3.2 Origin and Global Dissemination of Clonal Material in Planted Teak Forests

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Preamble

Anticipated for a long time, teak clonal forestry has finally become a reality. Teak clonal plantations have rapidly expanded over the past years, driven primarily by private commercial interests. This could explain why a lot of information is kept confidential. This report should therefore not be considered as exhaustive and definitive, but more as an eye opener on certain aspects of teak clonal plantations.

3.2.1 Background

3.2.1.1 Rationale of Cloning Teak

Propagation by seeds remains for teak as for any other species the easier, the more natural and efficient way to produce new genotypes. This is essential for guaranteeing a suitable genetic diversity and also for genetic improvement through wise breeding activities. Propagating teak through seeds has been practiced for centuries, with the possibility of storing the seedlings in the form of "stumps" when necessary, for instance while waiting for suitable planting conditions (Kaosa-ard, 1986). However, mass producing teak planting stock by seeds is hindered by serious handicaps such as:

i) A negative correlation between the onset of fruiting/seed production and clear bole length (Kaosa-ard *et al.* 1998, Callister 2013), affecting the commercial value of the latter. Practically, seeds collected from early flowering individuals will ultimately give rise to poor quality trees.
ii) A quantitatively limited seed production that is prone to tree, year and site variations (Wellendorf and Kaosa-ard 1988, White, 1991).
iii) An overall low and unpredictable seed germination capacity that rapidly declines with time after collection, although differences may exist between seed sources (Kaosa-ard, 1986, White, 1991).
iv) A substantial variability among individuals, even when derived from the same mother tree, affecting traits of major economic importance like growth, trunk form, technological and aesthetic characteristics of the wood (Bedel 1989, Chaix *et al.*, 2011, Monteuuis *et al.*, 2011).
v) Limited accurate knowledge about the inheritance of economically significant traits making the ultimate gain uncertain, notwithstanding the time constraints associated with sound breeding programs (Kjaer and Foster, 1996, Chaix *et al.*, 2011, Monteuuis *et al.*, 2011).

By contrast, cloning consists in duplicating genotypes, theoretically unlimitedly by asexual or vegetative propagation methods, while preserving through mitotic divisions their original genetic make-up. Consequently, all their characteristics, including those of great economic impact which can be poorly inherited by seed propagation, will be transferred to the offspring. The resulting crop will uniformly exhibit all the features of the original tree it arises from. This emphasises the importance of reliably selecting candidate plus trees to be cloned, the so called CPTs, which must be really outstanding for economically important traits, the more the better (Murillo and Badilla 2002, 2004, Goh and Monteuuis 2005, Goh *et al.*, 2007).

Moreover, vegetative propagation can be applied to any individual that does not produce fertile seeds, either because it has not entered the mature stage yet, or due to unfavourable environmental conditions.

Theoretically, for teak as for any other tree species, cloning can be useful for research as well as for commercial planting (Monteuuis and Goh 1999). More specifically, teak clonal plantations are expected to produce high yield of premium and uniform quality timber in the shortest delays. Practically, this will depend upon the capacity of the species to be efficiently mass clonally propagated.

3.2.1.2 From Theory to Practice: the Determining Impact of Efficient Mass Clonal Propagation Techniques

The mass production of teak clones, especially from mature selected trees has for a long time been hindered by the lack of efficient technology. Grafting has been practised for decades on a small scale mainly for establishing clonal seed orchards or "CSO" in various countries (White 1991, Monteuuis and Ugalde, 2013). A few experiments have demonstrated that teak genotypes of various ages could be propagated *in vitro* but not with the efficiency required for mass production (Gupta *et al.*, 1980, Mascarenhas and Muralidharan, 1993), except in Thailand, where young seedlings were used under the Forest Royal Department during the 1980s (Kaosa-ard *et al.*, 1987). However, the field behaviour of such tissue culture-derived plantlets was not sufficient to offset the production cost, and as such, seedlings have remained the

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main source of planting stock for national teak plantation programs in this country.
The situation changed dramatically during the 1990s with the development of efficient nursery and tissue culture techniques adapted to the mass production of clones by rooted cuttings and microcuttings of any selected teak tree, regardless of its age (Monteuuis 1995, Monteuuis *et al.*, 1995, 1998). Moreover, the possibility to export tissue-cultured teak microshoots to international destinations opened up wide market prospects mainly under the impulse of two big private companies: Thai Orchids from Thailand and YSG Biotech (www.ysgbiotech.com) – ICSB at that time – from Sabah, East Malaysia. Amazingly, although Thai Orchids activities on teak remained very limited in its native country, the company expanded quite rapidly, generating most of its business returns at the international level thanks to a very dynamic marketing policy and through partnerships with Monfori (subsidiary of Monsanto) in Indonesia, Forbio in Australia and Tropbio in Malaysia.

