



ISTF NEWS

5400 Grosvenor Lane
Bethesda, Maryland 20814, USA

Special Report, December, 2009

MANAGEMENT OF TEAK PLANTATIONS FOR SOLID WOOD PRODUCTS*/

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Abstract

Teak is the premier fine furniture wood being grown in plantations around the world. Although teak was once managed on rotations of 80 to 100 years, current rotation lengths have been shortened to 20 or 25 years for commercial wood production. There are some unique characteristics to consider in teak management: It grows well in alkaline soils, it can withstand extreme drought, it forms a corky pith, adventitious buds form sprouts after branch pruning, and trees can develop

several distinct heartwood grain patterns. Old growth natural teak has been used primarily for yachts, decking, interior paneling and fine furniture. Plantation teak wood still has not been well accepted in such traditional markets and log prices for plantation teak are much lower than those for old growth natural teak. A major challenge for teak growers is to develop innovative markets for plantation teak and find uses for low value wood from thinnings.

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Introduction

Teak (*Tectona grandis*) is the premier high value furniture wood being grown in plantations around the world. Teak is relatively easy to establish in plantations and, because of the enduring global demand for teak wood products, it has good economic prospects as a plantation species for fine woods.

Teak is indigenous to India, Myanmar, Thailand and Laos. Its range is tropical, occurring between latitudes 25°N and 9°N (White, 1991). The natural distribution is discontinuous and the eastern or Burmese populations are considered to be distinct from the western or Indian populations. Although teak is the name used for international trade, there are many local names used as well: sagun, tegu, tegina, thekku (India); lyiu, kyun (Burma); mai sak (Thailand); jati (Indonesia); fati (Malaysia); teca (Latin America); and teck (France) (Chudnoff, 1984; Keiding, 1985).

In 1856, realizing the commercial and strategic importance of the forests on the Indian subcontinent, the British brought several German botanists and foresters to India for the purpose of developing sustainable forest management plans. Notable among those individuals was Dr. Deitrich Brandis who developed a silvicultural management plan for the natural forests of India, called the “Brandis Selection System”, which involves timber removal every 30 years and a final harvest between ages 120 and 150 years (Kahrl et al., 2004). The final harvest age has now been reduced to 30 to 60 years with coppicing and replanting used to regenerate the teak forests (Pandy and Brown, 2001). In 1881, Brandis organized the official teak management plan in Burma (Fernow, 1911). At about the same time, he also visited Indonesia and instituted a management plan for the teak plantations in Java which is still

in use to this day, however with shortened rotation lengths.

Teak has a long history of planting within its natural range as well as around the world. Burma (now Myanmar) began planting teak using the taungya system in 1856 and, by 1941, had a total of 47,000 hectares planted. Large scale planting was again initiated in the 1980's and there were 307,000 ha of teak planted by 2002 (Swe Swe Aye, 2003). The rotation length to final harvest is 40 years.

Teak was thought to have first been planted in the Indonesian archipelago on the islands of Madura and Sulawesi about 300 to 400 years ago and is now considered to be a naturalized species in Indonesia (Keiding, 1977). On the Island of Java there have been more than one million hectares planted with teak since the middle of the Nineteenth Century (White, 1991).

Teak was first planted in Nigeria in 1902, in Togoland (now Ghana) in 1905 and in the Ivory Coast (Côte d'Ivoire) in 1929 (Horne, 1966; Kadambi, 1972). Initial plantings in West Africa were made using seed obtained from India, but it was soon learned that Burmese seed sources were superior in form and growth in the environments of West Africa.

Teak was first introduced into the Americas at Trinidad in 1913 using Burmese seed sources (Streets, 1962). Teak was first planted in Central America in 1926 at the Summit Botanical Garden in the former Channel Zone of the Panama Canal (De Camino et al., 2002). The following year other plantings were initiated in other Central American countries including Honduras, Panama and Costa Rica. Since then it has been planted in nearly all tropical American countries.

By 2000, the total area in teak plantations worldwide was 5.7 million hectares, or 3% of

all forest tree plantations (FAO, 2001). By far, the largest extension of teak plantations is in Asia (Table 1).

Table 1. Area in teak plantations by geographic region in 2000

Region	Teak ha
Asia	5,409,131
Africa	206,550
Central America	76,000
South America	17,500
Oceania	7,022
World total	5,716,203

Environmental issues

When planted as an introduced species outside of its natural range, teak has sometimes been maligned and criticized by those who claim that it causes erosion, especially when planted on slopes (Fonseca, 2004; Ugalde and Gomez, 2006). In Costa Rica, there have been severe criticisms of teak by some environmentalists, particularly where it was widely planted on overgrazed sites in Guanacaste Province on the Pacific side of the country. Photos of young trees planted on such sites show exposed roots as proof of soil loss under teak trees. However, similar root exposure was observed in plantations of pochote (*Bombacopsis quinata*) in Costa Rica, of the same age and growing in adjacent plantations to teak. Criticisms have not been leveled at pochote, perhaps because it is an indigenous tree species in Costa Rica whereas teak is an introduced species. The probable cause of the exposed roots of young trees is improper management rather than any inherent ability unique to teak that causes erosion in plantations (Ugalde and Gomez, 2006). Eroded pastures that are adjacent to some of those same teak plantations show clearly that the erosion is due to overgrazing that existed prior to establishing teak or

pochote plantations. Similar criticisms have often been made of tropical pine plantations in Colombia, where trees were planted on overgrazed and highly eroded sites specifically as a means to control the erosion caused by overgrazing.

Large scale tropical tree plantations invariably become targets of environmental groups. This has occurred with pines, eucalypts, *Gmelina arborea*, and *Acacia mangium* as well as teak. A common criticism is that the natural forest is cleared and destroyed to be replaced with industrial tree plantations. The reality is that the great majority of tree plantations in the tropics have been made on deforested sites such as marginal agricultural sites or lands degraded by overgrazing. However, there have been exceptions where governments have created incentives to clear away the forest for agricultural use, as was the case in Brazil with the fiscal incentives program between 1967 and 1977. When the soils on the cleared sites are too poor to sustain food crops or grazing, such sites are abandoned and some of them are eventually reforested. In Indonesia, incentives initiated in 1988 promoted the conversion of marginal forests to tree plantations. The conversion was done primarily on the islands of Borneo and Sumatra and the program lasted for ten years. A large portion of the Indonesian lands cleared with incentives was planted to non-timber species, including oil palm and rubber trees, while other lands were planted for pulpwood production, mainly with *Acacia mangium* on the island of Sumatra.

