Behaviour of the "YSG Biotech TG1-8" teak clones under various site conditions: first observations

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Photo 1.
The YSG BIOTECH TG1-8 teak clones 2 yrs after planting in West Java exhibiting their characteristic features: self-pruned, fork-free and straight stems with almost no lateral branches and a high density of large leaves for enhanced photographsynthetic capacity and hence, promotion of growth.
Photo H. Sarwono.

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RÉSUMÉ

COMPORTEMENT DES CLONES DE TECK « YSG BIOTECH TG1-8 » DANS DES CONDITIONS DE SITE VARIÉES : PREMIÈRES OBSERVATIONS

Au début des années 1990 au Sabah (Malaisie orientale), la division « Biotech » du groupe Yayasan Sabah a développé avec des chercheurs du Cirad Forêt une technique efficiente de clonage industriel par bouturage et microbouturage de tecks, *Tectona grandis*, de tous âges. Les premiers clones ont été produits à partir de huit tecks “Plus” sélectionnés au Sabah, pour leurs caractéristiques phénotypiques et de croissance supérieures, sous 2 500 mm de pluie bien répartis sur l'année. Le comportement tout à fait convaincant au champ des premiers représentants de ces clones a favorisé rapidement leur propagation à grande échelle pour répondre aux fortes demandes, locales et internationales. Depuis, plusieurs millions de tecks clonés ont été produits à partir de ces huit têtes de clone initiales et la demande ne cesse d’augmenter. Cette situation nous a incités à synthétiser les informations disponibles sur le comportement de ces clones dans les différents sites où ils ont été introduits. Les premières observations indiquent que ce matériel a fait preuve d’une grande faculté d’adaptation dans des conditions environnementales très variées, surpassant dans chaque site d’introduction toutes les autres origines de tecks, tant du point de vue de la quantité que de la qualité du bois produit. Cette remarque vaut également pour des lieux ne recevant que 1 000 mm de pluie par an avec huit mois de saison sèche, conditions pluviométriques bien inférieures à celles du Sabah. Des situations bénéficiant d’une forte pluviométrie équitablement répartie sur l’ensemble de l’année sont néanmoins préférables pour garantir le meilleur de ces clones. Un de leurs attraits majeurs demeure la formation précoce de fûts droits et hauts avec un minimum de branches, ce qui encourage leur utilisation en agroforesterie et réduit les opérations d’élagage. La disponibilité en clones de tecks présentant de tels avantages comparatifs est à l’origine de l’essor actuel des plantations clonales industrielles de tecks dans de nombreux pays.

Mots-clés : adaptabilité, clones, conditions environnementales, pluviométrie, croissance, caractéristiques phénotypiques, *Tectona grandis*.

ABSTRACT

BEHAVIOUR OF THE “YSG BIOTECH TG1-8” TEAK CLONES UNDER VARIOUS SITE CONDITIONS: FIRST OBSERVATIONS

During the early 1990’s in Sabah (East Malaysia), the Company Yayasan Sabah Group Biotech (“YSG Biotech”), jointly with CIRAD (France) Forest department scientists, has developed an efficient method for mass cloning superior teak trees, *Tectona grandis*, of any age by rooted cuttings and by micropropagation. The first clones were produced from eight superior (“Plus”) trees initially selected on phenotypic traits and growth in Sabah under 2,500 mm/yr of rainfall without a distinct dry season. The outstanding field behaviour of the clonal offspring assessed locally rapidly led to their mass propagation to meet local and international demands. Since then, millions of clonal offspring have been produced from the eight “Plus” trees and the demands keep increasing due to the attractiveness of these materials. This context has prompted us to compile the information available on the field behaviour of these clones during their early stages of development in the different countries where they have been planted. The first observations indicated that the eight clones adapt surprisingly well to a wide range of environmental conditions, outperforming all other teak sources in terms of productivity and qualitative traits in every location where they had been planted. These include places with annual rainfall of 1,000 mm and eight months of dry season, which is in total contrast to the conditions of their selection in Sabah. Nonetheless, sites with high rainfall evenly distributed throughout the year are observed to be more suitable to guarantee the best true-to-type development of these clones. One of their main assets is the early and rapid production of a long and straight clear bole with minimal lateral branching which helps to alleviate costly silvicultural practices such as pruning, while encouraging their utilization in agroforestry. The availability of these clonal materials has boosted large-scale establishment of clonal teak plantations in many tropical countries.

Keywords: adaptability, clones, environmental conditions, rainfall, growth, phenotypic characteristics, *Tectona grandis*.