3.2.2 Selecting and Propagating the Clones

3.2.2.1 Selecting the Genotypes to be Vegetatively Propagated

The selection of CPTs for clonal commercial plantations will be based primarily on economically-important traits such as vigour, growth rate, bole shape, branchiness and wood quality, taking advantage of non-destructive assessment methods (Murillo and Badilla, 2002, Goh *et al.*, 2007, Kokutse *et al.*, 2016). As a general rule, the larger the difference with the rest of the population, or the stronger the intensity of selection, the greater the commercial gain. Several of these traits are expressed and thus can be assessed only from developed or mature enough trees, as too many uncertainties are associated with juvenile trees or seedlings to allow for a reliable selection. In addition, for safer clonal deployment especially with regard to disease risks, the CPTs must not be too genetically close.

Also to be considered are genotype x site interaction issues: to what extent can these traits be modified by planting site conditions? This will basically depend on the capacity of the genotype initially selected by phenotypic assessment in a specific site to adapt to other environments. To answer this question is the main purpose of properly set up clonal tests, notwithstanding the time, space, plant material and human resources required.

The genetic quality and the diversity of the base populations or more seldom the breeding populations from which the CPTs are selected are essential (Goh and Monteuuis, 2005, Goh *et al.*, 2007), although attractive features of a few isolated CPTs can give rise to success stories (Goh and Monteuuis, 2012). The quality of the CPTs has always been an overriding concern for YSG Biotech which started its clonal propagation program from mature CPTs which can be more reliably selected than juvenile seedlings or seeds. The initial gene pool limited to a few individuals from the Solomon Islands has rapidly and considerably been enriched by new teak genetic origins from various sources (Goh and Monteuuis 2009). The company currently owns the richest teak gene pool from which new clones have been selected to be field-tested or sold to any potential buyers who can have access to the well documented genetic origin of each clone.

3.2.2.2 Propagation Strategies: Bulk Versus Separated Clones

There are basically two options for vegetative propagation of genotypes. This can be done without maintaining any individual identification, as a mixture. This strategy, referred to as “bulk propagation”, differs essentially from clonal propagation whereby the genotypic identity is rigorously and individually preserved through all the successive cycles of the clonal propagation process, and which may last several centuries in certain cases.

In contrast to clonal propagation, the bulk option does not require any strict and clear labelling of each genotype or clone during the successive cycles of the propagation chain, then during the subsequent nursery and field steps. Its main advantage is to make all these operations easier, simpler and cheaper.

Vegetatively propagating a mixture of unidentified genotypes will maintain a certain degree of genetic variability, depending on the number of genotypes involved from the very beginning. Consequently, the resulting wood populations may look phenotypically heterogeneous, teak being prone to noticeable phenotypic differences between genotypes. However, successive generations of bulk propagation will very likely result in a significant reduction of the original genetic base, which may eventually consist of only one genotype. This is due to genotypic differences in the multiplication and rooting rates, the genotypes producing the more shoots the higher the capacity for adventitious rooting supplanting ultimately the others.

Clonal propagation involving rigorous genotypic identification prevents such risks of losing control of the genetic fidelity of the material under propagation, the numbers of clones and of their respective clonal representatives remaining known throughout the entire propagation process. This information is of great importance in the further use of the propagated plant material, be it for sales or field establishment, in the form of monoclonal blocks or of polyclonal varieties. These consist of a mix of selected clones, each being represented by an accurate number of plants. Polyclonal varieties differ in this respect from bulk propagation-issued populations of more uncertain genetic composition.

3.2.2.3 Techniques

Several vegetative propagation techniques have been successfully applied to teak. Although useful for mobilizing and clonally propagating in few numbers mature genotypes, layering and grafting are not applicable to large-scale clonal propagation of teak. Furthermore, the drawbacks resulting from the combination of two different genotypes for grafted clones should not be underestimated (Monteuuis and Ugalde, 2013).