Since the early 1800's, teak plantations on the Indonesian island of Java have been established on the multitude of small hills that exist within the area of lowlands dedicated to the cultivation of paddy rice, corn and other food crops. Traditional teak management has continued to follow the recommendations made by German foresters in the Nineteenth

Century with plantation establishment using the taungya system, where farmers tend the young teak trees and grow food crops in between the tree rows during the first few years. In this system, teak seeds are sown in rows 5 or 6 m apart, which allows for crop cultivation between the rows of young trees. The trees are initially thinned around 3 to 5 years of age to improve the stocking of the plantation. There are subsequent thinnings every 5 to 10 years until the trees reach 45, by which age stand density has been reduced to between 200 and 300 trees/ha. Following the initial management plans, these final crop trees were allowed to grow to a harvest age of 80 years. This management system worked well until the latter part of the Twentieth Century, but demand for teak wood has now reduced rotation ages to 40 years and the demand for land for food production is taking priority over the replanting of teak. Of the 1.2 million ha that once existed, it is now estimated that there are less than 350,000 ha of teak remaining in Java.

Besides wood production, another important purpose of teak plantations in Java was the protection of the soils on the hills so as to minimize soil erosion onto the very productive paddy rice fields in the lowlands. This method of soil protection with teak has been working successfully for more than a century and clearly demonstrates the value of teak plantations for soil conservation. This long tradition of teak management for soil protection in Indonesia clearly contradicts the claims that teak plantations cause soil degradation and erosion.

In Thailand, the Royal Forest Department uses teak as the species of choice to reforest land cleared illegally on slopes by local peasants. Although the primary objective of the plantation is soil protection and erosion control, those plantations are managed for wood production on long rotations.

The key to the success of a tree species to recover depleted soils and produce commercial wood is its ability to form leaf litter on the soil surface quickly to protect it against surface erosion (Kanowski & Savill, 1992). In Darjeeling, India, comparisons were made of soil properties under plantations of teak, plantations of rubber trees (*Hevea brasiliensis*), and under natural forests. The conclusion of the study was that there was more leaf litter accumulation under the teak plantation than under the rubber plantation or under the natural forest (Krisnakumar *et al.*, 1991). There were no significant differences in soil chemical characteristics under the three types of forest cover, except that there was more calcium in the surface soil under teak plantations.

Teak trees are deciduous and drop their leaves during the dry season. Because of this, teak can withstand severe droughts, such as those that occur in eastern Java, when there is little precipitation during five months each year. Teak also adapts well to relatively humid sites and has been successfully planted in Borneo in locations with virtually no dry season.

Teak is a fire-resistant species which grows a thick bark, similar to tropical pines such as *Pinus caribaea* and *Pinus oocarpa*. Once they reach the size of saplings 8 to 10 m tall, and diameters greater than 10 to 15 cm, they become quite resistant to wildfires (Centeno, 2004). Fire resistance is an important advantage for teak management on sawtimber rotations and is an important factor when considering investments in tree plantations.

Growth and yield

The early growth rate of plantation teak is quite good, but the average growth rate on very long rotations is low (Figure 1). Because of its past history of management on very long rotations, teak has sometimes been left

out of consideration by investors. Traditional long rotation management of teak has its roots in forestry concepts of another era, when there were extensive teak forests in South Asia, with government ownership of forest lands, and prior to the development of modern wood technology. During the colonial period, when there was abundant, old growth teak, the rational approach to plantation management was that of producing trees similar to the old growth trees while considerations as to the cost of forest management were of low priority. Of far greater importance was securing a strategic and continuous supply of teak wood for ship construction, as well as for decorative interior paneling and furniture for public buildings and for the houses of aristocrats.



Figure 1. Good early growth of a 3-year-old teak plantation in Guanacaste Province,

In spite of its long history as a plantation species, reliable information on teak growth and yield is relatively scarce. Management plans in the Nineteenth Century were designed with multiple thinnings and long rotations, where early growth and yield information was seldom of interest. Recent growth and yield models of teak plantations in northern Ghana give growth rates of 14 m³/ha/year at 24 years on the best sites, with

total heights of 20 m. Growth on second class sites is 9 m³/ha/year at 24 years, with total heights of 15 m (Oteng-Amoako and Sarfo, 2003). In Myanmar, teak thinnings produce between 12 and 17 m³/ha using a 30-year thinning cycle (FAO, 1999).

Trinidad is one of the best sources of teak growth and yield information, where plantation growth data were registered periodically during a 20-year span (Miller, 1969). Three site classes were defined in Trinidad and, using the available growth data, it is possible to create growth curves for teak during a 20 year growing cycle (Figure 2).

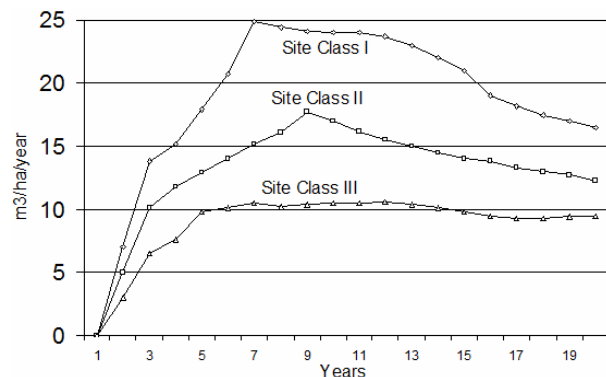


Figure 2. Mean annual increment of teak plantations in Trinidad

The maximum value for the mean annual increment occurs at a relatively young age, between 7 and 12 years, depending on the site class (Miller, 1969; Fonseca, 2004). These curves follow patterns that are quite similar to those of fast-growing tropical pines, which are often grown on rotations of 15 to 25 years of age. Thus, when teak is grown on relatively short rotations, the MAI at time of harvest can be between 10 and 15 m³/ha/yr. In Costa Rica, growth projections based on younger stands suggest that even higher MAI values can be obtained for plantations on good sites (Picado, 1997; Fonseca, 2004). Rotation age depends on site quality and the desired log

diameters, as well as financial considerations, but rotation ages of between 20 and 25 years are commonly used for teak on medium to good sites. Financial analyses in Costa Rica show that rotations over 25 years have internal rates of return below 12% (De Camino, 2002). Rotations over 25 years of age are not realistic from a purely economical point of view, due to the increasing interest accumulation on the investment. Government incentives that provide financial support to the investor in the form of reduced interest rates, tax relief and/or subsidies for planting and management activities are often needed to incentivate investments in sawtimber plantations, even for rotations of 20 to 25 years.

Tropical plantations for growing sawtimber are usually established at densities similar to those for growing pulpwood, with 1000 or 1100 trees/ha (400 - 450 trees/acre) being typical. These initial densities can shade out weed competition quickly as well as to minimize the tendency of teak to fork. Spacings for taungya or agroforestry systems often have rows 6 m apart to allow for planting food crops between rows and with close tree spacings within rows. For other plantations, it is common to use spacings of 3 x 3 m, 3.5 m x 2.8 m or 4 m x 2.5 m. Sawtimber plantations require thinnings to remove poorly formed trees and to reduce the overall stand density to that of final harvest. Final crop densities for teak are usually between 200 to 300 trees/ha (80 to 120 trees/acre).

One anomaly of teak is that, after thinning, the additional light that reaches the boles of the trees stimulates adventitious bud development and the formation of epicormic branches. Heavy thinning tends to produce more branching (Figure 3). Such branch initials must be removed; otherwise they will form small knots in the wood, which reduce the value of the logs. To minimize the effect

of epicormic branching and maintain the knot defects within a central core, thinning needs to be done at an early age.