RESUMEN

COMPORTAMIENTO DE CLONES DE TECA “SG BIOTECH TG1-8” EN DIVERSAS CONDICIONES DE SITIO: PRIMERAS OBSERVACIONES

A principios de los 90 en Sabah, Malasia oriental, la división “Biotech” del grupo Yayasan Sabah desarrolló, conjuntamente con el equipo Bosque del CIRAD, un método eficaz de clonación industrial de la teca, *Tectona grandis,* por estaquillado y micropropagación de tecas de cualquier edad. Los primeros clones se produjeron a partir de ocho tecas “plus”, seleccionadas por sus características fenotípicas y de crecimiento en Sabah, con una precipitación anual de 2 500 mm bien distribuida a lo largo del año. El sobresaliente desempeño de los primeros representantes de estos clones, en estas condiciones naturales, favoreció rápidamente su propagación clonal a gran escala para satisfacer la importante demanda local e internacional. Desde entonces, se han producido varios millones de tecas clonados a partir de los ocho ortetos originales y la demanda no deja de incrementarse. Esta situación nos ha llevado a sintetizar la información disponible sobre el comportamiento de estos clones en los diferentes sitios en los que se introdujeron. Las primeras observaciones indican que este material ha mostrado una gran facultad de adaptación en condiciones ambientales muy diversas. En cada uno de los sitios de introducción, la madera producida supera a la de las demás procedencias, tanto cualitativa como cuantitativamente. Esta observación también es válida en aquellos lugares que sólo reciben 1 000 mm de lluvia anuales con una estación seca de ocho meses; es decir, niveles de precipitación muy inferiores a los de Sabah. No obstante, las áreas que gozan de una fuerte pluviosidad, uniformemente repartida a lo largo del año, son preferibles para garantizar el mejor desempeño de estos clones. Uno de sus principales atractivos sigue siendo la formación temprana de fustes rectos y largos con poca ramificación, lo que fomenta su aprovechamiento agroforestal y reduce las operaciones de poda. La disponibilidad de clones de teca que poseen tantas ventajas comparativas es la causa del auge de las plantaciones clonales industriales de teca en numerosos países.

Palabras clave: adaptabilidad, clones, condiciones ambientales, pluviometría, crecimiento, características fénotípicas, *Tectona grandis*.

Introduction

The first activities on teak cloning by rooted cuttings started in the early 1990's in the Luasong Forestry Center (LFC), 120 km north-west of Tawau, Sabah, East Malaysia (figure 1), under the Plant Improvement and Seed Production (PISP) collaborative program between Innoprise Corporation Sdn Bhd (ICSB) and the Centre Technique Forestier Tropical (CTFT), which later became the Forest Department of CIRAD (Monteuuis, 1995; Monteuuis *et al.*, 1995). The presence of a senescing teak tree (ortet) adjacent to the LFC nursery prompted us to test the efficiency of vegetative propagation methods for teak which had previously been proven to be successful for mass propagating mature selected superior (Plus) trees of different broadleaved as well as coniferous species, under temperate and tropical environments (Franclet, 1981; Monteuuis, 1989, 1993). Adapting this cloning technology to this old teak tree yielded highly successful results (Monteuuis, 1995; Monteuuis *et al.*, 1995). In 1992, the first rooted cuttings obtained from this tree were field planted under the identity "clone 9". The phenotypic conformity of these rooted cuttings as well as the quality of their adventitious root system for ensuring a good soil anchoring ability were obvious, prompting further cloning activities on candidate Plus trees (CPTs).

Priority was given to eight outstanding individuals growing at LFC. These were derived from seeds brought from the Solomon Islands. The resulting clones were individually named TG 1 to TG 8, and referred to generically as YSG Biotech TG1-8 Solomon Island clones (photo 1), or TG1-8 for short. The first rooted cuttings from these TG1-8 clones were planted in 1994 in the LFC demonstration plot (demoplot).

In late 1992 the establishment within the same collaborative project of a tissue culture laboratory, known as the Plant Biotech Laboratory (PBL) in Tawau, allowed us to develop a more efficient mass-clonal micropropagation method for these TG1-8 clones that complemented the rooted cutting technology (Bon, Monteuuis, 1996; Monteuuis *et al.*, 1998; Monteuuis, 2000; Goh, Monteuuis, 2001). Further to the good performance and phenotypic conformity of the resulting tissue culture plants field-tested locally, the micropropagation of the TG1-8 clones was intensively pursued. From 1992 to 2004, the laboratory produced up to two million tissue-cultured plantlets, mainly from the TG1-8 clones to meet rising local and international demands (Goh, Monteuuis, 2001; Goh *et al.*, 2005, 2007). Tissue culture propagation remains the best option to cope with stringent phytosanitary requirements of importing countries. The possibilities to mass micropropagate and then to export plants to foreign countries within the span of a few days, as well as the aforementioned encouraging early performance of the clones in Sabah, prompted the PBL to embark on a commercial path.

In May 2005, the Plant Biotechnology Laboratory was relocated to a bigger and more convenient tissue culture facility in Kota Kinabalu which facilitates international dispatch. The PBL evolved to become a commercial subsidiary of the Yayasan Sabah Group, known as YSG Biotech Sdn Bhd[1] (Goh *et al.*, 2007).

The purpose of this paper is to report on the performance of the TG1-8 clones in the various environments across the tropics where they have been planted to date. This report is based on clients' as well as our own observations and findings, notwithstanding the lack of accurate and standardized data gathering due to the diverse and fragmentary sources of information, and also to a certain degree, the need for confidentiality of specific information by contributors.