Such hindrances can be overcome by the use of self-rooted teak clones mass produced by efficient rooted cuttings or *in vitro* micropropagation methods as described hereinafter.

Propagation by Rooted Cuttings

Rooting the first generation of shoots collected directly from *in situ* CPTs, also referred to as the mobilization phase, is considered the most critical step, especially when the CPTs are old enough to be reliably selected for economically important traits. The "stick method" developed in Sabah had helped to achieve this goal (Monteuuis *et al.*, 1995) and was preferred as more conservative than coppice shoots arising from the stump of the selected tree once this latter had been felled (Palanisamy and Subramanian, 2001, Singh *et al.*, 2006, Husen and Pal, 2007). The first few rooted cuttings obtained are used as intensively managed stock plants and this during 2 or 3 successive cycles of serial propagation by rooted cuttings until the material will be sufficiently physiologically rejuvenated to be used for clonal tests or large-scale plantations. Unlike many species, teak rooted cuttings develop true-to-type in absence of plagiotropic growth symptoms.

Developed first in Sabah (Monteuuis, 1995; Monteuuis *et al.*, 1995), this technique has been proven to be quite efficient and cost-effective in several countries for mass-clonally propagating any teak plus tree regardless of its age providing:

i) Suitable nursery facilities as described in Monteuuis (2000) are available, emphasizing the usefulness of a reliable mist system for rooting the cuttings and thereafter, facilitating their acclimatization.
ii) The cuttings and then the stock plants are judiciously and rigorously managed by competent and dedicated staff for achieving and maintaining the physiological rejuvenation needed for ensuring high multiplication and rooting rates.

Special mention has to be made of the mini-cutting technique developed initially in Costa Rica and then used in different Latin American countries (Murillo and Badilla, 2002; Monteuuis and Ugalde 2013; Morillo *et al.*, 2013). The shoots used as cuttings and the stock plants are both much smaller than those described previously (Monteuuis *et al.*, 1995). This system, proven to be quite efficient and attractive, requires, however, more sophisticated stock plant management and greenhouse facilities equipped with a high quality mist or fog system when shoots are rooted under aeroponics. The entire production cost of these mini-cuttings, including the facilities, has to be taken into consideration and might be a handicap compared to more conventional nursery techniques. They also will always be less efficient, more exposed to climatic constraints and requiring bigger facilities with competent staff for properly managing the stock plants than efficient tissue culture procedures (Monteuuis, 2000). Another major limitation is the impossibility to export rooted cuttings as any *in vivo* plant to foreign countries due to phytosanitary constraints, contrary to tissue-cultured plants which are by definition pathogen-free.

In Vitro Micropropagation

The easier and more efficient procedure for mass-producing teak clones in tissue-culture conditions is micropropagation by axillary budding. This is also the safest way for guaranteeing the genotypic conformity required for true-to-typeness. The protocol developed during the early 1990s in Sabah has proven to be quite adapted to the mass production of teak clones from *in vitro* germinated seeds and from teak trees of any age (Monteuuis *et al.*, 1998). Mononodal – single node – and terminal portions from vegetative shoots or 0.3 mm-long shoot apical meristems are the two types of primary explants utilized for initiating the cultures that can be sustained for several years through regular sub-cultures. The particularities of this technique including the pros and cons have been detailed (Monteuuis, 2000; Monteuuis and Ugalde, 2013). Notwithstanding a higher initial investment, the advantages of mass-propagating teak clones by tissue culture compared to more conventional nursery methods are of greater overall efficiency, especially when initiated from mature selected genotypes, using a much smaller surface area and regardless of the climatic conditions. In addition, only tissue-cultured clones, being pathogen-free, can be sent overseas across the globe and in the absence of any phytosanitary restrictions. This, and the access to superior teak clones supplied under specific conditions by a few private tissue-culture companies have accounted for the striking development of teak clonal plantations in many countries under the humid tropics over the past several years (Ugalde, 2013).

