THE CARE AND MANAGEMENT
OF TEAK (Tectona grandis l.f.)
PLANTATIONS

R.M. KEOGH.
THE CARE AND MANAGEMENT OF TEAK (*Tectona grandis* L. f.) PLANTATIONS

ERRATA SLIP

Page 26, table, second line out of sequence:

<table>
<thead>
<tr>
<th>THINNING</th>
<th>REMOVAL</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th</td>
<td>1 for every 2.6 or 6 in 15</td>
<td>(38)</td>
</tr>
</tbody>
</table>

Page 37-38, GENERAL INDEX TO MAIN TEXT

<table>
<thead>
<tr>
<th>Page</th>
<th>Delayed thinnings</th>
<th>27 (not 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Page</td>
<td><em>Taungya</em></td>
<td>add: 19, 21</td>
</tr>
<tr>
<td>Page</td>
<td>Wood - shrinkage</td>
<td>33 (not 32)</td>
</tr>
</tbody>
</table>

APPENDIX A

Page: Reference: line and observation:

| 40 1, | 2, replace ‘observacion en plantaciones de teca’ with ‘observaciones de erosion en plantaciones de teca’ |
| 41 10, | 2, ‘caribaea’ (underline) |
| 41 11, | 4, replace ‘758 p.’ with ‘p. 460 - 492’ |
| 41 15, | 2, replace ‘GONZALEZD.’ with ‘GONZALEZ, D.’ |
| 42 19, | 2, replace ‘Bulletin’ with ‘Bulletin’ |
| 45 54, | 2, add ‘)’ bracket after ‘(*Tectona grandis*’ |
| 46 59, | 1, ‘(Tectona grandis’ (underline) |

Acknowledgement:

photo, page 8, was kindly donated by

Dr. H. Keiding of DANIDA Forest Seed Centre
THE CARE AND MANAGEMENT OF TEAK PLANTATIONS

Contents

INTRODUCTION 7

GENERAL INFORMATION ON TEAK 9
Scientific name
Family
Common name
Natural distribution
Climate
Area
Seed source

SITE, PLANTING AND SPACING 11
Site
Plants and planting
Spacing

CARE AND MAINTENANCE OF THE PLANTATION 12
Cleaning
Fencing
Drainage
Fertilisation
Fire
Erosion
Diseases
Wind
Theft

TEAK AND AGRI-SILVICULTURE 17
The Taungya system
The group planting system

THINNING 21
General points
Determine site class
First and second thinnings
Subsequent thinnings
Thinning of the group planting system
INTRODUCTION

This booklet is intended to be used as a practical guide for the care and management of teak plantations in the Caribbean, Central America, Venezuela and Colombia. It is hoped that the contents are presented in a simple enough fashion to allow those involved in growing the species to carry out the operations themselves.

References in the main text are kept to an absolute minimum but an appendix has been added that supplies a regional teak bibliography with a key-word index. It was mainly from this list of references that the booklet was compiled.

It cannot be overstressed that teak is a quality product. Plantations, therefore, need special care and protection; care to see that they are thinned properly and on time, and are protected against man, animals, fire and disease. These and other points related to silviculture are considered. The question of economics has not been discussed at any length. However, it should be possible to compile estimates based on information contained within this document and current local timber prices of species employed for similar end uses.

Because of restrictions on site, it is probable that the species will continue to be planted on a small scale throughout the region in question, with the possible exception of Trinidad and larger countries like Venezuela, where extensive plantations might be established that could regularly produce a good quality product for the international market.

Improvements in the estimates of growth and yield could be achieved by gathering additional information based on research at the regional level. Further booklets could be compiled for other selected species that are widely used in industrial and fuelwood plantations and agroforestry systems in the area. These matters are explored in an earlier paper.1

GENERAL INFORMATION ON TEAK

SCIENTIFIC NAME  Tectona grandis Linn., f.

FAMILY  Verbenaceae

COMMON NAME  Teak

NATURAL DISTRIBUTION  Teak is native to India, Burma, Thailand and Laos (Figure 1). It is also found on Java where it was possibly introduced by man.

CLIMATE  Teak grows BEST in a warm tropical climate in which there is a dry season of 3-5 months, rainfall of about 1500 to 2000 or more millimetres per year and a mean annual temperature of 22-27°C.

AREA  The area devoted to teak in the region under discussion was 15-14000 hectares in 1978 and it is estimated that this is expanding by over 300 hectares per year. Trinidad alone contains over 20% of the planted area.

SEED SOURCE

This booklet deals with the management of the species in plantations rather than in the nursery. However, good seed is a primary requisite for the establishment of good plantations. Research work carried out identified 19 different strains of seed which were imported into the region.

The two most important introductions were: 1) Tenasserim to Trinidad in 1913 and 2) Sri Lanka (Ceylon) to Panama in 1926. The Tenasserim-Trinidad strain has been generally regarded as being a good one and it is difficult to recommend areas in the region other than Trinidad as seed sources.
Cuba and Venezuela are taking part in international provenance trials under the guidance of the Danish/FAO Forest Tree Seed Center; results from these experiments should be of interest to teak growers in the region.

