Advances in teak cloning

New developments in teak cloning lead to better plantation stock

by
Olivier Monteuuis[1] and Henri-Félix Maître[2]

[1]CIRAD-BIOS, TA 10/C
Baillarguet 34398 Montpellier Cedex 5, France
monteuuis@cirad.fr

[2]CIRAD-E.S. TA C-DIR /B
Baillarguet 34398 Montpellier Cedex 5, France
maitre@cirad.fr

New and improved: This Ghanaian village used improved planting stock for their ITTO supported teak plantation. *Photo: J. Gasana*

ALTHOUGH widely planted in the tropics, teak (*Tectona grandis*) originates from India, Laos, Myanmar and Thailand. Strong international demand for good quality teak has resulted in depletion of natural stocks, which are increasingly protected by strict conservation policies to preserve biodiversity.

This situation has resulted in changes in the basic plantation concept of teak. Traditional teak plantations, managed mostly by state organizations for harvesting in 60–80 years (Ball et al. 2000), are no longer well-adapted to the current needs of private investors looking for the best returns in the shortest possible time. For such investors, the quality and the origin of teak planting stock has become a crucial issue.

… the 'seedling route' is outdated and actually represents a deterrent to wide scale increased productivity in teak plantations, and as such to commercial teak plantation investment.

Limits of teak seedling forestry

The traditional means of propagating teak through seeds has been practiced for centuries. While it allows the possibility of storing seedlings in the form of 'stumps' for transportation, to wait for suitable planting conditions, etc., this mode of sexual propagation has the following serious handicaps:

- the quantity of seeds produced per tree is too limited and their germination rates remain low overall (20–25%);
- the period to reach the flowering/seed-bearing stage is lengthy, due to the desirability of maintaining the terminal meristem in a vegetative state for as long as possible (flowering status usually induces a fork formation and straight bole length directly affects teak's market value);
- significant variability of economically important traits (growth, form, wood technological and aesthetic characteristics, etc.) among individuals even when derived from the same mother tree ; and
- limited knowledge about the inheritability of such economically important traits (and consequent uncertainty about potential gains from costly breeding programs).

Several experts (e.g. Kjaer and Foster 1996, Kjaer et al. 2000) have documented these shortcomings. White and Gavinlertvatana (1999) stated that the 'seedling route' is outdated and actually represents a deterrent to wide scale increased productivity in teak plantations, and as such to commercial teak plantation investment. According to these authors, the magnitude of the real genetic gain associated with the seedling route remains uncertain, as does the value of teak breeding efforts employing it over the past several decades. This is undoubtedly a major concern for potential investors, for whom rapid and assured returns are crucial.

Propagating teak vegetatively

In contrast to seed propagation (where every individual is genetically different from every other), asexual or vegetative propagation involves duplicating (theoretically without limit) genotypes while preserving through mitotic divisions their original genetic make-up, and consequently their individual characteristics. This is essential to ensure the transfer of traits that are under non-additive control, especially those that are of economic importance. Moreover, vegetative propagation is applicable to any individual, even

Attack of the clones: Teak plantations at 42 months, established from local seedling stock (left) and from selected clones (right), under the same environmental and cultural conditions in Mato Grosso, Brazil. *Photo: O. Monteuuis*

those without fertile seeds, due to immaturity, unfavorable environmental conditions, or other factors.

As in other tree species, multiplying teak vegetatively by cuttings is a useful research technique in addition to its obvious application to operational or production activities. Research applications encompass, for instance:

- clonal tests, including between clone comparisons and within clone variability ('C effects');
- genotype—environment interactions;
- genetic parameter estimates i.e. broad sense inheritabilities, genetic correlations between traits, etc.; and
- ex-situ conservation of particular genotypes or gene complexes.

More practically, propagating teak vegetatively by cuttings can be useful for establishing 'safe' clonal seed orchards, avoiding risks of 'illegitimate' clones associated with clonal seed orchards traditionally produced by grafting on unselected stock. Vegetative propagation can also be used to develop timber production populations using either bulk or clonal strategies, the pros and cons of which have been documented by Monteuuis (2000). Clonal propagation by rooted cuttings from wisely selected teak 'plus' trees remains the only way to generate top grade teak timber trees in a reasonable time, counteracting the heterogeneity associated with seedling or even bulk options.

Comparative economic analyses have shown that for the production of more than 100 000 cuttings per year, tissue culture procedures are more efficient than nursery production.

New mass clonal propagation methods

In little more than a decade, the possibility to mass clonally propagate any mature selected teak trees at reasonable cost, either in nursery or tissue culture conditions, has radically changed the prospects of teak plantations (Monteuuis 1995).

The nursery techniques developed initially in Sabah (Malaysia) consist of serially propagating selected teak trees of any age by rooted cuttings under proper mist-system facilities. Average rooting rates of 70 to 80% were obtained from several thousand cuttings collected from mature teak genotypes intensively and properly managed as container-grown stock plants. On average 40 rooted cuttings were produced annually per stock plant, corresponding to 600 rooted cuttings per square meter (15 stock plants per square meter). This method has been successfully transferred to various countries of South East Asia, Latin America and Africa.

Comparative economic analyses have shown that for the production of more than 100 000 cuttings per year, tissue culture procedures are more efficient than nursery production. In addition to local uses, tissue culture plants can be exported (in the absence of any phytosanitary restrictions), contrary to rooted cuttings, for enriching local genetic bases. Moreover, these in-vitro plants can be produced year around, irrespective of the climatic conditions, unlike nurseries.

