PRELIMINARY PRUNING PROGRAMME FOR *TECTONA GRANDIS* PLANTATIONS IN COSTA RICA

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PÉREZ, L. D., VÍQUEZ, E. & KANNINEN, M. 2003. Preliminary pruning programme for *Tectona grandis* plantations in Costa Rica. End-users' requirements for fast-grown *Tectona grandis* timber include straight bole with least taper, reduced flutes and buttresses as well as wood free of knots. In Costa Rica and many other tropical countries, no official classification norms have been developed to differentiate wood quality improvements obtained from pruning. The aim of this research was to study the structure and composition of the crown biomass in order to develop a simple and practical pruning programme for *T. grandis* in Costa Rica. Regardless of site, the results indicate that the first pruning in *T. grandis* should be carried out when trees reach a total height of between 4 and 5 m, pruning up to 2–3 m. In a second intervention, trees should be pruned up to 4–5 m when the stand reaches between 9 and 10 m of total height. Finally, in a third intervention, all the branches up to 7 m should be pruned when trees reach 12 m of total height. According to the present results, the pruning of *T. grandis* in Costa Rica can be economically feasible for rotations of 15 years and more, if performed adequately and with precise timing.

Key words: Crown biomass - crown structure - knotted core - site quality - defects - quality

PÉREZ, L. D., VÍQUEZ, E. & KANNINEN, M. 2003. Program pemangkasan awal untuk ladang *Tectona grandis* di Costa Rica. Permintaan pengguna akhir untuk kayu *Tectona grandis* tumbuh cepat termasuklah batang yang lurus dengan tirus yang sedikit, kulit berbelimbing yang sedikit, banir yang sedikit dan kayu bebas buku. Di Costa Rica dan negara tropika yang lain, belum lagi terdapat klasifikasi rasmi untuk membezakan pembaikan kualiti kayu yang diperoleh daripada pemangkasan. Tujuan penyelidikan ini adalah untuk mengkaji struktur dan komposisi biojisim silara untuk membangunkan program pemangkasan yang mudah dan praktis untuk *T. grandis* di Costa Rica. Keputusan menunjukkan bahawa tanpa mengambil kira tempat kajian, pemangkasan pertama bagi *T. grandis* patut dijalankan apabila

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pokok mencapai ketinggian antara 4 m hingga 5 m. Pemangkasan patut dijalankan sehingga ketinggian 2 m atau 3 m. Pada pemangkasan kedua, pokok patut dipangkas sehingga 4 m atau 5 m apabila pokok mencapai ketinggian antara 9 m hingga 10 m. Akhir sekali, pada pemangkasan ketiga, semua dahan sehingga 7 m patut dipangkas apabila pokok mencapai ketinggian 12 m. Berdasarkan keputusan kajian, pemangkasan *T. grandis* di Costa Rica boleh dilaksanakan secara ekonomi untuk giliran 15 tahun atau lebih jika dijalankan dengan secukupnya dan dengan pengaturan masa yang baik.

Introduction

In the international wood market, straight stems and absence of knots provide higher quality wood and earn higher prices. Pruning has been a silvicultural technique commonly used, although empirically developed, to obtain high quality timber. Two fundamental factors give more relevance to the activity of pruning (Hubert & Courrand 1988).

- With the high competition in the wood market and with insufficient governmental economic support, foresters aim to reduce reforestation costs by reducing plantation densities.
- With reduced plantation densities, pruning and stem straightness, previously obtained in a natural way, are now less assured. Manual pruning is therefore required to replace the physiological process of self-pruning.

In Costa Rica, as in many other countries, no official classification norms have been developed to differentiate and grade wood quality improvements obtained with the pruning of branches. However, the growing demand for products from forest plantations and the ever-growing consumer demand begin to create an atmosphere of favourable competition. Moreover, an insufficient local demand or the need to reach international markets will require wood products of high quality only since the transportation of low quality products outside the plantation vicinities will be neither profitable nor competitive (Rojas & Torres 1994).