SITE, PLANTING AND SPACING

SITE

Good soil is the number one site requirement for teak. Look for deep (1-2 metres), well drained, flat or slightly sloping alluvial loam soils which tend to have a homogenous profile. The area should be influenced by a 3 to 5 month dry season ("dry month" being defined as that in which 50 millimetres or less of precipitation are accumulated), and should have an annual rainfall of over 1500 millimetres.

Avoid sloping ground because soil erosion under the plantations will be a problem unless an understory can be established.

Teak needs good quality sites; if these are not available CONSIDER ALTERNATIVE SPECIES.

PLANTS AND PLANTING

Planting teak stumps, which are root and shoot pruned plants, is the commonest and most successful method. This reduces establishment costs, and stumps may be planted several weeks before the beginning of the rainy season. They may also be kept out of the ground in bags, for several days. As regards time of planting, some foresters prefer to wait until several heavy showers have fallen before beginning the operation, because they do not consider the soil to be in a satisfactory condition before this occurs.

Only the largest nursery plants should be used; these produce bigger trees in the first growing season and are best able to compete against weeds. It is recommended that the diameter, at the cut part on the stem, should not be less than 1.25 centimetres.
A hole of appropriate size to take the plant is dug; the tree is placed vertically within and earth is carefully replaced before being pressed down tightly. Ensure there are no air pockets left at the roots where stagnant water can collect and rot them.

SPACING

Plants should be spaced at 2.5 metres along rows, and rows should be at intervals of 2.0 metres from each other. This results in 2000 trees per hectare.

Alternatively rows may be spaced 2.5 metres apart; plants would be then fixed at 2.0 metres along rows.

For another configuration, consult the section on teak and agri-silviculture below.

CARE AND MAINTENANCE OF THE PLANTATION

It cannot be overstressed that teak is a quality product. As mentioned in the introduction, plantations need special care and protection; care to see that they grow properly and protected against man, animals, fire and disease.

CLEANING

Teak is very susceptible to shading and it is essential to keep the stands free of weeds that could grow up and deform, suppress or otherwise damage the young plants. For this reason two to three cleanings must be made in the first year; two in the second year; one in the third and maybe one in the fourth. Chemical weeding is not considered here.

Intercropping is an alternative (consult the section on teak and agri-silviculture below).

FENCING

Protection against grazing animals should be ensured as the young shoots, although not often browsed, are readily broken or trampled.

DRAINAGE

Sites should be well drained. If expensive drainage seems necessary, then other species should be considered.

FERTILIZATION

None is recommended for the first rotation; the site should be adequate. However, it may be necessary to add some form of calcium before the second rotation commences. Proper thinning, rather than fertilizing, is recommended for enhancing the diameter growth of individual trees in the early growth period.

FIRE

Teak is resistant to fire, but fire tends to weaken the plant and causes unwanted side-effects, especially after the fourth year.

Very young stands may recover quickly by producing vigorous coppice shoots. However, it is advisable to provide fire protection during each dry season.

From the fourth year until the time when the bark is thick enough to withstand high temperatures, it may be killed and stripped in spots, and this renders the wood susceptible to fungal attack. Fire is also associated with epicormic branching, some loss of soil nutrients and humus, and it leaves the surface exposed to erosion. Repeated fires may reduce the site potential considerably, thus causing a decrease in growth rate.

EROSION

The following statement was made in 1973 in the case of Trinidad: "If soil erosion cannot be reduced to a degree less than that of soil formation, consideration should be given to abandoning the policy of teak planting..."
(Reference 5, Appendix A). Serious erosion was observed under some stands in El Salvador, and may be observed throughout the region wherever soils are unprotected by an understory of vegetation.

Look for tell-tale signs on the soil surface. Rain, falling on bare patches, causes displacement of soil particles (this is splash erosion). A typical sign of this type of erosion is the presence of columns of soil, protected on top by small stones, twigs or other material; small roots may also be found protruding.

Teak, planted at narrow spacings, tends to kill off vegetation in the herbaceous layers; at the beginning of the dry season, leaf fall occurs. The leaves may be blown away or destroyed by fire. Fire destroys humus and most remaining protective vegetation; when the rains begin again, large quantities of soil may be displaced and washed away. Sloping ground tends to exacerbate the problem. Leaching of soil nutrients is a further malaise associated with bare ground.

Solutions

Good site selection should virtually eliminate potential erosion. Growth rate of the main crop and the rapidity of development of the understory tend to increase with increasing rainfall. For this reason it is advisable to look for sites having an excess of 1500 millimetres/year. Teak will endure annual precipitations as low as 500 millimetres/year, but it must be emphasized that to obtain a quality product, without destroying the environment in the process, only the better sites should be planted. Avoid sloping ground. Flat alluvial soils near rivers that are fed by ground water and are influenced by high rainfall (2000 millimetres or more per year) generally maintain a good quality crop and a satisfactory understory. Provided other site requirements are satisfied (e.g. abundance of adequate nutrients), there should be no deleterious effects on the environment. As site becomes less idyllic, steps must be taken to ensure erosion is minimized. Some points worth considering are outlined below:

i) Protection against fire. Ensure that all crops, irrespective of site, are adequately protected against fire during the dry season.

ii) Encourage the understory. As the introduction of an artificial underlayer of vegetation may be expensive, it is advisable to encourage any existing natural undergrowth or introduce a crop that will give some economic return. A woody fire retardant layer, that maintains its cover throughout the dry season, is ideal. For this reason, the killing off of teak coppice shoots is to be encouraged. Azumane or other poison may be used.

