of teak plantations*. FORSPA Publication n° 24/2000, Teaknet Publication n° 3, 161-189.

MONTEUUIS O., 1995. Recent advances in mass clonal propagation of teak. *Proc. of Bio-Refor*, Kangar, Malaisie, 28 November -1st December 1994, 117-121.

MONTEUUIS O., 2000. Propagating teak by cuttings and microcuttings. FORSPA Publication n° 24/2000, Teaknet Publication n° 3, 209-222.

MONTEUUIS O., VALLAURI D., POUPARD C., HAZARD L., YUSOF Y., WAHAP LATIP A., GARCIA C., CHAUVIERE M., 1995. Propagation clonale de tecks matures par bouturage horticoles. *Bois et Forêts des Tropiques*, 243, 25-39.

MONTEUUIS O., BON M.-C., GOH D., 1998. Teak propagation by *in vitro* culture. *Bois et Forêts des Tropiques*, 256, 43-53.

MONTEUUIS O., GOH D., 1999. About the use of clones in teak. *Bois et Forêts des Tropiques*, 261, 28-38.

NAIR C.T.S., 2000. An introduction to technology, site and productivity issues. FORSPA Publication n° 24/2000, Teaknet Publication n° 3, 1-10.

WHITE K.J., GAVINLERTVATANA P., 1999. Vegetative reproduction of teak: the future to increased productivity. *In: Site, technology and productivity of teak plantations*. Chiang Mai, Thailand, 26-29 January 1999.