Thinning is, in reality, a cost of management, rather than a means for an early return on the plantation investment. On a purely volumetric basis, wood produced by thinning generally costs 40 – 50% more per cubic meter than wood from a clear-cut (Ladrach, 2004). In the case of teak, small wood produced by an early thinning has relatively little value, except for local use, such as construction poles, fence posts, firewood or charcoal. Each time a thinning is made there is the risk of damaging residual trees by scraping off bark at the base and allowing rot fungi into the wounds. When mechanized equipment is used during thinning, this can result in soil compaction and feeder root damage, especially when the soil is soft and wet. These are factors that can cause significant reductions in growth and/or value of the residual trees. With less thinnings there is less chance of mechanical damage to the residual standing trees.



Figure 3. In a 12-year-old teak plantation in Venezuela, a row of trees was removed for access by truck. One year later, adjacent trees exhibit a profusion of epicormic branches along the tree boles.

When managing teak on 20 to 25 year rotations, two thinnings are considered sufficient to eliminate the poorly formed trees and to reach a final stand density. Time to thin is based on tree height, rather than on plantation age. The first thinning is best made when the trees reach an average height of 6 meters. At that height, the first 5 m log is already formed and can be judged for its straightness (Figure 4). When making a thinning, it is important to eliminate poorly formed trees, but also to leave a residual stand with a uniform density. When the trees reach an average height of 10 to 12 m, a second and final thinning is made, leaving the desired final stand density. In the case of the Trinidad teak, Site Class 2, the first thinning would be made at age 3 and the second thinning would be at age 7. Unless there is a local market for poles or posts, the first thinning is considered to be a precommercial thinning, leaving the cut trees on the ground to decompose and recycle. In this way, trucks or tractors are not needed to remove the wood and this avoids soil compaction or equipment damage to residual trees.

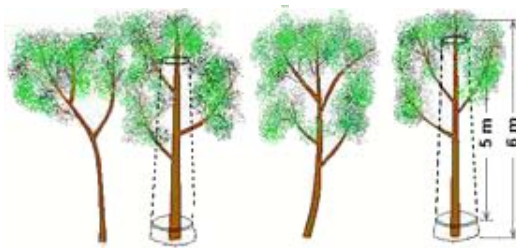


Figure 4. A precommercial thinning can be made once the form of the first 5 m log is apparent.

Another reason for early thinning is to take advantage of the rapid growth rate of the young trees. With early thinning, residual trees can use the additional growing space to more quickly increase stem diameter and log value. If thinnings are made late in the age of the stand when the rate of growth is diminishing, there will be less diameter added to final crop trees resulting in reduced overall stand value (Ladrach, 2004).

A spreadsheet program was developed in MS Excel format to calculate log and lumber production for fast-growing tropical tree plantations (Ladrach, 1998). With this program and the data from the Trinidad teak yield tables (Miller, 1969), it is possible to calculate teak lumber production for site classes I, II and III (Table 2).

The spreadsheet model in Table 2 uses the following assumptions:

- Survival prior to the first thinning is 90%
- Thinnings are made when average stand height surpasses 6 and then 10 m
- First thinning reduces stand density to 550 trees/ha
- Second thinning reduces stand density to 300 trees/ha
- No mortality after first thinning, all defective trees are removed as thinnings
- Teak stump height is 30 cm (12"). As teak trees age, they tend to flute at the base; a 30 cm stump height is a minimum for 20 year-old trees.
- Sawlog length at final harvest is 3.8 m (12½ feet)

- Minimum sawlog top end diameter at final harvest is 20 cm (8 inches)

$$\text{Teak log top diam. (cm ub)} = 1.0125 D((Ht-Hc/Ht-1.3))^{0.8351}$$

Where D = DBH (cm), and 1.3 m = height at DBH

Ht = total height (m), Hc = height of calculated diameter (cm ub)¹

- Sawlog volumes are calculated by a linear 3-variable regression for International 1/4" rule derived from tabular log volumes (Dillworth & Bell, 1984) using top diameters between 13 and 41 cm and log lengths between 2.4 and 5.5 meters

$$V = 5.28916 Dt - 88.9509 \log Dt + 10.3476 L - 0.49243$$

where V = sawn lumber volume in board feet, International 1/4" rule

Dt = top diameter of the log in cm

log Dt = logarithm (base 10) of top diameter of sawlog

L = sawlog length, m

- 5% of final harvest trees are considered to be culls (having no sawlog value)
- Total merchantable chip wood volume is calculated to a 10 cm (4") top diameter.
- Lumber volume is converted to cubic meters using 1 m³ lumber = 424 board feet lumber

Selection of good sites for growing teak sawtimber is critical to the success of such an endeavor. From the calculations in Table 2 it can be seen that tree and log diameters are noticeably greater on the better sites. Lumber production on Site Class II is 67% of that on Site Class 1. On Site Class III, lumber production is just 44% of that of Site Class 1. The numbers of logs as well as log diameters diminish notably on the lower class sites. The number of logs 3.8 m (12' 6") long is calculated by 5 cm diameter classes using the same spreadsheet program (Table 3).

^{1/} This unpublished teak taper equation was developed by Suhartono Wijoyo in Indonesia. It is based on 500 sample measurements obtained from 48 plantation teak trees that were cut in Java and measured at 2 m intervals for the entire bole length, with a DBH range between 21 and 52 cm. It uses a non-linear, 2-variable taper equation of the form developed by Omerod (1973).

Table 2. Lumber production calculated for Trinidad teak on a 20 year growing cycle.

	units	Site Class		
		I	II	III
Initial Plantation	trees/ha	1,100	1,100	1,100
Age of first thinning	years	3	3	4
Initial stocking at time of 1st thinning	trees/ha	990	990	990
MAI at age of 1st thinning ²	m ³ sub/ha/y	14	10	10
Initial volume, 1st thinning	m ³ sub/ha	42.0	30.0	40.0
Trees removed:	no./ha	440	440	440
Residual trees left	no./ha	550	550	550
Volume removed in 1st thinning	m ³ sub/ha	14.9	10.7	14.2
Volume left standing	m ³ sub/ha	27.1	19.3	25.8
Age of second thinning	years	7	7	8
Initial stocking at time of 2nd thinning	trees/ha	550	550	550
MAI at age of 2nd thinning	m ³ sub/ha/y	24	16	10
Initial volume, 2nd thinning	m ³ sub/ha	153.1	101.3	65.8
Trees removed:	no./ha	250	250	250
Residual trees left	no./ha	300	300	300
Volume removed in 2nd thinning	m ³ sub/ha	62.6	41.4	26.9
Volume left standing	m ³ sub/ha	90.4	59.9	38.9
Age at time of final harvest	years	20	20	20
Stocking at time of final harvest	trees/ha	300	300	300
MAI, final harvest	m ³ sub/ha/y	17	13	9.5
Total dominant height at time of harvest	m	21	18	15
Minimum top diameter, sawlogs	cm ub	20	20	20
Sawlog length	m	3.8	3.8	3.8
Initial volume, final harvest	m ³ sub/ha	262	208	149
Average DBH, final harvest	cm	37.3	35.8	33.2
Cull trees	%	5	5	5
Usable trees	no./ha	285	285	285
Lumber volume (thousand board feet)	mbf sub/ha	43.4	28.8	19.0
Lumber volume	m ³ sub/ha	102	68	45
Slab volume	m ³ sub/ha	100	69	50
Sawdust volume	m ³ sub/ha	26	17	11
Sub-total, sawlogs	m ³ sub/ha	228	153	106
Volume of roundwood for chips or other uses	m ³ sub/ha	35	54	43
Percent sawlog recovery as rough lumber		45	44	42
Percent of final harvest volume as rough lumber		39	33	30
Percent of total commercial plantation biomass as rough lumber		30	26	24