3.2.3 Current Status: Origin, Distribution and Deployment of the Clones Planted

3.2.3.1 Asia and Oceania

Notwithstanding a limited impact at the domestic level, Malaysia with YSG Biotech in Sabah and Thailand through Thai Orchids together with its subsidiary companies has played a major role in teak clone distribution all over the world. However, the genetic origin and composition of the materials supplied by Thai Orchids to Australia, Indonesia and Central America under the trade name of TOL Super Teak have never been clearly specified. Despite the fact of being tissue culture-issued, which was reported to have the miracle power of increasing its value by over 200% (see: http://www.tolusa.com/documents/TOL_Teak_Info.pdf), this material assumedly from

Northern Thailand origin turned out to be not so adapted to most of the sites where it had been planted. This could have caused the failure of Thai Orchids teak activities after some 20 years of intensive operations. Conversely, YSG Biotech, with a less dynamic marketing strategy, had placed more emphasis on genetic improvement of the species through the wise and prudent selection of mature CPTs (Goh *et al.* 2007, Goh and Monteuuis 2009). These activities have been supported and well documented by numerous scientific publications and field trials that can be visited by clients who are willing to acquire YSG Biotech clones. After more than 20 years of activities, YSG Biotech is still intensively supplying a broad variety of teak clones and genetically improved seeds from progeny/provenance trials all over the world.

Figure 1

Jati Jumbo/YSG Biotech clones 4 years after planting on steep slopes, Southern Java.

Maintenance was limited to weeding the first year, in absence of any pruning operation. The trees display the YSG Biotech TG1-8 characteristic features i.e., excellent straightness, reduced lateral branching and high leaf density accounting for increased photosynthesis and impressive growth rate. Photo: Monteuuis O.

In Indonesia, Superteak is currently considered as the best quality teak planting material for governmental teak re/afforestation projects. It is produced by Jati Unggul Nusantara “JUN” that has taken over PT Monfori Nusantara, the Indonesian subsidiary of Thai Orchids. In the absence of reliable information, it can be assumed that Superteak derives from Thai Orchids germplasm. However, this genepool has likely been improved by the enrichments from other sources such as Jati Jumbo, clonal materials from the company known as Tunas Agro Lestari (TAL), that can be easily identified based on its distinctive phenotypic features. In 2014, Superteak plants were sold at 15,000 IDR (1.14 US$) per plantable unit in plastic bag container, ex JUN nursery in Jogjarkarta. Based on farmer assessments, an average growth rate of 18 m^3/ha/yr of marketable teak wood could be expected for rotations of 5 years at 1000 trees/ha. However, the noticeable within-stand variations in yield and phenotypic traits observed for these Superteak materials prompted the users, mostly farmers, to carry out another round of plus trees selection. This had resulted in a more uniform, improved quality and cheaper material at 8,000 to 9,000 IDR (0.65 US$), depending on the quantities of plants ordered, per plantable unit in plastic bag container, from the ex Jati Utama Nasional nursery in the vicinity of Jogjarkarta. Annual yield of 20-22 m^3/ha can be expected from this Superteak improved material planted at 1000 trees/ha for 5 yr-long rotations.

Jati Jumbo turned out to be the Indonesian trade name of the YSG Biotech Solomon Island clones. On suitable sites, these clones planted in monoclonal blocks display very attractive and uniform phenotypic features (Figure 1). An average yield of at least 25 m^3/ha/yr can be expected for 1111 trees (3 x 3 m spacing)/ha after 5 years, the time at which a 50% systematic thinning must be done for allowing the remaining 555 trees to develop further. The selling price was 12,500 IDR (0.95 US$) per plantable unit in plastic bag containers ex nursery in Bogor.

Teak clones mainly from Thai orchids and YSG Biotech have been actively planted in Queensland, Eastern Australia during the early to the mid-2000s but due to changes of governmental policies, almost all the teak clonal plantations were later converted for other uses.

3.2.3.2 Latin America

Latin America is the region where teak clonal plantations have expanded the most rapidly since the early 2000s (Ugalde 2013). This was primarily due to the superiority of the clonal material acquired from YSG Biotech by a very dynamic private Brazilian company known as Bioteca before it became Proteca that specialized in mass propagation of teak by tissue culture (proteca.com.br, Goh and Monteuuis 2012, Ugalde 2013). From the beginning, Proteca had managed to develop its marketing activities to the whole of Latin America thanks to the possibility of exporting tissue-cultured plants to any foreign countries in the absence of phytosanitary restrictions as long as the shipping time is not too long. In this respect, Proteca had easier and safer access to Latin American buyers than YSG Biotech located at a far greater distance. Several millions of plantlets, mainly consisting of YSG Biotech clones, have to date been produced by Proteca, which has also developed nursery techniques for “on the spot” mass clonal production by mini-cuttings from juvenile or *in vitro*-rejuvenated genotypes (Ugalde, 2013; proteca.com.br). This option initially developed in Costa Rica (Murillo *et al.*, 2013) and whose pros and cons have been detailed elsewhere (Monteuuis and Ugalde, 2013) has been used routinely for mass producing clones selected locally or imported from abroad, at the domestic level. This has accounted for the large and uncontrolled dissemination of superior teak clones in many Latin American countries with special mention of the highly morphologically distinguishable YSG Biotech clones after they had been introduced directly from Malaysia, or via Proteca.