Tectona grandis has gained a worldwide reputation because of the attractiveness and durability of its wood. Market demands have prompted the establishment of plantations within and beyond its native countries (Hoare & Patanapongsa 1988, Monteuuis & Goh 1999, Bhat 2000).

Despite all the efforts invested in planting activity (5.7 million hectares planted worldwide in 2000), teak timber resources currently available are far below the needs of the huge worldwide market demand (Monteuuis & Goh 1999). In the last TEAKNET (Asia-Pacific Region Network) meeting held in 1999 in Chiang Mai (Thailand), the lack of planting stock, especially of superior quality, was unanimously identified as the primary cause of *T. grandis* timber deficit.

The important property requirements of end-users in fast-grown *T. grandis* include straight bole with least taper, reduced flutes and buttresses, and wood free of knots. Unsound hollow knots and deep flutes in the logs are the two major factors that affect sawn wood grade. However, no adequate data are available for the timber grown with intensive silvicultural practices including pruning (Bhat 1998).

Torres (1995) carried out a silvicultural evaluation of forest plantations in Costa Rica. He found that pruning was more often considered a cleaning activity than a silvicultural technique. There are few recommendations of pruning intensities for timber species in Costa Rica. In general, recommendations are to prune trees up to 50% of the total height just after the first thinning (Keogh 1987, Chaves & Fonseca 1991, Galloway 1993) or according to commercial log sizes, i.e. up to 2.5 m high (Murillo & Camacho 1997).

The aim of this research was to study the structure and composition of the crown biomass in order to develop a simple and practical pruning programme for *T. grandis* in Costa Rica. We hypothesise that there is an optimal pruning intensity, which can lead to a high proportion of knot-free timber, without detriment to tree growth (Smith 1954). This hypothesis is based on the functional relationship between foliage biomass and the conducting tissue in the stem (sapwood), which is explained by the Pipe Model theory (Shinozaki *et al.* 1964) and has been established for many tree species, including for *T. grandis* in Costa Rica (Morataya *et al.* 1999). Using this analysis, a drastic foliage biomass removal is expected to reduce tree growth (Vincent 1975, Långström & Hellqvist 1991, O'Hara 1991, Galloway 1993).

Materials and methods

Site description

The study was carried out in several forest plantations on the Nicoya peninsula, a coastal region of Costa Rica. The mean annual rainfall varies between 1390 and 3020 mm. Mean annual temperature ranges from 24.4 to 27.6 °C, with a maximum of 34.9 °C and a minimum of 18.5 °C. The mean relative humidity is 76%, with May and November as the most humid months (Instituto Meteorológico Nacional 1996).

Site selection

Plantations with ages between one and seven years were selected for the study, considering only those without pruning interventions. The selected plantations were classified as low, medium or high quality sites using the Site Index curves for *T. grandis* in Costa Rica developed by Vásquez and Ugalde (1995). In total, 14 plantations of different ages and site qualities were included in the study (Figure 1), with stand densities between 1111 and 625 trees ha^{-1}.

Sample plots establishment

Two square sample plots of 16 trees were established on each selected plantation. Variables measured were DBH (cm), total height (m) and crown length (m).