²/ MAI = mean annual increment, cubic meters per hectare per year
sub = solid under bark (or inside bark diameter)

Table 3. Log top diameter class, cm underbark

	Site Class		
	I logs/ha	II logs/ha	III logs/ha
Under 20 cm	-	-	-
20 - 25 cm	228	185	165
25 - 30 cm	219	157	165
30 - 35 cm	168	148	57
35 - 40 cm	88	23	3
40 - 45 cm	29	-	-
Over 45 cm	-	-	-
Total logs /ha	732	513	390

Pruning teak on short rotations

When managing teak on short rotations, it is necessary to prune branches to produce clear wood in the basal logs. The objective of pruning is to increase the value of sawlogs by concentrating the wood with knots in a central core and producing clear wood on the outside of the log (Figure 5). Thus, the pruning schedule needs to be coordinated with tree growth in order to minimize the diameter of the knotty central core. An optimum objective is to prune branches where the tree bole is 12 cm in diameter. This produces a minimal practical core of knots.

The length of the sawlogs that are to be harvested must also be considered when developing a pruning schedule. To maximize the return on the pruning investment, the entire log must be pruned so that knot-free wood can be sawn from the log. Partial pruning of logs seldom increases their value. Thus, if logs are to be cut to a 3.8 m (12' 6") length, pruning would be to a 4.3 m (14') tree height to allow for the stump. If logs are to be cut to a 5.0 m (16' 5") length, pruning would be to a 5.5 m (18') tree height, and so forth.

Pruning from below can reduce tree growth if too many live branches are removed. As a rule of thumb, when no more than 40% of the

live crown (leaf area) is removed from below, pruning will not cause significant growth loss. Large dead branches and live branches are pruned. In the case of teak, small lower branches near the base of the tree usually die and drop off by themselves. It is best not to prune small diameter "dry" or dead branches, since that is an additional cost and can actually increase the time until clear wood forms over the branch wound by leaving the branch stub imbedded in the tree. Ideally, pruning is only done on trees that will reach rotation age, not on trees that will be removed in thinnings that will not produce sawlogs. For this reason, the pruning is coordinated with thinning where possible.

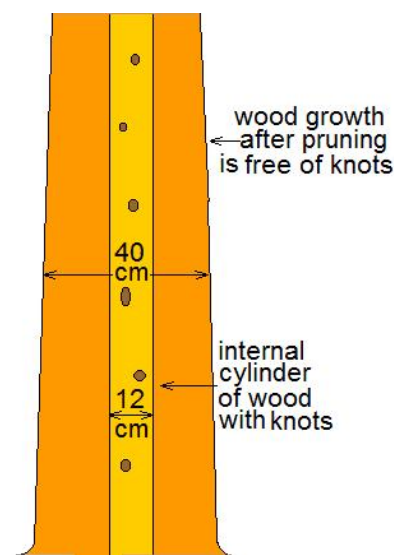


Figure 5. Early pruning keeps knots in a central core, allowing for the production of clear wood outside.

Cost studies for various tropical species generally show that the value of the basal 5 m sawlog of a tree is worth between 50% and 70% of the total stumpage value of the tree. Pruning higher than 5 m increases labor costs due the need for saws on extension poles, or the need for ladders to reach higher branches,

as well as reduced labor productivity. In the case of teak, branch wood is relatively hard and requires more time and effort to prune than does the wood of species with softer branch wood. To minimize the cost and time of pruning, as well as to keep knot diameters small, it is best to prune branches before they become overly large in diameter.

Another consideration with pruning is the number of years remaining after pruning for the trees to grow clear wood on the outside of the pruned core. With early pruning of the basal log, there is more growing time left for

the log to produce clear wood over the pruned core. However, when logs higher in the tree are pruned at a later age, they will have less time to increase in diameter and value on short rotations. Thus, high pruning is more expensive and results in less increase in log value than low pruning.

Using the height/age relationship of the Trinidad teak plantations (Miller, 1979), the following are examples of possible pruning and thinning combinations to minimize pruning costs:

Pruning schedule for 5 m logs, Trinidad Site Class 1

<u>Age</u>	<u>Total</u>		<u>Prune</u>	<u>Comments</u>
Years	height	Thinning	height	
	m		m	
3	7.0	yes	2.5	Prune all trees after thinning
5	10.0		5.5	Prune only crop trees
7	14.5	yes		

Pruning schedule for two, 2.8 m logs, Trinidad Site Class 2

<u>Age</u>	<u>Total</u>		<u>Prune</u>	<u>Comments</u>
Years	height	Thinning	height	
	m		m	
3	6.0	yes	2.0	Prune all trees after thinning
6	10.0		4.0	Prune only crop trees
7	11.5	yes	6.0	Prune crop trees after thinning

After pruning teak, it is common for secondary branches or suckers to sprout from adventitious buds located just above the pruned branch. This requires a second pruning to remove these suckers while they are still succulent. If they are not removed, they become woody branches and defeat the purpose of the original pruning.

Training and supervision of pruning crews is needed to insure that a proper pruning operation is carried out. The pruning cut must be made flush with the tree bole, but care is

needed not to cause damage to the surrounding bark. Pruning is done with a pruning saw, not with a machete. In the case of heavy or long branches, a first cut is made about 30 cm from the base of the branch to remove the weight of the branch. Then a final pruning is made flush with the tree bole to eliminate the branch stub (Figure 6). If the branch were to be pruned flush without relieving the branch weight, there is a risk of bark tear-out below the pruned branch, which causes a defect and an entry point for rot

fungi. For high pruning, a motorized pruning saw on an extension pole is useful (Figure 7).

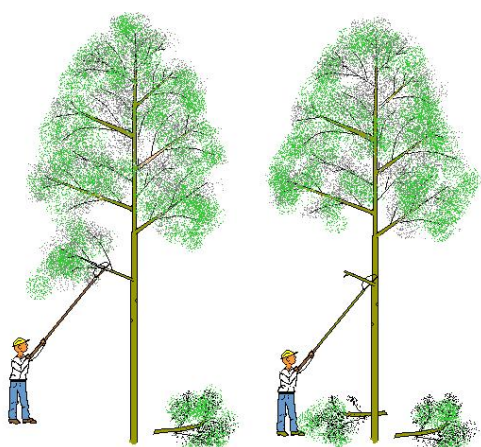


Figure 6. The first cut removes the weight of the branch and the second cut removes the branch stub flush with the bole



Figure 7. Use of a motorized pruning saw to prune teak in Indonesia

Experience has shown that poor pruning practices, such as where live branch stubs are left exposed, where there is bark tear-out below the pruned branch, or where machetes have been used to hack into tree bark, this can create sites for infection and result in heart rot that destroys the value of the logs that are pruned.