[1] Incorporated as a collaborative research project known as the Plant Biotechnology Laboratory with CIRAD, a French R & D organization in 1989, YSG Biotech Sdn Bhd is now a wholly owned subsidiary company under the Yayasan Sabah Group (Sabah Foundation Group). The Company specializes in the mass production of tissue culture plantlets of selected superior genotypes of teak *(Tectona grandis)* and *Acacia hybrids* for large-scale plantation establishments at the local and international levels. http://www.ysgbiotech.com

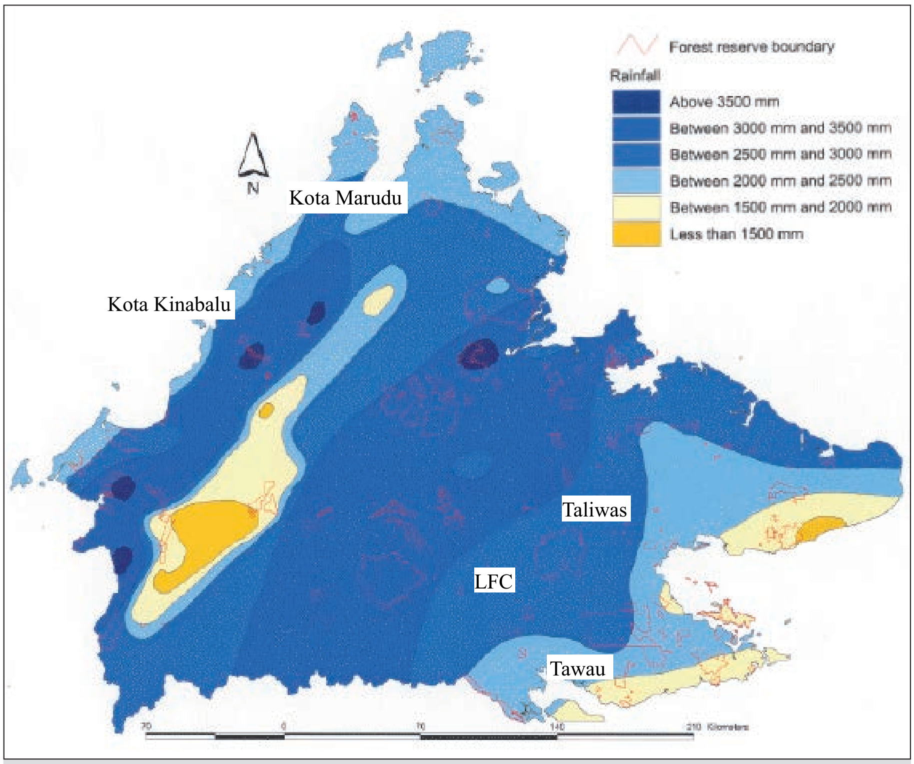


Figure 1.
Map of Sabah showing annual rainfall distribution and the main locations quoted in the paper.

Characteristics of the YSG Biotech TG1-8 teak clones

The eight ortets that gave rise to the TG1-8 clones were derived from a few seeds given by the forestry service in the Solomon Island (SI) to a visiting ICSB official in 1988. In the absence of more detailed information, the genetic base of this SI material is assumed to have originated in Myanmar (ex. Burma), from where the first teak seeds were imported to SI in the early 1900's (Kevin White, personal communication), or perhaps via Papua New Guinea (Camron, 1966), an exporter of teak seed to the SI (Sandiford, 1990). These eight ortets were initially selected when 3 years old, based on relative growth rate as well as on bole and crown criteria. At that time, they already exhibited promising traits such as a long, clear and straight bole, attaining an ever-increasing height of more than 15 m without flowering. There was also minimal lateral branching, guaranteeing knot-free wood in the absence of pruning operations. These practices being time-and labor consuming, are not only costly, but need to be carried out at the right time. If undertaken too early, photosynthesis, and hence, growth rate will be affected; if too late, then wood quality will depreciate due to the presence of knots in timber or veneer produced.

Seven years after planting in Sabah, the TG1-8 clones showed an unexpectedly high proportion of heartwood (Goh *et al.*, 2007), the segment more valuable commercially. Wood characteristics were similar to those of Burma wood samples (CIRAD, unpublished data), which strengthens the hypothesis of Burmese origin mentioned. In addition to these wood traits, DNA microsatellites of each of the eight clones were profiled (Goh *et al.*, 2007). The DNA fingerprints, which revealed a rather narrow genetic base among the individuals, can be also used for resolving property right issues. It is recognised by YSG Biotech that there is a need to explore a broader pool of diversity and for the development of a back-up suite of clones to offer clients in the future. These needs are being addressed through the testing of clones from a much wider genetic base that was established in different sites in Sabah (Goh, Monteuuis, 2009).