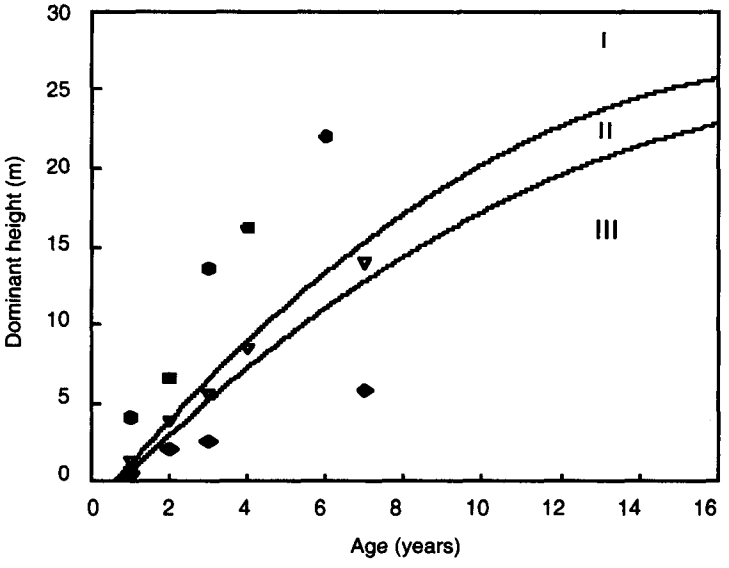

Figure 1 Site Index curves for *Tectona grandis* plantations in Costa Rica. Dots correspond to the plantations sampled. I, II, III refer to high, medium and low site quality respectively

Biomass quantification and measurement of crown structure variables

Based on field observations and technical criteria, plantations aged four years or more as well as those on low quality sites were discarded since on these sites the pruning was considered to be economically unfeasible. On the former, trees presented an advanced diameter and height development and a considerably high number of thick branches, which would make the pruning extremely expensive, and trees would have already formed a high amount of knotted core. In the latter, trees presented extremely low growth rates (less than 25% of growth potential known for teak in Costa Rica), which suggested that pruning costs would be much higher than its benefits. Moreover, the cost of opportunity for further forest management on these sites is questionable.

A total of 24 trees were sampled, including dominant, co-dominant and suppressed trees. The ages selected for sampling were two, three and four years on high quality sites, and three years on medium quality sites. Other ages were considered as too early or too late for pruning intervention. For each selected age (on both sites), a total of six trees were selected based on the standard deviation of the total height: two trees representing average height, two suppressed trees and two dominant trees. Once selected, DBH (cm), total height (m) and crown length (m) were measured for each tree. After this, they were felled and sectioned into 1 m logs. On each stem section, the following variables were measured:

- Diameter at both ends (cm)
- Number of living branches
- Diameter of the two thickest living branches (cm)
- Foliage biomass (kg) on branches and attached to the stem. (The 2-year-old trees on high quality sites and three-year-old trees on medium quality sites had leaves attached directly to the stem in the first 1 to 2 m of height from the base of the tree. They were weighed separately).

Green weight was recorded using a hanging scale with 0.1 kg precision. Branch and foliage samples of 1.0 and 0.5 kg respectively were taken from each tree at different stem sections for dry biomass determination. The samples were taken to the laboratory for oven drying (65 °C) to a constant weight in order to determine the moisture content and dry weight.

The recommendations for the time and intensity of pruning were based on considerations regarding possible reactions on tree growth with different foliage biomass removals. In addition, other important criteria, such as the number and diameter of branches and the stem diameter (using as criterion a maximum defect core of 10 cm, suggested as well by Hubert and Courrand (1988), and Vincent (1975) for other high quality timber species), were considered for definition of the timing and intensities of pruning.

A pruning scenario for *T. grandis* was simulated in the present study to illustrate the feasibility of pruning; this according to the previous mentioned criterion of maximum defect core diameter. The scenario considered two different pruning heights (4 and 7 m) and four different final rotations (15, 20, 25 and 30 years) with initial densities of 1111 trees ha^{-1}. Stem diameter at pruning height was projected to final rotation, using the stand growth scenarios for *T. grandis* in Costa Rica developed by Pérez *et al.* (2000). A diameter reduction factor of 1.5 cm m^{-1}, calculated from stem analysis of 10- to 45-year-old trees, was used to estimate the stem diameter at both pruning heights and for each rotation. Similar to this, a second diameter reduction factor of 1.0 cm m^{-1}, calculated from trees harvested for this study (two to four years), was used to estimate the stem diameter at present, i.e. when pruning should be done according to current findings.