The effect of flowering on height growth

Teak generally begins to flower between the 6th and 9th years, but some plantations have been known to initiate flowering as early as 2 years of age (Keiding, 1985; White, 1991). Teak trees in plantations tend to flower heavily and, when they do, the crowns fork and height growth is diminished (Figure 8). Thus, when flowering occurs at an early age, the length of the commercial bole is reduced. The total height of plantation teak grown on 20 to 25 year rotations is less than for other tropical plantation species such as *Gmelina*, acacias, or pines, which often have average, dominate heights in excess of 25 m at harvest age³. Eucalypts frequently have heights in excess of 30 m when harvested at 6 or 7 years. In the case of the Trinidad teak, total heights at 20 years of age were 21 m, 18 m and 15 m for the three site classes (Miller, 1969).

The causes of differences in the age of flowering and the intensity of flowering appear to be due to genetic differences among seed sources (White, 1991). Early flowering in plantations in West Africa and Trinidad is considered to be the result of seed collections from early flowering trees and prolific seed producers (Keiding, 1985). It stands to reason that delayed flowering habits would be an important trait to include in a tree improvement program to increase tree height growth.

A combination of reasonable planting densities along with opportune thinning to minimize early root competition among individual trees may also be a factor for delaying the onset of flowering in teak plantations. This may be particularly impor-

³/ Common rotations for *Gmelina* grown for sawlogs are often between 8 and 12 years; for tropical pines harvest age is between 12-15 years for pulpwood and 20 – 25 years for sawlogs; tropical acacias are harvested at 6 – 7 years for pulpwood.

tant on sites prone to extended droughts. The periodicity and intensity of the dry season may be a critical factor that influences the age of initiation and the intensity of flowering. Casual observation of teak trees seems to indicate that flowering tends to be greater on marginal sites as a reaction to adverse

conditions (Keiding, 1985). Even though teak defoliates during the dry season, trees still require soil moisture. Moisture stress in root systems can occur during extended droughts and such root stresses may contribute to the stimulation of heavy flowering.



Figure 8. Teak plantation in Colombia with heavy flowering (tan colored trees)

Reproduction, nurseries and seed orchards

Teak sprouts readily after harvest and coppice regeneration of teak has been used to regenerate natural teak forests on long rotations in Asia (White, 1991). Coppice regeneration is seldom an option for short rotation plantation management since trees are removed during thinning operations and the stump sprouts need to be eliminated so that they don't compete with the residual trees for soil moisture and nutrients.

This presentation does not go into detail concerning seed production or nursery procedures for teak, but there are some points worth mentioning⁴. Teak produces a hard drupe (dry stone fruit), which has four seed chambers. One or two initials may germinate,

⁴/ Good references for seed handling of teak are: Seed leaflet No. 4, teak (*Tectona grandis*), 1985, by Keiding, Danida Forest Seed Centre, and: Desarrollo de un paquete tecnológico para la producción y certificación de material forestal reproductivo de teca (*Tectona grandis* L.f.) by CONIF, 2008.

but seldom are there four viable seeds within a stone.

Teak can be grown bare-root and transplanted as stumps. When used as stumps, the plants are grown from seed at relatively wide nursery spacings to produce large diameter seedlings. These are lifted from the nursery bed and pruned, top and bottom. In some locations, stump planting of teak has had problems with incipient heart rot appearing as the trees grow.

Teak can be easily propagated through bud and cleft grafting for use in clonal seed orchards (Suhaendi, 1998). It can also be reproduced by vegetative cuttings produced in clonal gardens (Kjaer *et al.*, 1999). Due to the relatively low yield of terminal shoots from young donor trees, one method used to increase the length of stem that can produce apical shoots is to bend the donor trees over and stake the tops to the ground.

Juvenile seedlings can be multiplied by tissue culture for mass reproduction for commercial planting (Kaosa-ard *et al.*, 1998). Clonal seed orchards have been established for seed production using the grafting technique known as budding (Kaosa-ard *et al.*, 1998).

Site selection for teak

Teak grows best on well drained, loam to clay-loam soils that are slightly alkaline (alfisols). It also grows on soils that are slightly acidic and less fertile (ultisols), but does not do well on excessively drained sands. Teak has been planted successfully on young clay loam soils where there is no distinguishable clay accumulation layer or "B" horizon (inceptisols).

Teak can withstand dry seasons lasting 5 months, but grows best when the dry season is

short. For sawtimber production, it is best to select sites where the dry season is less than 3 months, with well drained clay loam to sandy loam soils that have an effective rooting depth of more than 80 cm and a soil pH ranging from 6.0 to 7.5. Teak grows best with an annual precipitation between 1500 mm and 2500 mm per year and where calcium levels are greater than 10 meq/100 ml soil, *i.e.* alkaline soils (De Camino *et al.*, 2002).

Wood quality

The stability of teak wood, as well as its attractive color and grain pattern, makes it valuable for many uses, including shipbuilding, joinery, furniture, flooring, carving, cabinetwork, paneling and turnery (Chudnoff, 1984). Natural teak wood from Asia has a medium-high specific gravity of 0.55 (Chudnoff, 1984). The wood is quite stable with very little shrinkage during drying. Teak wood contains oily resins called tectoquinones that naturally repel termites and resist rot (Steber, 1997). In spite of having an oily feel when fresh, the dry wood glues well.

There exists a common myth that faster growth invariably results in lower wood density. However, genetic studies with many tree species have shown limited to no correlation between the two traits. In the case of teak, studies conducted at the Forest Research Institute at Dehra Dun, India, did not find any significant relationship between growth rate and wood density (Sekar, 1972). In Nigeria, studies of 27-year-old teak plantations did not find any significant correlation between tree size and wood density (Sanwo, 1986).

In Costa Rica, the specific gravity of plantation teak trees was found to vary with age and also from the inside to the outside of the bole (Moya, 2001). Wood in the center

and at the base of trees was found to have wood specific gravities of 0.40 to 0.45, whereas wood on the outside and higher in the trees had specific gravities of 0.55 to 0.60 (Moya, 2001). Wood density for 20-year-old teak in plantations in western Venezuela is reported to vary from 0.54 to 0.67 (Valero *et al.*, 2005). In another study of teak in Venezuela, wood specific gravity at DBH for 10 to 20 year-old trees varied from 0.45 to 0.52, with the higher density readings towards the outside of the tree (Camcore, 2008). In Borneo, the specific gravity of wood from teak trees 6 and 7 years old varied little from pith to bark with values between 0.45 and 0.44 (Camcore, 2008).