Since its inception in year 2000, Genfores, a Costa Rican tree improvement and gene conservation cooperative, has actively contributed to teak breeding and clone selection in close collaboration with private companies like Precious Woods, now Novel Teak, Barca, and Pan-American Woods (Murillo and Badilla, 2004; Murillo *et al.*, 2004). Initiated at the national level where 60% of the teak plants produced in Costa Rica nowadays are clones, (Murillo personal communication), Genfores expertise has benefitted an increasing number of Latin American countries including Brazil, Columbia (Espitia *et al.*, 2011), Ecuador, Nicaragua, Panama. For newly selected clones which have not been soundly field tested in operational planting conditions yet, GenFores recommends planting a sufficient number of these "candidate" clones in mixture, whereas more certified clones can be deployed in monoclonal blocks.

Teak clonal plantations are also rapidly expanding in other Central American countries like Mexico, and Guatemala, but unfortunately little is known regarding the genetic background of the clones that are massively supplied and planted there. The dramatic consequences of establishing large-scale plantations with too few clones and particularly, of questionable value, should not be minimized. And it should be kept in mind that whatever the origin, the greater the number of propagation cycles and intermediaries between the original source i.e., the CPT in situ and the operational planting, the higher the risks of mixing and losing the initial clones especially when those have been propagated or supplied as a mixture, in bulk.

3.2.3.3 Africa

Kilombero Valley Teak Company, KVTC for short, in Tanzania, East Africa is currently the biggest private teak plantation for the whole Africa. They started planting clones 12 years ago with the YSG Biotech TG1-8 (Goh and Monteuuis 2012) later enriched with locally selected materials. Out of the 8000 ha currently planted with teak, 300 ha are clonal plantations encompassing clonal tests and to a lesser extent, commercial plantations of clones in mixture. The origins of the clones are YSG Biotech (50%), KVTC own selections (40%) and various others (10%). All the different clones are individually propagated in-house by rooted cuttings (up to 100,000 per year) allowing a total control of the genetic composition of the clonal material deployed.

100 ha of teak clonal plantations consisting exclusively of a mixture of the same 8 YSG Biotech TG1-8 clones have recently been established by PFM in Gabon, Central Africa, under average rainfall of 2,500 mm/yr with a 4 month-long dry season. A clonal test comprising 32 YSG Biotech clones supplied as micro-cuttings has also been set up within the same project, to be ultimately converted into a CSO. All these clones, well identified, have been individually planted in a clonal bank.

In West Africa, large-scale clonal propagation by rooted cuttings from juvenile CSO seedlings took place in SODEFOR, Côte d'Ivoire, during the years 1995-2005 (Martin *et al.*, 2000), before applying the technology developed in Sabah (Monteuuis *et al.*, 1995) for mature selected CPTs. This technology was also proven to be successful in Forig, Ghana, and more recently in Togo, where all the 25 Plus trees selected could be cloned (Kokutse *et al.*, 2016). At SoGB, Grand Béréby, Côte d'Ivoire, 24 YSG Biotech clones have also been established within a clonal test that can be ultimately utilised as a CSO after proper thinning, the TG1-8 clones being planted between rubber tree rows as a pilot agroforestry plantation.

3.2.4 Critical Issues and Recommendations:

3.2.4.1 Genetic Background of the Planted Clones

The main risk of teak clonal forestry is the lack and loss of information regarding the genetic origin of the clones that have been mass-propagated and planted. This can be due to different reasons such as:

- The genetic background of the clone is unknown from the start;
- Inadvertent identity error or mix-up while manipulating the clones during the propagation process, setting up stock plants or during the planting operation.
- Genotype-induced differences of capacity for mass clonal propagation, especially when the vegetative procedures applied and particularly the *in vitro* protocols are not sustainably compatible with every clone requirements or particularities.
- Long-term use of bulk propagation as described earlier, where clones, which are more responsive and produce the higher numbers of shoots that can be easily rooted, will eventually supplant the others.
- Marketing strategies for clones supplied in mixture like the Malaysian Solomon clones, without revealing the accurate quantity and identity of the genotypes, or referring only to the country they are coming from. This kind of information is too vague and imprecise as the same clones can be found in various countries. Consequently clones assumed to be different as imported from different places or suppliers may actually be the same.