In Trinidad some plantations have been invaded by a leguminous shrub (Flemingia strobilifera), but attempts to introduce it artificially, by broadcasting seeds, have not been successful. Leucena glareana may be another choice, but care should be taken to prevent this plant from suppressing the teak. In Venezuela, sombreiro (Eliotia arborescens) might be introduced after thinning. In Cuba, teak has been planted on terraces in mixture with coffee. Bamboos are another possibility; in native areas these species form natural understories.

iii) Increase initial plant spacing. The greater the distance between the canopy trees, the greater is the ground vegetative cover. However, wide initial spacing encourages branching and development of heavy branches. Therefore, it is silviculturally undesirable. Alignment of plants in the group planting system is an alternative; this is described later.

iv) Mixtures. No adequate mixtures of teak with other species have been found; most are harmful to the main crop and so this does not seem to provide a solution.

DISEASES

Teak in the region has not suffered much from disease. However, several maladies that have been reported are discussed below.

Ants

Leaf cutting ants (Atta sp.) attack plantations. These are otherwise known as bachac or parasol ants (bachacos or
zompopas in Spanish). Normally no control measures are applied. If they are seen to be a problem, then the nests are easily destroyed with carbon bisulphide. The following commercial products may be used: Aldrin, Mirex, Chlordane.

Fungi

It has been mentioned that one of the undesirable side-effects of fire is that the wood may be rendered susceptible to fungal attack. Lesions on the bole of the tree, including those caused by careless pruning, may have the same effect. It is more desirable to prevent the entry of fungi into stems by protecting them against fire and other types of mechanical damage, than control the disease after penetration.

A heart-rotting fungus, Plectus commiscibilis, and one causing damage to roots (Rosellinia spp.) have been recorded in Trinidad. Another, Ustulina deusta, was reported in Venezuela.

Mistletoe

Mistletoe, or Birdvine, parasites of the family Loranthaceae, have been found in Trinidad. Several species are documented: Phthirusa aduncus (Heyer) Maguire is common. Phoradendron piperoides H.B.K. and Viscum spp. have also been reported.

These epiphytic flowering plants damage the crowns of trees after the fourth year and may cause problems in older plantations. They reduce growth of the infected trees but rarely kill them.

To control the disease, infected branches should be pruned off at about 30 centimetres below the point of attack and burned during the leafless period or when the fruits of the loranthus begin to ripen. Heavily infected trees may be removed when thinning. Other control measures suggested are:

i) isolation of new plantations from older ones, and

ii) removal of mistletoe in the surrounding forest within 400 metres of the plantations.

WIND

The species is not unduly prone to wind damage. However, very high winds, caused by cyclonic storms, may damage plantations. In Puerto Rico teak was classified as being susceptible both to withdraw and breakage after the hurricane "Betsy" had crossed the island in 1956.

Occasional damage has been observed in Central America. Good site selection should help to offset these instances.

THEFT

The problem of theft is especially related to small plantations in areas of high population density. Very often the best trees are taken and this may destroy the potential of the stand. If this is thought to be a problem and no security measures can be taken, then it might be wise to consider an alternative use of the site.

TEAK AND AGRI-SILVICULTURE

Intercropping with agricultural crops in the early years of the plantations may have several beneficial effects:

i) increased utilization of the site

ii) benefits to the local community, and

iii) maintenance of the area free of weeds.

This approach is feasible only where there is a demand for cultivable land and would, therefore, normally be practiced in high population density areas. Where carried on, care is needed to ensure that the teak plants are not damaged in the process. Two methods of intercropping are considered:

a) the Teungya system, as reported in the literature for Trinidad, and

b) The Group Planting System.
a) THE TAUNGYA SYSTEM

Taungya, in Burma, means raising a forest crop in conjunction with agricultural crops. The practice is described here for Trinidad, where natural forest is replaced by an even age plantation. The land is owned by government authorities and is leased to peasant contractors, rent free, for a 12 to 18 month period. The terms of contract are made out before the work commences and if not obeyed, the person in question will not receive a plot the following year. Constant vigilance by the forest authorities is needed.

First Year

The natural forest is cleared by timber merchants and charcoal burners. In wet areas, (where rainfall is in excess of 2000 millimetres) a final clearance is made by contractors and in September or October, the first crop is planted. This may be maize, beans, tomatoes, acajou or other acceptable cultivars.

Second Year

In February, or March in wet areas, the first crop is harvested before the site is prepared for planting. The final clearance of the natural forest is made in dry environments, before the end of April, when all debris is burnt. Any remaining vegetation is also destroyed at this time on wet sites. Fire traces, 8.0 metres wide, are made on the outer edges of areas to be planted.