Teak trees form a corky pith in the center or heart of the tree which is normally about 3 to 5 mm in diameter. The pith is a defect in lumber and must be sawn out. Even if the pith is not visible on the surface of a piece of rough lumber, it can be exposed after the wood is planed. Boards with pith must be resawn to remove the pith or discarded.

Teak forms a distinctive golden brown heartwood, which turns darker with exposure, while the sapwood has a cream or ivory color. In old growth teak, the proportion of sapwood is quite small since trees grow slow, but the sapwood proportion of young plantation trees is significant. Market demand has traditionally been for teak heartwood with no sapwood. However, as smaller sawlogs from plantations become more common, sapwood inclusions will tend to become more important. Thus, a key consideration with teak management is how to maximize the diameter of the higher value heartwood, not just the diameter of the tree itself.

There exist notable variations in the grain and color of teak wood (Figure 9). In Indonesia, four distinct types of wood have been identified (Suhaendi, 1998):

- Light colored wood with lime concretions in the wood, this teak grows on calcareous soils,
- Oily teak is hard and shiny and feels waxy due to the tectoquinone in the wood,
- Wrinkled, rippled or waxy teak,
- Striped teak, having dark brown stripes or streaks in the grain pattern.

The Indonesian market generally prefers darker colored wood for furniture, but lighter colored wood is preferred for export for use in decorative interior paneling. Observations made in provenance tests at two sites suggest that the streaked teak is related to site. At a site where the soil is marginalitic (black calcareous), the occurrence of streaked wood in progenies is 100 percent, while at a site on volcanic ash soil (slightly acidic andosols), it is only 37 percent (Suhaendi, 1998).

In Thailand, teak wood with dark brown stripes is known as tiger stripe teak. The tiger stripe teak is in demand for use in furniture, but is not desirable for interior paneling. The causes of the variations in the color and characteristics of the teak grain are not well understood nor well documented. Soil and site differences may be important in the definition of the teak grain, but genetic variation may also be important.

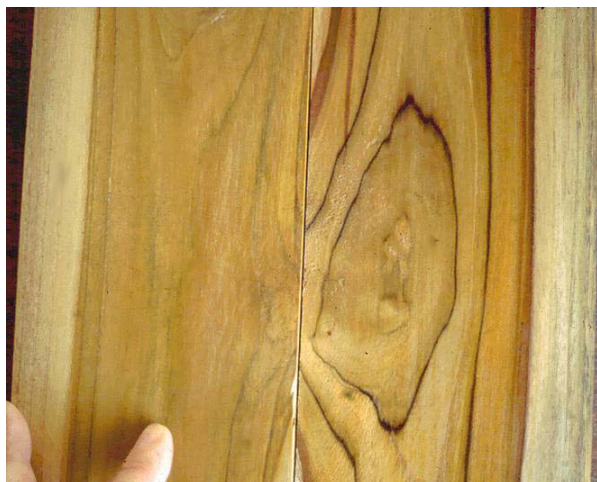


Figure 9. Sliced veneer from plantation trees in Colombia comparing golden teak to striped teak.

There exist teak grades for logs from natural forests in Myanmar. The grades, in descending order of value, are:

- Second quality veneer
- Third quality veneer
- Fourth quality veneer
- SG1 sawlog grade 1
- SG2 sawlog grade 2
- SG3 sawlog grade 3
- SG4-SG6 sawlog grades
- ER-1, ER2

Grades 2, 3 and 4 are for sliced veneer logs and have the highest value. Logs of 4th quality, SG1 and SG2 are over 48 cm (19") diameter. Logs in the SG3 class have diameters between 30 cm and 48 cm (11" to 19"). There are also lower grades, from SG4 to SG6, plus two grades for local use (ER1, ER2).

Standard grades for young plantation teak logs have not yet been established. Lumber grades for teak are also needed and should include information regarding the amount of sapwood and the presence or absence of pith in the board, among other traits. A standardized grading system for small

diameter plantation teak logs and lumber is needed to facilitate international teak trade.

Harvesting and marketing

Forest land in most Asian countries is owned and/or controlled by the government. In some, the military is responsible for forest management and timber harvesting. Age-old log handling practices, developed in the 1800's, continue to the present. Girdling of standing trees two years prior to harvesting continues to be practiced to allow the wood to dry prior to felling, as a means to reduce log weight for skidding by animals. Girdled trees are frequently attacked by wood borers⁵ that make large holes in the wood and reduce log value. Elephants are still an essential part of teak harvesting in Myanmar (Kloos, 1995). They are used for skidding and also for handling logs in the woodyard. In Indonesia, buffalo are still used for moving logs. Cross haul or manual methods continue to be used to load small trucks with logs.

In Java, logs and large branches are moved to shaded woodyards operated by Perum Perhutani, a government forestry company, where individual logs or even branch pieces are sold to customers. Besides the problem with wood borers, logs in woodyards often have severe end splitting; this in spite of having shade trees covering the log yards as a means to control ambient humidity. There is little incentive to modernize the forest harvesting methods where forest management is controlled by government agencies or the military. Similarly, there continues to be a strong demand in Asia for even small pieces of teak wood for use by small furniture operations and artisans who make fine carvings, furniture detailing and wood figurines from even the smallest pieces of

⁵/ Common borers found in teak are in the Order *Lepidoptera*, Family *Cossidae*.

wood. Asian teak furniture continues to be in high demand in Europe and America (Sinaga, 1998).

In 2004, Myanmar was estimated to have 60% of the world's remaining primary teak forests. Forestry is controlled by the military and most benefits from Myanmar's timber exports are being used for military spending. Forest harvesting and wood manufacturing in Myanmar is controlled by the Myanmar Timber Enterprise, a state-run organization. Teak harvesting, as reported by government sources, was 409,000 m³ in 2001 (Asian Timber, 2001). In spite of being declared illegal in 1993, a large movement of teak logs continues from the northern state of Kachin across the border and into China's Yunnan Province. China's roundwood timber trade with Myanmar was 295,000 m³ in 1997 and grew to 948,000 m³ by 2002 (Kahrl *et al.*, 2004). However, according to Myanmar's published customs statistics, India is the largest destination for Myanmar timber exports, receiving 76% (770,554 m³) of all hardwood log exports in 2001 (Kahrl *et al.*, 2004). On the other hand, China comprised just 0,3% (3,237 m³) of Myanmar's official hardwood log exports, but China's customs statistics record 2001 log imports from Myanmar at 513,574 m³. This rather obvious discrepancy suggests that illegal logging is taking place on a massive scale along Myanmar's border with China (Kahrl *et al.*, 2004).

Prices of teak in Myanmar are based on a traditional log grading system that separates highest quality veneer logs from lower grade sawlogs. Grading is based on top diameter, log length and straightness and number of defects. Log prices in Myanmar are listed in Euros per hoppus ton⁶. Table 4 provides FOB log values for 2008 and 2009 converted to

US\$/m³. It can be seen that there was a drop in prices after the world economic downturn of September, 2008, but that prices began to recover in early 2009.