Results and discussion

The present results indicate that on high quality sites the first pruning must be carried out at the age of 2.0 to 2.5 years, pruning up to 2–3 m high. At this time, trees reached between 4 and 5 m of total height and a crown length of 3 to 4 m. The average diameter of branches was less than 3 cm, and trees produced only one branch per metre of stem height (Figure 2a), for a cumulative number of two branches (in some cases three) at the height of 2–3 m (Figure 2b), suggesting that pruning will be relatively simple to perform. Even though at this time there are only two or three branches to prune, which certainly present no problem in wood quality, waiting for the next year to prune will allow the trees to produce several branches with larger diameter, and then the activity will be more time consuming

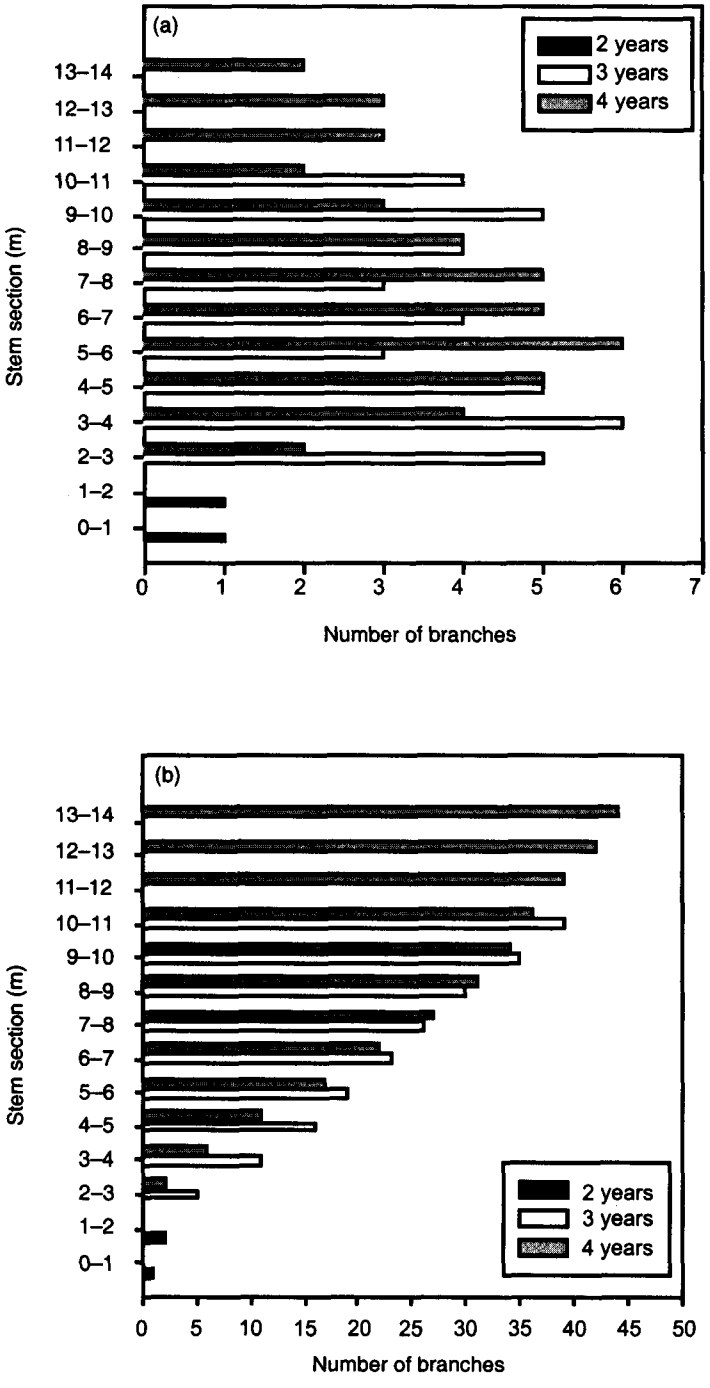

Figure 2 Number of branches at different tree heights (a) and cumulative number of branches at different tree heights (b) in two-, three- and four-year-old *Tectona grandis* trees on high quality sites in Costa Rica

and expensive and may also threaten the wood quality of the stems. According to this finding, between the second and the third year, teak trees increased their growth rate considerably, inducing the rapid formation of branches to fulfil nutrient requirements.