Should fire be used to clear debris? Mention has been made of the association of fire with nutrient and soil humus loss. But in areas where the natural forest is being replaced, clearfelling followed by insolation leads to a decrease of soil humus anyway. Further disadvantages at the pre-planting stage may be destruction of woody plants and their seeds which could form a potential undercover. On the other hand new seeds will be brought in by wind and birds at a later stage and with encouragement should help in the build up of a new understory. Furthermore, burning makes planting and tending easier and, therefore, cheaper. It also gets rid of fire hazard in young plantations by eliminating debris. It releases potash and other minerals and while these may be leached, they may also be taken up by the new teak plants.

All obstructions to the rapid exit of surplus water, through natural watercourses, are cleared at the onset of the rainy season. Other necessary drainage improvements are undertaken at this time.

During May and June, planting takes place and a picket or stake is placed in the ground beside each teak tree to identify its position.

By the end of June, when planting is finished, the second crop (or first in dry areas), is sown. This is hill rice, beans or tomatoes. A minimum distance of 30 centimetres are left around each teak plant. Maize may also be planted, but a minimum distance of one metre for the trees is then required.

Cassava, pigeon peas, ochroes and tannias are not allowed to act as the second crop species in areas where they would outgrow the forest trees. Permanent crops and bananas are also forbidden.

In August, all dead teak trees are replaced and double leaders removed. November sees the harvesting of the second crops and, where possible, the sowing of a third crop: pigeon peas.

It should be possible to apply this system, with modifications, to suit local conditions in other parts of the region. One point should be clear: replacement of the natural forest, by teak, is not being advocated here. The description given above reflects the system as outlined in the literature.

b) THE GROUP PLANTING SYSTEM

This is an extension of the Taungya System. Instead of the trees spaced equally throughout the whole plantation they are planted in groups. The original spacing given (Reference 37, Appendix A) results in over 2800 trees per hectare, which is excessive. It is suggested here that the following spacing be adopted: 6.3 metres square spacing, center to center of each group. Within groups: plants to be arranged at the corners of two squares, the inner having a side of 1.0 metre and the outer square a side of 2.0 metres. This provides 250 groups of 8 trees per group or 2000 trees per hectare (Figure 2).
Advantages of this system are: cultivators may utilize the land for a longer period than in the Taungya System described previously and in addition to the traditional Taungya crops, it may be possible to interplant with banana clumps.

Thinning of this system is described on page 26.

THINNING

GENERAL POINTS

It is important to thin the species adequately and on time. If this is delayed beyond 10 years or so, the crop is unable to respond fully to later thinnings.

Assuming that the operation is carried out on time, the forester must approach it in an organized manner. First: it is necessary to know the area of forest to be worked, and second: a plantation history should be established. Maps and crop records should be gathered to obtain as much information as necessary. If no map exists, one should be made. The most important crop record is the date of planting. If this cannot be established, then fell a small tree and count the number of annual rings at its base. A walk through the stands will enable a rough classification of the area to be drawn up.

Plots are used during thinning operations to:

1) segregate plantations into site classes,
2) enable the forester to decide on when to thin, and
3) make sure that thinning is being carried out properly. This is thinning control and is important in the third and subsequent thinnings.

It must be left to the judgement of the forester to select the number of plots required in each case. An area where the crop growth is variable will need more plots than an area in which the stands are uniform. As the forester gains more experience of the plantations, it will be found...
that less plots are needed to obtain the information.

**DETERMINE SITE CLASS**

In order to know at what rate the stand is growing and in order to decide when to thin, it is necessary to find the site class from top height and age.

**TOP HEIGHT** is the mean height of the 100 largest diameter trees per hectare, or equivalent. It may be found by laying down a plot of convenient size in a representative area of the stand. A circular plot of radius 8 metres (0.02 hectares) is adequate in young plantations. Select the two largest girth trees and measure their total height with a hypsometer; the mean of the two is top height. A plot of 12.62 metres radius (0.05 hectares) should suffice in older stands. In that case it is necessary to obtain the mean height of the five largest trees in the plot.

Once top height and age have been obtained, go to the chart (Figure 3) and find out what site class the stand belongs to. For example, a stand of top height 22 metres and 10 years falls into site class I, because 22 metres and 10 years intersect within the lines that demarcate that class.

Site classes IV and V represent poor sites and are not recommended for planting.

**FIRST AND SECOND THINNINGS**\(^2\)

First thinning: When the stand reaches 8 metres mean height, the first thinning is made; every second tree on each line is removed (Figure 4). It is possible to apply certain selection criteria to favour well-formed trees or remove very badly formed one. Nevertheless, it is inevitable that in a semi-mechanical thinning of this type, some well formed trees will be felled and some badly formed or small ones will be left behind.

The primary thinning reduces the density from 2000 trees per hectare to 1000 per hectare. On good sites, stands may reach 8 metres in the third growing season; on poorer sites (class III, Figure 3), this may not happen before the sixth year.

**MEAN HEIGHT** may be found by laying down a plot of convenient size in a representative area of the plantation. A circular plot of 8 metres (.02 hectare) should suffice. Select, at random, three or four trees;

\(^2\)Mean heights have been given, to determine time of first and second thinnings, because equivalent top heights were unavailable to the author. Mean heights should be replaced when enough data is gathered to do so.
measure the total height of the chosen trees and calculate their mean.