Teak logs from younger plantations do not command the prices of those in Myanmar. Similarly, there are fewer buyers interested in young plantation logs from sources outside of Asia. In 2000, teak logs FOB from African and Latin American plantations were reported to be in the range of US\$140 to \$250/m³ (Maldonado and Louppe, 2000). These plantation teak log prices are lower than the lowest Myanmar export log grade (SG-6) for natural teak (Keogh, 2008).

Of the total amount of teak wood imported into the United States in 2000, 73% was natural teak from Myanmar, Malaysia and Thailand (U.S. Dept. of Commerce, 2001).

In Venezuela, there were 5,000 ha of teak plantations established in the federal forest reserves of Ticoporo and Bum-Bum in the western state of Barinas during the 1970's and 1980's. Most of them were not thinned and had not been pruned. When many of the plantations had reached 20 years of age, most of the trees were in the range of 25 cm to 35 cm DBH. They were sold to Malaysian buyers at a stumpage price of US\$200/m³. On the north coast of Colombia, near the city of Monteria, teak plantations 20 years old were sold to Indian buyers for a stumpage price of US\$225/m³, but the real net price after discounting defects was US\$168/m³.

In Costa Rica there are few published data on teak prices. Most plantations are still young and there are few reliable data on older plantations (De Camino, *et al.*, 2002). The Costa Rican Forestry Chamber (CCF) does provide some price information. In 1998, logs in woodyards with diameters between 14 and 25 cm were sold at prices around US\$160/m³ (CCF, 1998). Between 1997 and 1999,

⁶/ A hoppus ton is a measure of volume used in Myanmar, with 1.8 m³/ton.

thinnings from teak plantations in the Ivory Coast were sold at prices ranging from US\$90 to \$100/m³ FOB for export. These were first thinnings from 10-year-old stands that had minimal silvicultural treatment.

In tropical America, teak is being planted and managed on private landholdings. Markets for small diameter teak logs from plantations will be different from the traditional markets for large diameter logs. The marketing strategy for selling plantation teak will need to include advertising that demonstrates the value of teak from young plantations.

Many teak growers are showing increasing interest in producing value-added consumer

products from their wood and engaging in the processing and marketing of their own finished or semi-finished products, as opposed to trying to sell stumpage or logs.

The major challenge for plantation growers is to produce quality teak wood that is acceptable in international markets (Figure 10). The creation of uniform international log grades for plantation teak, along with standardized lumber and product grades would be of great help to improving the marketability of teak wood products. Standardized descriptions are needed so that buyers know the exact quality of the products being offered for sale.

Table 4. Selected prices of teak logs FOB at monthly auctions at Yangon, Myanmar, in 2008 and 2009

Log class	Minimum Top diam.	Minimum Length	2008			2009	
			Feb	Nov	Dec	Feb	Mar
Veneer quality	cm	m	US\$/m ³	US\$/m ³	US\$/m ³	US\$/m ³	US\$/m ³
2 nd quality	48	2.4	4 054	3 026	-	-	-
3 rd quality	48	2.4	3 687	3 134	2 736	3 281	3 438
4 th quality	48	2.4	3 336	2 274	2 295	2 900	2 851
Sawlogs Grades							
SG-1	48	2.4	2 215	1 679	1 770	2 063	1 992
SG-2	48	2.4	1 961	1 398	1 456	1 853	1 895
SG-3	33	2.4	1 577	-	-	1 593	-
SG-4	38	2.4	-	1 313	1 405	-	1 622
SG-5	38	2.4	-	1 160	1 126	1 243	1 237
SG-6	38	2.4	-	894	890	1 011	1 022
ER-7	33	2.4	-	777	752	811	797

*/ Missing data indicates that no logs of that grade were sold during that month.

Sources: ITTO TTM reports, 2008 and 2009

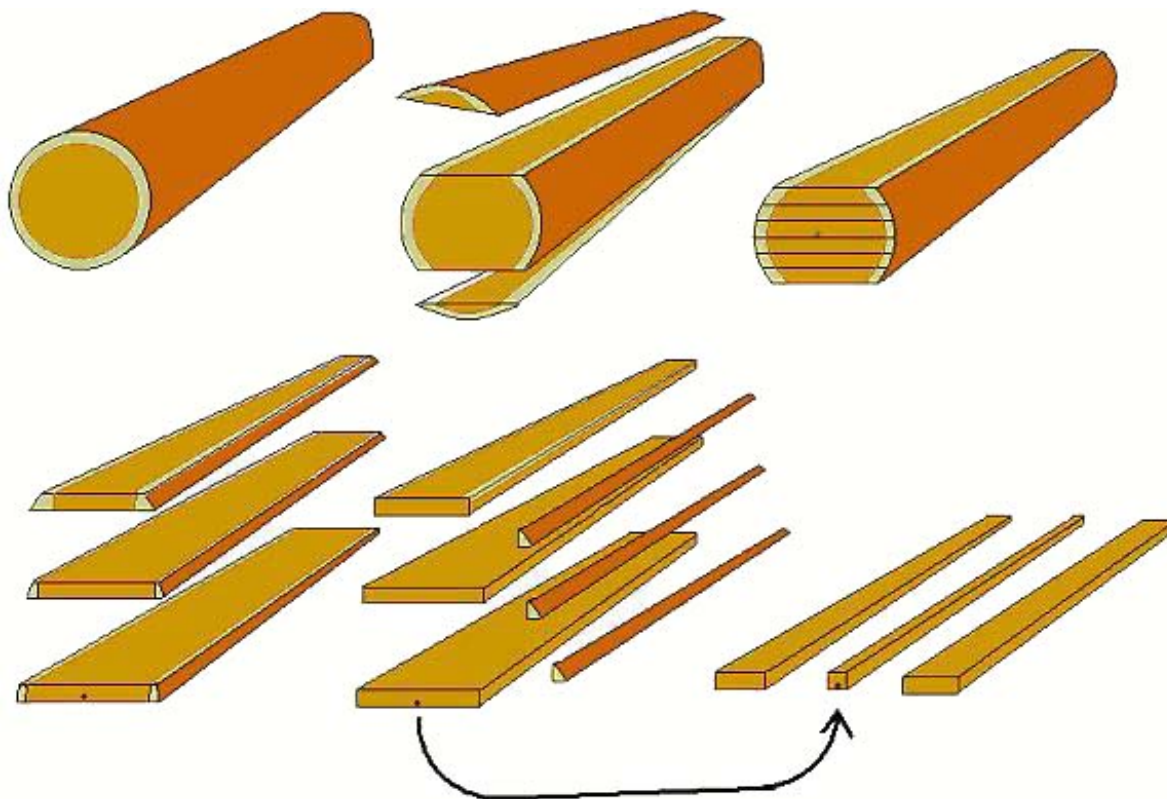


Figure 10. Sawing for quality in small teak logs involves sawing boards, edging boards to remove sapwood and wane and then removing the pith from the center board.

Dr. Raymond Keogh suggests the following guidelines for development of a standardized pricing mechanism for teak plantation logs (Keogh, 2008).