The tissue culture protocols developed for teak were conceived as simply as possible in order to be easily applicable, cost efficient and highly productive (the latter two are particularly important to large-scale applications). The micropropagation technique established is similar to propagation by rooted cuttings. Shoots are raised from auxiliary buds, in order to limit the risks of somaclonal variations and maintain genotypic fidelity. The in-vitro elongated shoots are rooted in more natural nursery conditions. This technology allows the mass micropropagation of any teak genotype to give rise to an unlimited number of clonal offspring, resulting in exponential multiplication rates through successive subculture cycles. Several million cloned teak plantlets have been produced in different laboratories using this technique to date.

Once transferred to the field, the rooted cuttings or microcuttings have performed satisfactorily, remaining true-to-type. The first mass-produced rooted cuttings and microcuttings from mature trees were field planted in 1993 and in 1995, respectively. In addition to superior phenotypic traits, after 6–8 years the clonal offspring display (depending on site conditions) an unexpectedly high proportion of valuable quality heartwood (Goh and Monteuuis 2005, Goh et al. 2007).

Innovative technologies for teak forestry

Usually only phenotypic (external) criteria are considered when selecting the candidate plus trees (CPT), from which the clones arise. The importance of also using intrinsic wood qualities along with external traits for CPT selection is obvious given the high value of teak timber, and the variations between grades and prices of this timber based on wood quality. This is now possible thanks to the development of non-destructive wood core sampling analyses as described in Goh et al. (2007). Near Infrared Spectroscopy (NIRS) technology allows rapid analysis of such core samples for basic density, the modulus of elasticity and strength, radial and tangential shrinkage, natural durability as well as the extractive content of the wood. Once properly calibrated, NIRS is a fast, low-cost, easy-to-use, non-destructive, reliable and versatile analytical method, which can accommodate heterogeneous wood samples, and identify slight chemically induced wood variations.

Adapted DNA molecular markers are another innovative technology to assist the development of clonal forestry with teak. This technology allows the primary origin of various teak populations available locally to be determined, i.e. whether they were initially imported from India, Myanmar (ex-Burma), Thailand or Laos. This is useful for basic research (i.e. determining range of adaptability of native teak provenances to other environments in various countries), as well as for operational and commercial activities. For example, the highly prized Burma teak may now also exist in several other countries. Much Latin American teak (introduced largely via Trinidad and Tobago) appears to have been originally from Tenasserim (Burma), as does the Solomon Islands' teak.

Assessing the genetic diversity and levels of co-ancestry/inter-breeding in the teak germplasm that exists locally allows for optimal management and utilization of tree improvement programs. Knowledge of the genetic background of CPTs and/or seed producers will enable tactics to reduce risks of inbreeding to be employed, for instance by limiting the numbers of close relatives included in seed orchards. Information on the genetic relatedness of candidate clones for wood production plantations will also enable implementation of tactics to control the level of genetic diversity/recombination in such plantations and possibly improve pest and disease resistance. Clonal identification by DNA fingerprinting can also have applications in establishing property rights or genetic fidelity of mass-propagated clones.

Conclusion

Since the mid-1990s, millions of rooted cuttings and microcuttings of clonally propagated teak trees have been produced and planted by private companies all around the world. The superiority of such planting material compared to seedlings has led to increasing interest in this technology from both private investors and landowners eager to maximize returns in a reasonable time. In addition to enabling superior volume yields and enhanced wood quality in both traditional plantation systems and agroforestry applications, teak clones also offer an opportunity to enrich local teak genetic resources. Tree breeders should continue research and development to ensure that the best available clones are available for teak plantation establishment throughout the tropics. This will help to ensure that the excellent properties of this remarkable timber continue to be enjoyed in perpetuity, regardless of the declining availability of natural stocks.

Adapted DNA molecular markers … allow the primary origin of various teak populations available locally to be determined …

References

Ball, J.B., Pandey, D. & Hira, I.S. 2000. *Global overview of teak plantations*. FORSPA Publication No 24/2000, Teaknet Publication No 3: 11–33.

Goh, D. & Monteuuis, O. 2005. *Rationale for developing intensive teak clonal plantations, with special reference to Sabah*. Bois et Forêts des Tropiques, 28: 5–15.

Goh, D.K.S., Chaix, G., Baillères, H. & Monteuuis, O. 2007. *Mass production and quality control of teak clones for tropical plantations: The Yayasan Sabah Group and Forestry Department of Cirad Joint Project as a case study*. Bois et Forêts des Tropiques (In press, July 2007).

Kjaer, E.D and Foster, G.S. 1996. *The economics of tree improvement of teak (*Tectona grandis L.*)*. Technical note No 43, DANIDA Forest Seed Centre, Denmark, 23p.

Kjaer, E.D., Kaosa-ard, A. and 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 No 24/2000, TEAKNET Publication No 3: 161–189.

Monteuuis, O. 1995. *Recent advances in mass clonal propagation of teak*. Proc. of BIO-REFOR, Kangar, Malaisie, 28 Nov–1 Dec1994: 117–121.

Monteuuis, O. 2000. *Propagating teak by cuttings and microcuttings*. FORSPA Publication No 24/2000, Teaknet Publication No 3: 209–222.

White, K.J. and Gavinlertvatana, P. 1999. *Vegetative reproduction of teak: the future to increased productivity*. Paper presented at the Regional Seminar on site, technology and productivity of teak plantations, Chiang Mai, Thaïland, 26–29 Jan.1999, 7p.