Second thinning: For good classes (site class I), the second thinning should be made when the stand reaches 16 metres mean height. For site class II this should be done when the stand reaches roughly 15 metres mean height and for class III it is made at about 13 metres mean height.

As in the first thinning, 50 percent of the standing trees are removed (Figure 4). This results in a reduction from 10000 trees to 5000 trees per hectare. Every second tree on each line is removed but again it is advisable to apply certain selection criteria to favour very well-formed trees and remove badly formed ones.

Better stands will reach the second thinning stage at about 7 years, poorer ones (site class III) at about 12 years.

SUBSEQUENT THINNINGS (3rd, 4th, 5th and 6th)

For subsequent thinnings, the standing basal area should be allowed to build up to 20 or 21 m²/ha, when a removal of 6 m²/ha should be made.

Total basal area will indicate when to thin. It may be estimated using a relascope or by laying down plots of convenient size in representative areas of the stand and measuring directly.

Thinning control plots are also needed during the marking operation to ensure that the correct amount of basal area is being removed. Here, marked trees are measured by a relascope or by a total tally within a plot of fixed size. If the relascope is employed, then trees should be marked on 4 sides to make sure that they will be seen when scanning.

For convenience, plots of 0.05 hectare (12.62 metres radius) would be adequate to measure total basal area for 3rd and most later thinnings and for calculating marked basal area in the 3rd and 4th thinning. It might be necessary to increase this to 0.1 hectare (17.84 metres radius) in order to compile marked basal area in the 5th and 6th thinnings. Again, the judgement of the local

Figure 4: Marking of trees for removal in the first and second thinning (50% of stems are felled at each extraction).

→ Arrow shows the direction in which the forester travels while marking.
• Indicates the trees marked for removal
○ ○ Trees
forester is called upon.

About 40% of tree stems are removed in the 3rd thinning, 38% in the 4th, and this decreases to about 36% in the 5th and 6th thinnings. A rough guide has been included below showing the percentage of stems taken out at each thinning, with the equivalent ratio of felled to total pre-thinned standing trees.

<table>
<thead>
<tr>
<th>THINNING</th>
<th>No. of trees to be removed in a stand</th>
<th>REMOVAL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Table 1 shows numbers of trees removed per hectare)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd</td>
<td>1 for every 2.5 or 2 in 5</td>
<td>(40)</td>
</tr>
<tr>
<td>4th</td>
<td>1 for every 2.6 or 6 in 15</td>
<td>(38)</td>
</tr>
<tr>
<td>5th and 6th</td>
<td>1 for every 2.8 or 5 in 14</td>
<td>(36)</td>
</tr>
</tbody>
</table>

As thinnings advance from the 3rd to the last, there are progressively less trees to choose from and greater effort must be made to avoid felling the best trees that will constitute the final crop. One way to do this is to select and assign a special mark to the final crop trees when making the 3rd, or a later thinning. It should in no way be possible to confuse a mark on trees to be felled with that on final crop trees.

If initial spacing happens to be 2 x 2 metres, which is quite common in the region, the same proportion of trees should be removed in the 1st and 2nd thinnings as above (i.e. 50%), and the same build up and removal of basal area should be allowed for subsequent thinnings.

THINNING OF THE GROUP PLANTING SYSTEM

After the fifth year, the two best trees in each group are selected and the others are removed in one or two thinnings. This leaves 500 trees per hectare, equivalent to the first and 2nd thinnings combined. Thereafter, the plantations should be managed in accordance with suggestions for subsequent thinnings given above.

DELAYED THINNINGS

If thinning is delayed beyond 10 years or so, then volume accumulated on released trees will be slowed down. This means that for the later thinnings and the final crop, trees will not have reached their maximum dimensions. The financial returns, which depend on a price size gradient (more money for larger trees), will therefore suffer.

Thinning treatments for crops left well beyond the recommended times are not covered in this document. In fact, if stagnation has set in it might be better to fell the crop and replant; economic considerations would have to be taken into account before a decision could be made. This underlines the importance of thinning on time.

Practical problems may sometimes arise that cause some stands to be treated outside the recommended times. It must be emphasized that these deviations should be limited.

TRINIDAD YIELD TABLES

Yield tables from Trinidad have been included as a guide to foresters (Table 1). The classes are for that island, and are not regional site classes as shown in Figure 7. Height class I, Trinidad, is roughly equivalent to regional site index 1/II; class II, Trinidad, is about regional site index II/III and class III, Trinidad, is equivalent to regional site index III.3

It is evident, from these tables, that the higher the growth rate the greater is the number of thinnings. Furthermore, all thinnings take place in the first 37 years of the crop; from an economic viewpoint this is an advantage, because the earlier a crop can produce revenue, the more likely it is to obtain a positive net discounted revenue. No attempt has been made, in this paper, to evaluate the costs and returns on plantation teak, but the Trinidad yield tables should be of assistance to foresters who wish to do so.

For a summary of thinning practice see Box on page 28.