- Develop standard grading rules for plantation teak stumpage and logs
- Grades include log dimensions (5 cm diameter classes and standard lengths)
- Log roundness (amount of fluting and/or taper)
- Wood quality (percent heartwood, color, rings/cm, density)
- Defects (knots, splitting, shake, heart rot)

Additionally, standardized product descriptions are needed for lumber (thickness, width, length), sliced veneer flitches (thickness, width, length) as well as partially manufactured pieces such as edge glued blockboard, finger jointed lumber and furniture blocks for turnings.

There is a need for an international teak producers association if standardization of teak products is to become a reality. This is not a simple undertaking, considering the diversity and number of teak growers in the tropics and the multiple and varied objectives of landowners who have teak plantations.

A model well worth considering for setting up a teak producers association is that of the cooperative tree breeding programs. Such programs have a long history of cooperation

among universities, forest industries and government forestry agencies, with the cooperatives in the United States and Brazil being noteworthy examples. The CAMCORE cooperative established in 1980 and located at North Carolina State University now has 37 members in 21 countries (Camcore, 2008). Camcore is initiating genetic research on teak seed sources in 2009. This model of cooperative action is a clear example that international cooperation among diverse entities is not only possible but highly successful. A teak growers association based on a similar style of cooperative action could be a mechanism for establishing standardized grading procedures for teak marketing, as well as a center for the teak product research and development.

Conclusions: Where do we go from here?

In early planting trials, it was discovered that Myanmar seed sources generally had better form and better growth than Indian seed sources for planting in many locations in Africa and Central America. Indonesia initiated some provenance testing of local sources in 1930 and began plus tree selections for establishing clonal seed orchards in the 1970's (Suhaendi, 1998). Teak tree improvement activities began in Thailand in the early 1960's. In 1965, the Teak Improvement Center (TIC) was established at Ngao, Lampang province (Kaosa-ard *et al.*, 1998). Continued work in the 1970's between the DANIDA Forest Seed Center, Denmark, and the TIC has produced seed for provenance testing on an international scale, with financial support from the United Nations Food and Agriculture Organization. The participation of DANIDA in this effort continued through the 1980's as the international trials were evaluated (Keiding *et al.*, 1986), while the Thai research continued into the 1990's (Kaosa-ard *et al.*, 1998).

There have been international provenance trials in some countries. In an international provenance trial in Thailand, the mean heritability value of stem straightness was found to be 0.83, indicating that the trait of stem straightness is strongly controlled by provenance and is thus genetically inherited (Kaosa-ard, 1999). Nonetheless, there is a dearth of provenance trials to evaluate multinational seed sources within the natural teak range. Studies are needed to evaluate the growth and development of teak in exotic plantations as well as within its natural range.

It is worth noting that most tropical tree plantations for wood production have been made by large pulp and paper companies. There has been considerable research carried out by universities, cooperatives and individual companies to improve the quality and productivity of plantations destined to fiber production. In contrast, however, interest in teak silviculture and teak genetic studies has been extremely limited and there has been precious little cooperation among teak producers to improve the quality of the plantations and wood products. If plantation teak is to become a valuable commodity with increasing profitability for investors, there must be a ramp-up of forest and wood technology research.

Research is needed to minimize fluting of teak trees (Figure 11). Fluting is a common occurrence in old teak stands and it occurs in younger plantation teak as well. Fluting reduces the utility of the lowest portion of the tree bole which has the largest diameter and the greatest amount of heartwood. If stump height can be reduced through reduction or elimination of fluting, stumpage values will improve. Leaving high fluted stumps after harvesting not only reduces the profitability of the timber harvest, but it also increases the costs of site preparation and stand management of future plantations.

Early and heavy flowering limits the height growth of teak trees. Traditional selections for early and heavy seed producers in past years have exacerbated this problem. Provenance testing and selection for increased height growth and delayed seed production can have a positive impact on the profitability of teak plantations.

Very little research has been done on the relationship of heartwood to growth rate and seed source. One study in India found a positive correlation of the percent heartwood to ring width and tree diameter (Bhat, 1997). This means that faster growth rates may be associated with greater heartwood content, contrary to popular belief. Increasing the early production of heartwood with reductions in the amount of sapwood would increase the value of young teak trees. Such research has not been a consideration for pulp species, but is critical when growing trees for solid wood products.



Figure 11. Basal flutes of teak can reduce sawlog yields significantly.

One trial was made in Costa Rica to determine if spacing affected the percentage of heartwood formed in plantation teak trees. The spacings tested were 6 m x 2 m (830 trees/ha) and 3 m x 3 m (1100 trees/ha). At 10

years of age, no significant difference was found in the formation of heart wood due to initial spacing; not in the height of heartwood within the tree, nor in the proportion of heartwood in the tree diameter (Ledesma and Moya, 2001).

There exists a negative environmental reaction to teak among some importing countries and there have been campaigns to try to stop consumer use of teak products. Environmentalists claim that by buying teak, even plantation teak, buyers are causing environmental damage to tropical sites (Rainforest Relief, 2002). Teak growers and producers need to provide alternative environmental views of teak growing to explain to importers and buyers of teak products the positive aspects of teak silviculture and the impact of teak plantations on the environment and on local economies. A critical evaluation and well-founded arguments are needed to explain the value of teak plantations for watershed protection, soil protection, job creation and welfare for people living in local communities where teak is grown.

There exists a need for improved market strategies through innovative product development. One important method to do this is through cooperation among teak producers and universities that have facilities for wood technology and wood product design. Because of its characteristics as a fine wood as well as a stable wood, teak shows great promise for providing wood products such as parquet flooring, household utensils, fine furniture, deck furniture, as well as sliced veneer for laminated flooring, paneling and doors skins (Figures 12-13).

Length-wise veneer slicers can produce quality heartwood teak veneers from small dimension stock. Length-wise veneer slicers have a relatively low capital cost, compared

to traditional veneer slicers designed to handle large quartered logs. They are ideal for producing sliced veneers from small plantation wood and for use in small, local wood industries (Krishnapillay, 2000).

Research is also needed to evaluate the use of teak for certain grades of wood pulp and paper products, or for use in charcoal for home and industrial use. The Brazilian steel industry is based exclusively on pig iron smelted with wood charcoal instead of coke. Teak charcoal could become an important use for small dimension stock and waste products from teak plantations. Teak poles are used in some localities for roof poles and for local transmission poles and the expansion and promotion of such uses is well worth investigating.

Teak is by far the most important species of fine wood in tree plantations. In spite of being one of the earliest species to be tried in forest plantations, and having a long history of planting in the tropics, there is still much research needed to develop its full potential.

The old growth teak is rapidly disappearing from the natural forests of South Asia and there exists a good opportunity for plantation teak wood to increase in importance in world markets. The key to the success for teak plantations is for teak producers and investors to work together to develop this potential.



Figure 12 A doorskin made from plantation teak with 10 cm wide, book matched sliced veneer, Thailand



Figure 13. A teak table made with wood from thinnings in Colombia

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