Observations from South-East Asia Sabah, East Malaysia

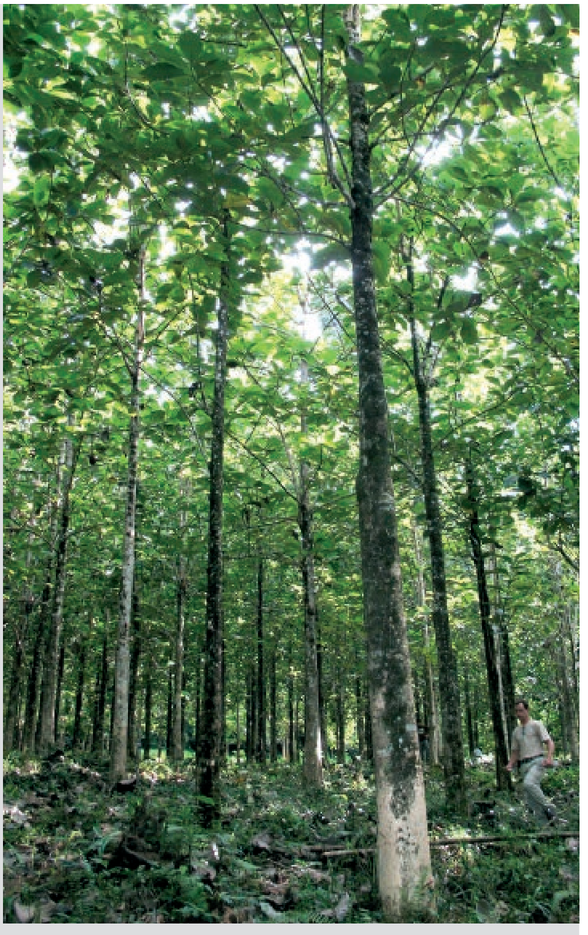
The first rooted cuttings and microcuttings of TG1-8 clones were planted in 1994 and 1997, respectively, in LFC, where monthly temperatures range 26-28°C and annual rainfall averages 2,500 mm without a distinct dry season. They developed true to type, exhibiting the same striking phenotypic features and impressive growth rate as the original ortets. The largest-sized representatives of TG1-8 clones attained heights of about 26 m and girths of 120 cm after 10 years (photos 2).

Photos 2.
The first rooted cuttings from the TG1-8 clones shown at 10 yrs (left) and 12 yrs after planting in LFC demoplot.
Photos O. Monteuuis.

Photo 3.
A 9 yr-old representative of the TG1-8 clones produced by meristem culture and planted in Taliwas demoplot (no pruning applied). Note excellent tree form.
Photo O. Monteuuis.

In 1997 and in 2000, the TG1-8 clones were planted in Taliwas, also located inland and at 18 km on the main road from Silam to Danum Valley (figure 1), on greyish fluvisols with pH of 6.0 to 6.3 and similar climatic conditions as in LFC. The 1997 trial compared trees from the different vegetative propagation methods that could be used for producing the eight TG1-8 clones *i. e.* rooted cuttings, microcuttings from nodal explants and from meristem culture (photos 3, 4), the treatments being distinguished according to the single meristem from which they were derived (Monteuuis *et al.*, 1998; Monteuuis, 2000).

The primary purpose of these clonal trials and demonstration plots was to visually assess between and within clone variation of growth, branching, form, and also possibly wood properties (Goh *et al.*, 2007). Part of the 2000 trial was set up according to an experimental layout suitable for comparing the eight TG1-8 clones to one another. This was done on a sloping piece of land referred to as site 1, and on a flatter one, site 2, prone to occasional waterlogging (photos 4). Survival was nearly 100% and five years later the clones had reached average heights and DBHs (diameters at breath height) of 15.8 m and 13.8 m, and 15.9 cm and 16.8 cm for sites 1 and 2 respectively (see table I for individual clone means). The mean annual increments were 3.16 m and 2.76 m for height and 3.18 cm and 3.36 cm for DBH.



Photos 4.
The 5 yr-old TG1-8 clonal tests established as replicated single-clone rows and blocks in Taliwas.
Photos O. Monteuuis.

Table I.
Comparative average height (H) and diameter at breast height (DBH) of the eight TG1-8 clones (under different names) in two different planting sites in Taliwas 5 years after planting. N: number of trees recorded.

Clones	Site 1			Site 2		
	N	H (m)	DBH (cm)	N	H (m)	DBH (cm)
D	20	15.61	15.31	30	13.79	17.73
X	20	14.81	13.67	30	13.42	17.18
Z	20	13.88	14.44	30	13.71	17.82
O	20	16.8	15.58	30	15.31	14.62
C	20	15.26	16.82	30	13.54	17.26
E	20	15.66	18.06	30	13.70	17.88
K	20	17.45	15.34	30	13.27	14.88
S	20	17.28	17.99	30	13.54	17.23
Mean	160	15.84	15.90	240	13.78	16.82

Table II.
Comparative average height (H) and diameter at breast height (DBH) of seven 7 of the TG1-8 clones (under different names) in Brumas 7 years after planting. N: number of trees recorded.

Clones (cm)	N	H (m)	DBH
U	80	14	16.3
O	80	15.3	21
M	80	15.7	20.1
E	80	16.1	19.6
B	80	17.1	20.3
Y	80	19	22.5
T	80	19.3	21.3
Mean	560	16.6	20.1

Though clone-by-site interaction has not been analyzed for this paper, it can be seen that clone E ranked first for DBH at both sites (though not for height) while clones Z and O ranked quite differently for DBH in sites 1 and 2. Studies of this kind will lead to the matching of clones to sites for optimal adaptability and productivity. For sustainability, such a strategy will require increasing and maintaining genetic diversity in the base and breeding populations, an aspect being addressed through management of an infusion population planted at 2 sites in Sabah in 1997 (Goh, Monteuuis, 2009; Chaix *et al.*, 2011, Monteuuis *et al.*, 2011).

In 2002, these clones were also established as clonal tests (2 x 10 trees/rep, 4 totally randomized complete blocks *i. e.* 80 trees/clone, photos 5) and demonstration plots (photo 6) in Brumas, south-east of LFC (figure 1), on red/yellow latosols with pH ranging between 4.8 and 5.6, and with average annual rainfall of 2,200 mm and same temperature conditions as in LFC. Planting losses were insignificant.