3 Site index may be thought of as any height-age curve or line on Figure 5.
THINNING PRACTICE - A SUMMARY

1) BEFORE DECIDING ON THINNING PRACTICE, IT IS ADVISABLE TO KNOW AT WHAT RATE THE STAND IS GROWING. TO DO THIS FIND THE SITE CLASS FROM TOP HEIGHT AND AGE (FIGURE 3)

2) FIRST THINNING: WHEN THE STAND REACHES 8 m MEAN HEIGHT EVERY SECOND TREE IS REMOVED (FIGURE 4).

3) SECOND THINNING: WHEN THE STAND REACHES

- 16 m MEAN HEIGHT (FOR SITE CLASS I) AND OVER OR
- 15 m MEAN HEIGHT (FOR SITE CLASS II) OR
- 13 m MEAN HEIGHT (FOR SITE CLASS III)

- EVERY SECOND STANDING TREE IS REMOVED (FIGURE 4)

4) SUBSEQUENT THINNINGS: THE STANDING BASAL AREA SHOULD BE ALLOWED TO BUILD UP TO 20 OR 21 m²/HA, WHEN REMOVAL OF 6 m³/HA SHOULD BE MADE.

REMEMBER: IT CANNOT BE OVERSTRESSED THAT TEAK IS A QUALITY PRODUCT AND IT IS IMPORTANT TO THIN ADEQUATELY AND ON TIME.

THE ROTATION

The rotation, or the age at which the stand should be clearfelled, will depend on the quality and the price the final crop can fetch. Rotations from 50 to 80 years and more have been proposed. As a general rule, the crop should be thinned in accordance with the directions given and an economic assessment carried out, say 10 years after the final thinning, to determine if it is most profitable to clearfell then or let the crop grow on.

PRUNING

Early pruning is advisable in order to improve the quality of the wood and increase the merchantable height on the best trees. This becomes more important as spacing between trees increases, whether it is caused by: wider initial planting distances, removal of neighboring stems, or location at the edge of stands.

Teak does not respond well to pruning and, therefore, great care must be taken to minimize damage. For example, in young trees, it may be advisable to sever branches, with a machete, about 30 centimetres or more from their connection with the stem before cutting the stub with a saw. This prevents the branch breaking when the saw cut is nearly complete and tearing a strip of bark from the stem as it falls. Wounds heal slowly and fungi may penetrate through large lesions. No protective chemical is recommended for cuts but branches should be pruned before reaching a diameter of 5 centimetres.

There is some evidence to suggest that pruning should be carried out in August, just after the period most new leaves are produced during May to July. Numbers of trees supporting later adventitious branching and numbers of new branches per tree are reduced by doing this. At least 35-40% of the total height of the tree should be left in live crown, in order to prevent hindrance to growth.
Table I. Provisional Yield Tables for Teak (underbark) in Trinidad, after Miller, 1969.

<table>
<thead>
<tr>
<th></th>
<th>TEAK HEIGHT CLASS I</th>
<th></th>
<th>TEAK HEIGHT CLASS II</th>
<th></th>
<th>TEAK HEIGHT CLASS III</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>3</td>
<td>7</td>
<td>12</td>
<td>16</td>
<td>26</td>
</tr>
<tr>
<td>No. Trees/ha.</td>
<td>2196</td>
<td>986</td>
<td>494</td>
<td>296</td>
<td>185</td>
<td>118</td>
</tr>
<tr>
<td>Mean ht (m.)</td>
<td>8</td>
<td>16</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>Mean dia. (cm.)</td>
<td>9</td>
<td>17</td>
<td>24</td>
<td>32</td>
<td>40</td>
<td>49</td>
</tr>
<tr>
<td>Basal Area (m²/ha.)</td>
<td>6</td>
<td>12</td>
<td>14</td>
<td>15</td>
<td>19</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>6 cm.</td>
<td>9</td>
<td>53</td>
<td>85</td>
<td>107</td>
<td>126</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 cm.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>23 cm.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vol. m³/ha. to top</td>
<td>6 cm.</td>
<td>9</td>
<td>53</td>
<td>85</td>
<td>107</td>
<td>126</td>
</tr>
<tr>
<td>diam. U.B.</td>
<td>15 cm.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>23 cm.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. Trees per ha.</td>
<td>-</td>
<td>1206</td>
<td>494</td>
<td>158</td>
<td>111</td>
<td>67</td>
</tr>
<tr>
<td>Mean dia. (cm.)</td>
<td>-</td>
<td>6</td>
<td>14</td>
<td>20</td>
<td>26</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>6</td>
<td>14</td>
<td>20</td>
<td>27</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Av. vol per tree m³</td>
<td>-</td>
<td>.007</td>
<td>.035</td>
<td>.177</td>
<td>.405</td>
<td>.851</td>
</tr>
<tr>
<td>U.B.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 cm.</td>
<td>9</td>
<td>27</td>
<td>35</td>
<td>45</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>15 cm.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>23 cm.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vol. m³/ha. to top</td>
<td>8 cm.</td>
<td>9</td>
<td>27</td>
<td>35</td>
<td>45</td>
<td>57</td>
</tr>
<tr>
<td>diam. U.B.</td>
<td>15 cm.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>23 cm.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basal area (m²/ha.)</td>
<td>-</td>
<td>11</td>
<td>23</td>
<td>32</td>
<td>38</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>11</td>
<td>23</td>
<td>32</td>
<td>38</td>
<td>44</td>
</tr>
<tr>
<td>Vol. to 8cm. U.B. (m³)</td>
<td>-</td>
<td>16</td>
<td>89</td>
<td>156</td>
<td>223</td>
<td>298</td>
</tr>
<tr>
<td>(ha.)</td>
<td>-</td>
<td>16</td>
<td>89</td>
<td>156</td>
<td>223</td>
<td>298</td>
</tr>
<tr>
<td>Basal area (m²/ha.)</td>
<td>-</td>
<td>3.6</td>
<td>3.2</td>
<td>1.6</td>
<td>1.1</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>3.6</td>
<td>3.2</td>
<td>1.6</td>
<td>1.1</td>
<td>0.8</td>
</tr>
<tr>
<td>Vol. to 8cm. U.B. (m³)</td>
<td>-</td>
<td>6</td>
<td>16</td>
<td>13</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>(ha.)</td>
<td>-</td>
<td>6</td>
<td>16</td>
<td>13</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Basal area (m²/ha.)</td>
<td>-</td>
<td>6</td>
<td>13</td>
<td>12</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>6</td>
<td>13</td>
<td>12</td>
<td>11</td>
<td>10</td>
</tr>
</tbody>
</table>