On average, 55% of the tree height will be pruned, which corresponds to 45% of the crown length and 40% of the foliage biomass on branches (Figure 3). Since at this age (2.0–2.5 years) approximately 50% of the total foliage biomass is attached to the stem, the foliage biomass removed from the tree represents only 20% of the total foliage biomass. It was observed that some farmers removed these leaves when pruning. This is not encouraged since this biomass contributes to tree photosynthesis but will not produce knots on wood.

Pruning before two years old is not recommended since total height and crown length, in particular, have not reached sufficient size, except in some sites with extremely high growth rates. At the age of three years, *T. grandis* trees reached a total height of approximately 11 m and the diameter at the base of the crown surpassed the suggested defect core limit of 10 cm (Figure 4), being therefore too late to prune.

The above-mentioned recommendations, as well as the following ones, are based on measurements of plantations with stand densities varying from 620 to 1111 trees ha^{-1} (4 × 4 to 3 × 3 m spacing). The few examples of available plantations without pruning interventions did not allow studying of each sample density separately.

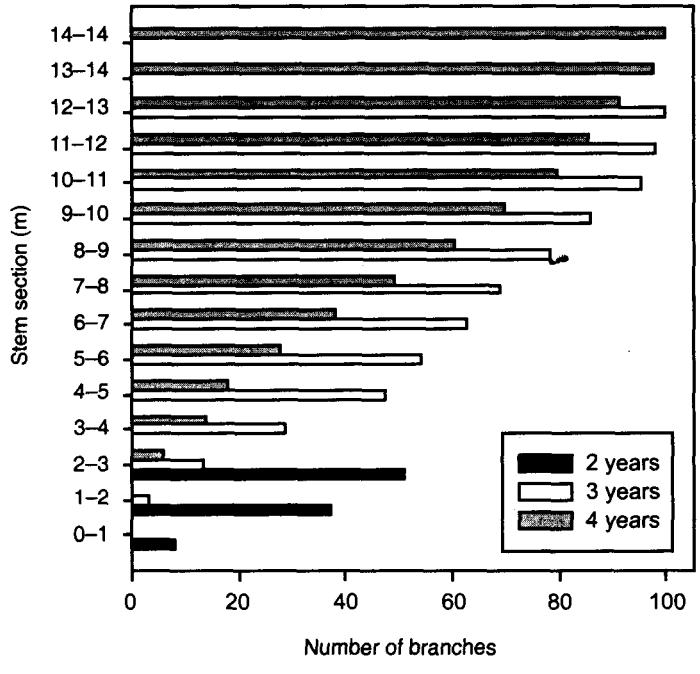

Figure 3 Cumulative foliage biomass on branches of *Tectona grandis* in relation to the total foliage biomass at different ages on high quality sites in Costa Rica

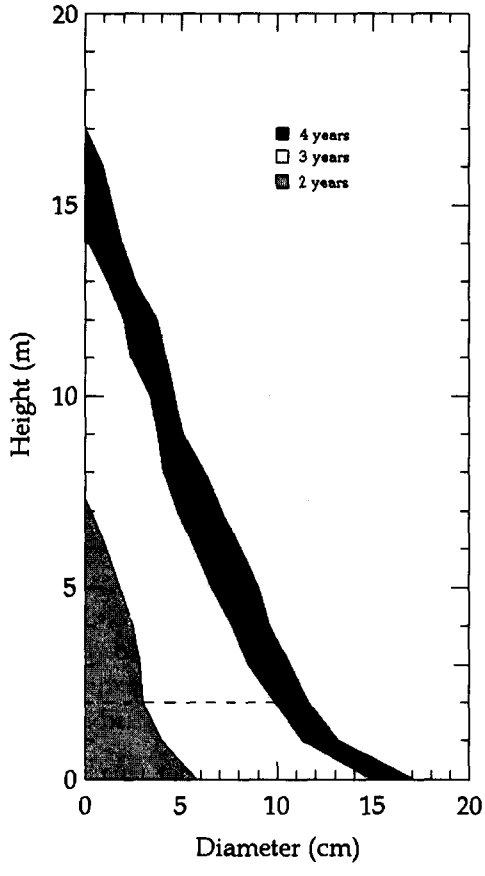

Figure 4 Average stem diameter at different tree heights in *Tectona grandis* trees of different ages on high quality sites in Costa Rica