Seven years after planting, records indicated mean height and DBH of 16.6 m and 20.1 cm (see table II for individual clone records), that corresponded to mean annual increment of 2.4 m in height and 2.9 cm in DBH, thus poorer than at Taliwas.

Photo 5.
The 7 yr-old TG1-8 clonal test established in Brumas (right), compared to seed-derived clones from Thailand origin, planted on the same site at the same date.
Photo D. Goh.

Photo 6.
Demonstration plot of the same TG1-8 clones 11 yrs after planting in Brumas.
Photo O. Monteuuis.

Indonesia

Between 2003 and 2005, the TG1-8 clones were sent to Indonesia to be planted in different places, mainly in West Java under rainfall and soil conditions similar to those of the Sabah sites, and also in Kalimantan, south Sumatra, and Belitung islands. The high number of subsequent clients scattered in different places hindered access to accurate and reliable data on the behaviour of these clones in the various sites where they had been planted. Although the information gathered to date is limited, the continuous demand of the TG1-8 clones provides evidence of early superiority in yield and phenotypic traits of these clones over other sources of teak planting materials. Early development of trees planted in West Java at an elevation of 300 m again reveals features of outstanding growth, near perfect straightness with long clear bole and small branches. The average mean height and DBH for 3-year old trees is 10 to 12 m and 9 to 12 cm, respectively (photos 7).

Photos 7.
The TG1-8 clones in West Java under similar conditions as in Sabah, displaying in the first year (left) and second year (right) after planting in such favorable conditions all their expected assets: high growth rate, good form and minimal lateral branching.
Photos H. Sarwono.

Photos 8.
Under 1,000-1,200 mm of annual rainfall and 8 months of dry season in KVTC, the TG1-8 clones developed more lateral branches (left) than in wetter sites, which required pruning operations (center), but their superiority in growth rate and straightness remained (right).
Photos R. Freyer.

Photo 9.
A well-distributed adventitious root system produced by a TG1-8 clone tissue- cultured teak plant a few months after field establishment in KVTC.
Photo O. Monteuuis.

Observations from Africa Tanzania

The Kilombero Valley Teak Co. Ltd. (KVTC) project is located in the Kilombero Valley in southern Tanzania at about 450 km east/south east from the capital Dar Es Salaam. It was incorporated on December 1st, 1991 with the mandate of planting teak on 15,000 ha identified as suitable for this species (Bekker *et al.*, 2004). The aim was to produce high quality wood on a sustainable basis via 32-year rotations. The plantation was established on flat and deep soils of varying fertility, and under annual rainfall of 1,000 mm to 1,200 mm, with a long and marked dry season of 8 months, lasting from May to December.

Four hundred in vitro-produced microshoots for each of the eight TG1-8 clones were sent from Sabah in two separate consignments to KVTC in 2004 and in 2005. After successful acclimatization in KVTC misting facilities, part of the rooted microcuttings were used for establishing two clonal tests in combination with stumps and seedlings from the local seed origin (Tanzanian Tree Seed Agency, Mtibwa seed stand). These two trials were planted in January 2004 at the beginning of the rainy season on two sites differing in soil characteristics and referred to as class 2, considered as the best, and class 3, supposedly of inferior type. The experimental design was a 2-replicate randomized complete block with 60 trees per plot planted at 3m x 3m (60 x 2 = 120 trees per origin).

One year and a half (1.5 yr) after planting, the trees performed better overall on soil class 3 than class 2. The clones outperformed the local seedling source in height by 27% on average, in spite of noticeable between-clone differences with respect to unexpected early flowering and die-back symptoms. At age 3.5 yr, mean height and DBH varied according to the clones from 10.4 m to 11.0 m, and from 11.0 cm to

Photos 10.
TG 3 and TG 8 representatives of the TG1-8 clones near Mossman, northern Queensland reaching 20.5 and 21.4 m in height, 24.6 and 25.4 cm in diameter at breast height (DBH) and with clear bole length of 17.5 and 13.4 m, respectively, 7 years after planting. These trees are characterized by self pruning or very reduced lateral branching in the butt logs in absence of any pruning operation. Photos O. Monteuuis.

14.0 cm, respectively, with lesser within clone variation than among the seed-derived trees. The clones exposed to KVTC much drier conditions than those of the Sabah sites aforementioned produced early lateral branches as shown in photos 8. These were however smaller and less vigorous than those produced by the local planting stock, which requires regular pruning. The question on whether these lateral branches will die without leaving any noticeable effect on final wood quality remains at this stage. Examination of the adventitious root system showed that the roots are abundant, evenly distributed all around the base of the stem with a strong positive geotropism, providing strong evidence of good and solid root establishment and anchorage (photo 9).

In spite of these climatic conditions that are much too dry to allow the phenotypic expression of some of their specific superior traits, TG1-8 clones have nonetheless demonstrated higher growth performances than the local teak sources in various KVTC sites. This has accounted for annual productions of up to 250,000 TG1-8 clone cuttings to meet planting requirements (Hans Lemm, personal communication).