30
TEAK WOOD

Studies carried out in the region suggest that plantation grown teak is in no way inferior to that obtained from indigenous areas in India or Burma.

Teak has long been recognized for its excellent wood properties, making it one of the most valuable many-purpose timbers of the world. These properties include among others: strength with lightness; durability; dimensional stability; non-corroding properties; ease of working and seasoning; termite, fungus and weather resistance; attractiveness. It has been employed for a wide range of end uses such as bridge and wharf construction; for furniture, cabinet work, sleepers and general carpentry; it is highly prized as a shipbuilder's timber; it is suitable for carving and lasts well in contact with the ground. This description refers to the heartwood, which begins to form from about the 6th year.

Sapwood does not possess all these qualities and constitutes a large proportion of the wood from early thinnings. It needs special protection if used outdoors. Untreated fenceposts have a life expectation of only 4 to 5 years as against 20-25 years for treated ones.

UTILIZATION

Particular attention is needed, in the early years, to find markets for small dimension material that has a high sapwood content. First thinnings may find an outlet as banana props. Fence posts are an obvious product of later operations. With special cutting techniques, dimensions up to 25 centimetres top diameter from second and third thinnings may be converted into: nailing lethes, skirting boards, facing and flooring strips, broom handles, collapsible chairs, or similar objects. In Trinidad, small stems from these thinnings have been split into prickets and treated with creosote for use in wire fencing for homes and gardens. Small sized material from all thinnings and the clearfelling, including branches, may be sold as firewood.

Heartwood lumber, which is olive green when freshly cut, becomes golden brown and eventually very dark brown upon exposure. Its uses are extremely wide as already stated. It has been described as the ace of decking timber. It should find a ready market for general boat building, flooring, veneer, high class joinery, doors, windows, interior panelling, outdoor structures, carvings and many other uses.

The wood has an oily feel and gives off a fragrant odour when freshly cut. Some people are allergic to the dust produced when sawing. The timber has a dulling effect on cutting edges; this is due to a high silica content, and may be overcome by using carbide or other high quality steel.

It is relatively easy to air season or kiln dry without appreciable defect. The following shrinkage rates have been reported in the region for green to oven dry wood:

- Radially: 1.9 - 2.3%
- Tangentially: 4.6 - 5.4%
- Volumetrically: 5.1 - 5.7%

Green to air dry values are about half of these.

There appears to be a positive correlation between all strength properties and specific gravity. Specific gravities of 0.56 to 0.63 (oven dry wt.; green volume) or 0.59 to 0.67 (oven dry wt.; oven dry volume) have been found in the region.

The wood takes nails and screws fairly well and glues moderately well. It can be varnished and polished with good results.

Teak is resistant to fungal decay and termites. It possesses excellent weathering characteristics and unpainted wood is almost free from warp and checking when exposed outdoors.

Note: The following reference contains a comprehensive section dealing with teak in which there are many references for those interested in pursuing studies on wood properties.

THE CARE AND MANAGEMENT
OF TEAK (TECXTNA GRANDIS L.)
PLANTATIONS

A PRACTICAL FIELD GUIDE FOR FORESTERS IN
THE CARIBBEAN, CENTRAL AMERICA, VENEZUELA
AND COLOMBIA

R. M. KEOGH
1987
Biomass Equations (Simple linear regressions)

Individual tree biomass (kg per component per tree): 1-9 year old teak from Caparo forest reserve in West Venezuela

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Independent Variable (range)</th>
<th>Intercept (range)</th>
<th>Slope (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln (leaf)</td>
<td>ln (D)</td>
<td>-3.249 to -6.026</td>
<td>+1.871 to + 2.846</td>
</tr>
<tr>
<td>ln (twigs + branches)</td>
<td>ln (D)</td>
<td>-4.704 to -8.344</td>
<td>+2.116 to + 3.829</td>
</tr>
<tr>
<td>ln (bolewood)</td>
<td>ln (D)</td>
<td>-3.333</td>
<td>+2.668</td>
</tr>
<tr>
<td>ln (twigs + branches + bolewood)</td>
<td>ln (D)</td>
<td>-3.443</td>
<td>+2.789</td>
</tr>
<tr>
<td>ln (roots &gt; 1 cm.)</td>
<td>ln (D)</td>
<td>-2.722</td>
<td>+2.046</td>
</tr>
</tbody>
</table>

Source: Reference 16, Appendix A.