On medium quality sites, trees must be pruned at 2.5 to 3.0 years of age, when most of the branches had a diameter of 3 cm or less, and trees produced between one and three branches per linear metre (Figure 5a), for an accumulated number of four branches at the height of 3 m (Figure 5b). The stem diameter at the base of the crown was still below 10 cm (Figure 6). Pruning after the third year is not convenient since stem diameter at the base of the crown will be greater than 10 cm and several branches (> 15) will appear. The pruning intensity is similar to that of high quality sites (i.e. pruning up to 2–3 m high, on trees of 4–5 m of total height). Approximately three branches must be removed, which corresponds to 22.0% of the foliage biomass on branches and 13.2% of the total foliage biomass (Figure 7). Plantations on low quality sites are not worth pruning because of economics, since they present poor growth rates (MAI of 0.5 m in total height and 0.5 cm in DBH).

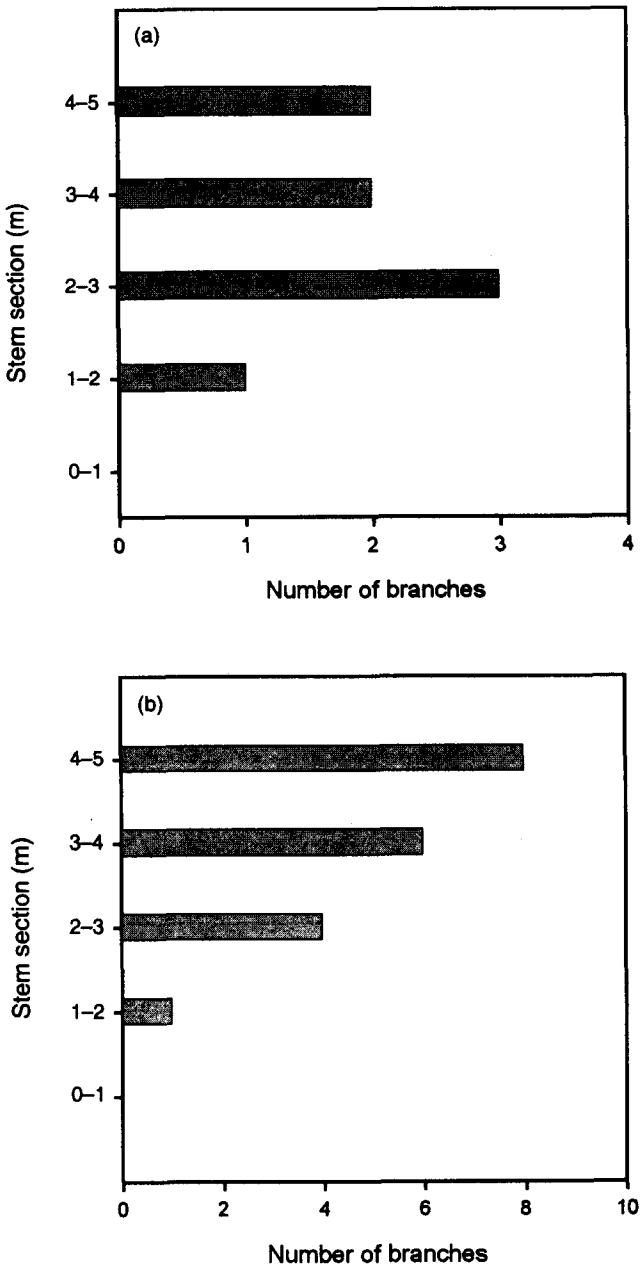

Figure 5 Number of branches at different tree heights (a) and cumulative number of branches at different tree heights (b) in three-year-old *Tectona grandis* trees on medium quality sites in Costa Rica