Observations from Australia (Queensland)

Teak can only be introduced into Australia in the form of contamination-free tissue cultured plantlets owing to strict quarantine regulations. Having first met the stringent requirements of the Australian Quarantine and Inspection Services, a total of 100,000 microcuttings of TG1-8 clones were despatched to northern Queensland in year 2002 and 2003. The early plantings however suffered from severe drought and wild fires, accounting for the survival of only very few trees. Growth and form characteristics of these remaining trees were observed to be superior to other teak sources overall. Unreplicated 20-tree plots of 3 TG1-8 and 20 Thai clones were planted within a species-demonstration area near Mossman, northern Queensland, under 2,000 mm of annual rainfall mainly concentrated within a period of eight months. The 3 TG1-8 clones quantitatively and qualitatively outperformed the other clones from Thailand except one which demonstrated similar performances as the inferior of the 3 TG1-8 clones (table III). Seven years after planting, some of the TG1-8 clone representatives reached more than 20 m in height and 24 cm in DBH, exhibiting distinctive characteristics *i. e.* long clear bole and reduced lateral branching, typical of the TG1-8 clones (photos 10).

Table III.
Comparative mean scores of the TG1-8 clones (3 clones) vs 20 clones from Thailand for height, diameter at breast height (DBH), volume index (basal area x height x 0.33), bole length and straightness (6 being the straightest) 7 years after planting near Mossman, northern Queensland (data kindly provided by G. Dickinson and D. G. Nikles of the Department of Employment Economic Development and Innovation).

Source and number of clones compared	Height (m)	DBH (cm)	Volume index (m^3)	Bole length (m)	Straightness (scale 1-6, 6 best)
TG1-8 (3 clones)	19.2	21	0.23	12.1	4.4
Thailand (20 clones)	15.7	13.6	0.09	9.7	3.8

These first introductions were followed by more substantial importations amounting to more than 1 million clonal microshoots in the period 2005-2009, spurred on by keen private investment projects. The acclimatization, or “deflasking”, was subcontracted to private specialised nurseries that handled these activities successfully. At the same time, some of the same Sabah clones were also imported in lower quantities from Indonesia where they had been micropropagated using different *in vitro* protocols.

Several thousand hectares were planted on flat areas with deep agricultural soils previously occupied mainly by sugar cane plantations in the Innisfail-Tully-Bilyana areas under high precipitations (3,000 to 4,000 mm/yr, photo 11). These were restricted to a 4-month period, January-April (500 to 600 mm/month), and with the months of August, September and October being much drier (50 mm/month on average). This unevenly distributed rainfall resulted in a variable dry season in different sites. Due to uncertainties on clonal adaptability to planting site conditions in the absence of results from previous clonal tests, preference was given to polyclonal deployment rather than large monoclonal blocks. Various genotypes were intermixed in operational plantations at an initial density of 800 to 1,000 trees/ha. This was done to reduce the size impact of clones which might be less adapted than others within the whole area, while at the same time, enabling machinery application of herbicides between rows.

Early observations from these industrial plantations in Northern Queensland indicated that:

▪ Planting at the end of the rainy season or the beginning of the dry season led to high mortality of trees. Such practices that are likely dictated by budgetary constraints are unsuitable from a physiological standpoint, and thus, should be avoided.

▪ Even under high annual rainfall of 3,000 to 4,000 mm/yr, a marked, even short, dry season is liable to induce a deficit stress at the shoot apical meristem stage of the main stem, thereby suppressing apical dominance and stimulating the production of lateral branches from the axillary meristems at the axil of the leaves underneath. Manual pruning will then be needed for preventing the development of big knots that will affect the quality of timber from the trees. Despite the superiority of the TG1-8 clones over other teak sources in a wide range of rainfall regimes, their planting is preferable under an evenly distributed high rainfall regime of 2,000 mm/yr or more throughout the year.

▪ Regardless of the genetics, inappropriate *in vitro* propagation methods can induce detrimental effects, at least in the first stages of plant development, like stunted growth, multiple stems and short internodes. In this respect, the YSG Biotech protocols have proven their efficiency by guaranteeing true-to-type development of the clonal offspring.

▪ Notwithstanding adverse environmental effects, mean average height increments can still be outstanding varying from 3 m to 4.2 m according to the clones for the first year at the Maccarone site in northern Queensland. At Ringrove, mean annual growth rates ranged from 2.5 to 3 m in height and 3 to 3.5 cm in DBH two years after planting, with slight between clone differences. It would be interesting to follow up these first observations with data recorded at an older stage, bearing in mind that in this region, the plantations are prone to cyclone damages.

Photo 11.
The TG1-8 clones 10 months after planting near Ingham (Queensland) showing already their characteristic features: straight stems, high density of large leaves, and vigorous growth.
Photo H. Baillères.

Observations from Latin America
Brazil: Mato Grosso

The first TG1-8 clone microcuttings sent to Latin America were to Cuiaba in the State of Mato Grosso, Brazil. *Ex-vitro* acclimatization of plantlets under optimal misting conditions gave rise to high survival rates (photo 12). The first clonal tests were planted in 2003, in a flat area of loamy soils with pH varying between 6 to 7 and under 1,400 mm/yr of rainfall mainly concentrated between November and May. Once field established, the TG1-8 clones could be distinguished from other teak of local origins by a prolonged retention of their leaves even after the dry season starts (photo 13).