The threat is a rapid impoverishment of the genetic diversity of the clones deployed for large-scale planting, exposing them to greater risks of pest and disease problems and ultimately of a too high uniformity of the end-use products.

This is why maintaining wise genetic improvement programs aiming at producing new clones is crucial (Monteuuis and Goh, 2005). The different clones introduced recently in trials by PFM in Gabon and SoGB in

Côte d'Ivoire with their eventual conversion to CSOs are a good illustration of what can be done in this respect.

Noteworthy is also the sound utilization of adapted DNA markers that can be very helpful for overcoming genetic origin and relatedness issues (Monteuuis and Ugalde, 2013), but unfortunately these technologies are currently still underused especially at the operational level.

3.2.4.2 Planting Site

Precipitations appear to be of great importance. As long as they are well drained and not prone to waterlogging, planting sites exposed to high and well distributed rainfall regime – 2000 mm/yr or more – are recommended to get the earliest returns on investments for superior teak clones which are usually more expensive than unselected seedlings. Conversely, long dry periods have been observed to promote lateral branching of certain clones, depreciating their log quality even if the volume of wood produced remains superior to what can be obtained from other origins (Monteuuis and Goh 2012). Further, soil acidity has apparently less influence on teak development (Chaix *et al.*, 2011, Monteuuis *et al.*, 2011, Goh *et al.*, 2013).

3.2.4.3 Clone Deployment

Clones can be used for establishing monospecific plantations, but also to be intercropped with other species of a different kind within agroforestry systems or even for silvopastoralism.

Clones for monospecific plantations can be mixed with seedlings or are usually planted in mixture as a bulk with the purpose of minimizing the negative impact of unadapted genotypes as compared to monoclonal blocks which are more uniform, for better or worse. Such mixtures can be warranted as most of the clones are not tested in the conditions of large-scale deployment prior to their utilisation owing to time, space and cost reasons. In addition, intercropping clones with seedlings diminishes planting stock cost, seedlings being cheaper than cutting or microcutting-derived clonal material. On the other hand, selected clones, contrary to seedlings, do not require intensive thinning operations for removing the poorest trees and thus can be planted at a lower density, compensating at least to some extent for their higher cost.

Silvicultural practices consisting in harvesting several times from the same stump, taking advantage of teak specific coppicing ability for avoiding replanting have been undertaken, but were apparently not as successful as expected (Martin *et al.*, 2000, 1999). Similarly to industrial eucalyptus plantations, the best way of deploying teak clones proven to be adapted to the local conditions is in the form of monoclonal blocks established according to a space-time mosaic design. The intention is to avoid overly large areas planted with genetically related clones which are more susceptible to potential pest and disease damages. The size of these monoclonal blocks will depend on the total number of clones, their genetic relatedness, their individual phenotypic characteristics, the rotation length and the total area to be planted.

Teak clones can also be selected on trunk shape and crown form criteria to be intercropped with other fruit or vegetable species within highly productive agroforestry systems, benefiting from the culture conditions provided to the other crops for a higher return than could be obtained from seed-issued trees.

Finally, teak clones due to their higher vigour, stronger root systems and attractive phenotypic features have been observed to be more suitable and economically profitable for silvopasture than seedlings (Ugalde, 2013).

3.2.5 Concluding Remarks

For teak, the high-value tropical timber species that has been the most planted worldwide, clonal forestry has demonstrated its capacity to overcome most of the limitations associated with seedling-derived plantations. It is now possible to establish fast growing and uniform teak clonal stands of enhanced yields, high wood quality and commercial value on short rotations. The clonal option appears to be the best way to maximise returns on investments for the establishment of monospecific or mixed teak plantations. Teak clonal forestry can thus become a success story providing outstanding genotypes that can be wisely and reliably selected to be mass clonally multiplied using appropriate methods before sound deployment on suitable planting sites.

Acknowledgements: The information provided by Hans Lemm and Olman Murillo on teak clonal plantations in KVTC and in Latin America respectively is gratefully acknowledged.

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