Volume Equations

Costa Rica

\[ V = 0.0359 + 0.000022 (D^2H) \]

Range (D) = 10 - 44 cm, Standard error = 0.0118

El Salvador

\[ V = -0.0111 + 0.000025 (D^2H) \]

Range (D) = 18 - 53 cm, Standard error = 0.0139

Where \( V \) = Volume in m\(^3\) under bark, between 0.3 m overground to a top diameter of 8 cm under bark.

\( D \) = Diameter at breast height (1.3 m) under bark.

\( H \) = Total height of tree.

Sources:

Costa Rica - Reference 21, Appendix A.

El Salvador - Reference 20, Appendix A.
LIST OF ABBREVIATIONS

cm  Centimetres
C.A.I.  Current annual increment
D  Diameter at breast height (1.3 m)
FAO  Food and Agriculture Organization of the United Nations
H  Total tree height
ha  Hectare
IUFRO  International Union of Forestry Research Organizations
kg  Kilogram
ln  Natural logarithm
m  Metre
MAI  Mean annual increment
mm  Millimetres
n.d.  No date
p.  Page
PSPs  Permanent Sample Plots
V  Volume
wt  Weight
U.B.  Under bark

GENERAL INDEX TO THE MAIN TEXT

Abbreviations list  36
Agri-silviculture  17
Ants  15
Biomass equations  34
Cleaning of plantation  12
Delayed thinnings  21
Diseases  15
Drainage  18
Erosion  13
Family (Teak)  9
Fencing  13
Fertilization  13
Fire  13
Fungi  16
Group planting system  19
Height - mean  22
  - top  22
Mistletoe  16
Natural distribution (teak)  10
Plants (type)  11
Planting 11
Pruning 29
Rotation 29
Scientific name (teak) 9
Seed source 9
Site (climate) 11
  - class (determination) 22
  - selection 11
Spacing 12, 20, 26
Taungya 17, 18
Teak - family 9
  - natural distribution 9, 10
  - scientific name 9
  - wood 32
Theft 17
Thinning 21
  - delayed 27
  - first and second 22
  - group planting system 26
  - spacing (2 x 2 m) 26
  - subsequent (3rd to 6th) 24
  - summary 28
Top height definition 22
Volume equations 35
Wind 17
Wood 32
  - shrinkage 32
  - specific gravity 33
Utilization 32
Yield tables (Trinidad) 27, 30, 31
MAIN REGIONAL TEAK REFERENCES WITH KEY WORD INDEX


38. ———, 1970. The importance of the early establishment of plantations in Venezuela for the supply of teak seeds of improved genetic quality. 9 p. (copy obtainable from the National University of Costa Rica).


52. SMEATHERS, R.A., 1951. A comparative study of some of the more important mechanical and physical properties of Trinidad and Burma grown teak. Imperial Forestry Institute paper 27, Oxford. 19 p.

53. SYLVA, 1968. Estudio de factibilidad - técnica y económica para el establecimiento de una plantación de teca. Sylva Ltd., Medellín, Colombia.


55. TORRES LEZAMA, A., 1982. Influencia del sitio y la espesura en el crecimiento de plantaciones de teca.


Addition after going to press:


KEY WORK INDEX FOR MAIN TEAK REFERENCES

(Number refers to reference in Appendix A)

Agroforestry 9, 37
Biomass 16
Colombia 3, 11, 44, 54
Costa Rica 14, 15, 17, 21, 31
Cuba 12, 33
Ecology 29, 44, 48, 49
Economics 11, 53
El Salvador 1, 2, 18, 20, 34
Erosion 1, 5, 34
Fertilization (Sée Nutrient Status)
Genetics 4, 10, 23, 38
Growth 7, 14, 19, 20, 21, 22, 24, 25, 30, 33, 35, 43, 45, 52, 55, 56, 57, 58
Honduras 49, 51, 56
Nicaragua 57, 58
Nutrient Status
(Pertilization) 2, 16

Panama 26, 30
Protection 3, 5, 18, 39, 51, 54
Pruning 6, 51
Puerto Rico 7, 32
Region 22, 23, 24, 25

Site Classification Chart 25

Thinning 13, 22, 24, 35
Trinidad 4, 5, 8, 9, 10, 27, 28, 35, 36, 39, 46, 47, 48, 52
Venezuela 13, 16, 29, 37, 38, 40, 43, 45, 54, 55
Virgin Islands 6, 41
Volume Tables 20, 21

Wood 12 (See also page 33 for regional reference)
- Characteristics 32
- Properties 15, 26, 52
- Resistance to fungi 34, 46

Yield Tables 35