This allowed a longer period of photosynthetic capacity that probably accounted for their superiority in growth (table IV and figures 2, 3 and 4).

More recent results from 5-year-old field tests have confirmed average differences of more than 30% in the total volume for the TG1-8 clones compared to the seedlings of local teak sources. The clones also appear straighter, less branchy and more uniform than the seedlings (photos 14). The superiority of the clones over the seedlings was further emphasized during the last Teaknet meeting[2] held in November 2011 in San-Jose, Costa Rica. Substantial improvement in uniformity of wood properties is expected for teak timber derived from clonal plantations compared to the great heterogeneity associated with teak wood produced from seedlings. Planting TG1-8 clones will likely lead to a shortening of the rotation period of teak plantations, while increasing substantially in volume and quality the wood produced after a growing period of 20 to 25 years.

[2] International Forestry Conference "Planted Teak Forests – a Globally Emerging Forest Resource", San Jose, Costa Rica, 31 October - 5 November 2011. The conference had been jointly organized by CATIE, FAO of the United Nations and TEAKNET. The presentation could be downloaded at the following internet link: http://web.catie.ac.cr/conferencia_teca/presentaciones/Sesion_7_7.pdf

Photo 12.
Acclimatization of microcuttings from the TG1-8 clones in state-of the art facilities in Mato Grosso.
Photo O. Monteuuis.

Photo 13.
The TG1-8 clones (left) retain their leaves longer than teak of local origins (right) when the conditions become drier (dry season) in Mato Grosso.
Photo G. Chaix.

Table IV.
Comparative average height (H), diameter at breast height (DBH) and volume 4 years after planting of the TG1-8 clones versus seedlings of local origin grown under the same conditions in various Brazilian sites (CV: Coefficient of variation).

	Height (m)		DBH (cm)		Volume (m^3)	
	Clones	Seedlings	Clones	Seedlings	Clones	Seedlings
Mean	17.9	15.3	12.7	11	0.2	0.128
CV	8.53	13.6	9.04	13.1	22.7	35.5

These observations made since 2003 have led to the noticeably increasing demand for and production of these clones by Bioteca first, then the company PROTECA[3], to reach the current estimated 10 millions cloned offspring produced for plantation establishments in the states of Mato Grosso, Pará and Tocantins.

[3] PROTECA is a private company headquartered in Cuiabá, Mato Grosso, Brazil, specialized in forest biotechnology and is the leading supplier of superior clonal teak plants (*Tectona grandis* L.f.) for forestry projects in Brazil and Latin America. Benefiting from the unique expertise of its founding and managing partners in the forestry business, PROTECA offers dedicated project management and advisory services for the success of both existing and new forestry enterprises. http://proteca.com.br/

Photos 14.
Three year old teak plantations comparing planting material produced from local seeds (top) and from the TG1-8 clones (low), established at the same site, on the same date, and managed under the same conditions in Mato Grosso.
Photo F. Torres.

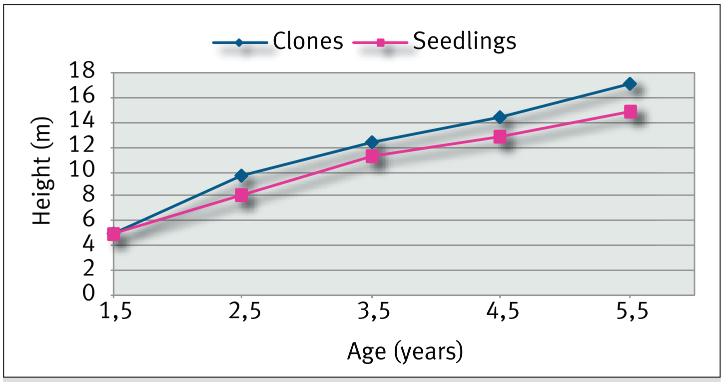


Figure 2.
Comparative progress of height growth of the TG1-8 clones and local seedlings to age 5.5 years across several sites in Brazil.

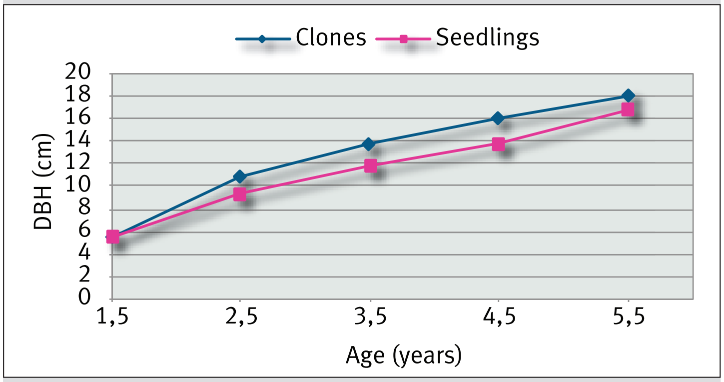


Figure 3.
Comparative progress of growth in diameter at breast height (DBH) of the TG1-8 clones versus local seedlings to age 5.5 years across several sites in Brazil.

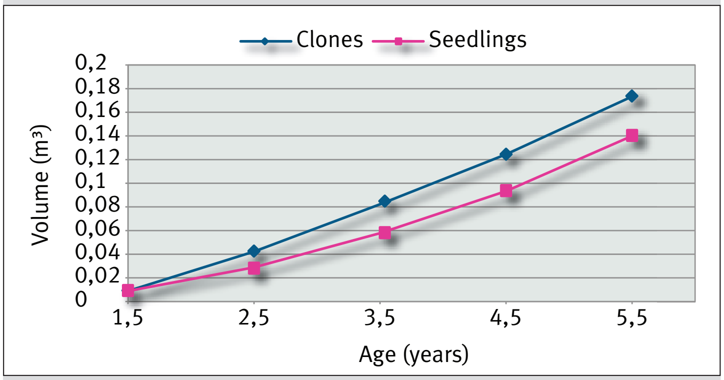


Figure 4.
Comparative progress of growth in volume with bark per tree for the TG1-8 clones versus local seedlings to age 5.5 years across several sites in Brazil.

Mexico

The TG1-8 clones have recently been planted on a flat area of fertile land in the eastern part of Tabasco province under 2,000 mm of annual precipitation concentrated mainly in the months of August and September. Under such conditions, these materials have outperformed the local seedling sources rather dramatically (photos 15). The superiority in growth rate and in phenotypic characteristics (straightness) 11 months after planting is impressive. The uneven distribution of rainfall during the year may here also stimulate unexpected lateral branching which will warrant repeated pruning operations.

Ecuador

Seven of the TG1-8 clones were compared separately and in mixture to local seed orchard (SO) and Plus tree (PT)-derived seedlings within proper experimental layouts in seven different sites in Guayas, Los Rios, Pichincha and Esmeraldas Provinces. The altitude varied from 50 to 250 meter above sea level and rainfall from 1,400 to 2,500 mm/yr with a more or less pronounced dry season. Despite being planted at the end of the rainy season, the survival rate for all the clones combined (398/480 = 82.9%) was comparable to those recorded for the two sources of seedlings (62/72 = 86.1% for PT and 60/72 = 83.3% for SO). Three years after planting, the clones exhibited better growth and qualitative traits than the seedlings from seed orchard and plus tree in every site with average DBH of 13.7 cm versus 11.7 cm and 11.5 cm respectively for clones and PT and SO seedling sources. This indicates an overall good adaptability of these clones to different site characteristics, notwithstanding site X clone interactions.

Photos 15.
Eleven-month-old teak trees from seeds (left) and from the TG1-8 clones (right) growing under the same conditions in Tabasco province, Mexico.
Photos O. Monteuuis.

Overview, Prospects and Conclusions

The YSG Biotech TG1-8 teak clones, along with broad information on their origin (ex. particular Solomon Islands seeds) as well as growth and form characteristics under Sabah conditions, are the first such materials to be sent as individual clones or bulks to different countries and continents for planting under quite diverse environments. This was made possible due primarily to the contamination-free *in vitro* conditions under which these clones were produced and shipped. Special appreciation is extended to the clients who have provided us with the relevant information on the behaviour of these clones, without which it would not have been possible to assess the initial adaptability of this material to a wide range of environments and planting practices.

This information, nonetheless, remains limited and not clone-specific enough to allow reliable between clone comparison in various sites. Some clients may also prefer to keep confidential such indications for commercial reasons in an increasingly competitive context. Being able to produce the best teak timber in the shorter delays is becoming indeed a highly challenging issue considering the alarming depletion of premium value timber such as teak, worldwide. The information gathered so far corresponds to the early stages of development and will need to be revaluated after a longer period of growth in order to better assess more mature traits such as branching, fluting and especially wood characteristics, despite encouraging analyses already undertaken in Sabah. Notwithstanding these reservations, these clones have been observed to outperform,during their first stages of developpement, every other source of teak planted under the same site conditions. This superiority was obvious for not only quantitative traits such as growth, but also for more qualitative features like shape, bole straightness and within clone uniformity, which contrasts with the higher variability noticed for these traits in teak trees arising from seeds. Several observations have provided strong evidence and rationale for the production of these cloned plants using optimal tissue culture methods, and also to plant at the right time, preferably at the beginning of the rainy season. High precipitations evenly distributed throughout the year will promote growth in height and diameter, and therefore in yield, while seeming to limit the development of lateral branches responsible for branch then knot formation. The possibility to produce big volumes of high value and knot-free teak wood in absence of repeated time and labor consuming pruning operations must be considered as a real asset. An increasing number of observations tend to demonstrate that these are the more appropriate conditions to draw the best financial returns from the utilization of these teak clones for monospecific or agroforestry plantations.

Acknowledgements

The authors are very grateful to all the contributors for the valuable information graciously provided by them, and more specifically to Mr Tony Sturre, Mr Geoff Dickinson and Dr Garth Nikles (Queensland Department of Employment, Economic Development and Innovation), all from Australia, Mr Fernando Torres and Dr Wirifran Andrade from Brazil, Mr Fernando Montenegro (Ecuador), Mr Hartono Sarwono (Indonesia), Ms Yani Japarudin, Sabah (Malaysia), Messrs Luis Van Zyl, Roland Freyer, Henk Pretorius and Hans Lemm from KVTC (Tanzania). Lastly, special thanks and appreciation are addressed to Dr Garth Nikles for his useful comments on an early draft of this paper.

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