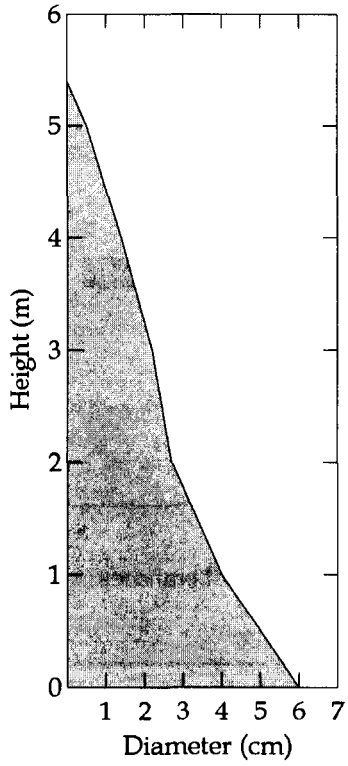

Figure 6 Average stem diameter at different tree heights in three-year-old *Tectona grandis* trees on medium quality sites in Costa Rica

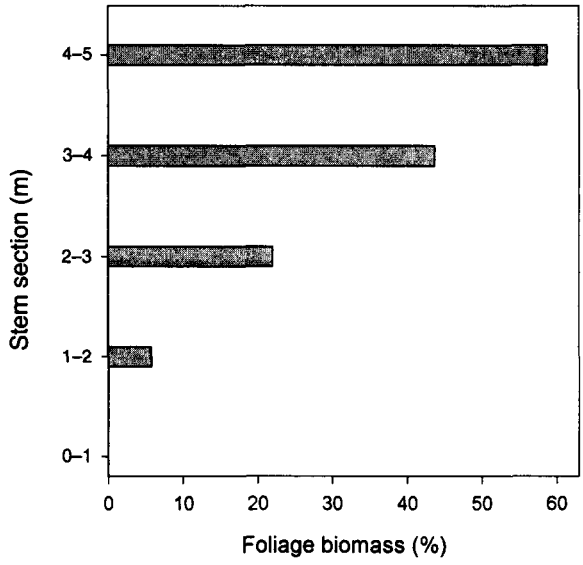

Figure 7 Cumulative foliage biomass on branches in relation to total foliage biomass of three-year-old *Tectona grandis* trees on medium quality sites in Costa Rica

Regardless of site quality, our results indicate that the first pruning in *T. grandis* must be carried out when the stand reaches a total height of 4 to 5 m. A second pruning should be carried out when the stand reaches between 9 and 10 m of total height, pruning up to 4–5 m. This would be near the third year on high quality sites and near the fourth year on medium quality sites. Around 50% of the total tree height would be pruned, removing 30 to 40% of the total foliage biomass.

Finally, a third pruning should eliminate all the branches up to a height of 7 m when the stand reaches 12 m of total height. More than half of the stem length (60%) would be cleared, removing 20% of the foliage biomass. On high quality sites, this pruning should be done in the fourth year, while on medium quality sites it should be performed in the fifth or sixth year.

The present study does not consider the removal of apical shoots, which arise mainly when stumps from seedlings are used as planting material. Normally, they are removed during the first six months as a regular silvicultural practice to eliminate competition and concentrate growth on the best apical shoot.

Hubert and Courrand (1988), Hochbichler *et al.* (1990) and Raets (1964) consider that a tree must end with a diameter at pruning height three times greater (than that presented when pruned) by the time of harvesting, in order to make the activity economically profitable. A projection of stem diameter at two possible pruning heights and four different rotations was made in the present study to exemplify and analyse this criterion (Table 1).

Table 1 Projection of stem diameter at different tree heights for *Tectona grandis* on medium and high quality sites, and for different rotations

Site quality	Variable	Rotation (years)			
		15	20	25	30
High	H	24.5	28.1	30.6	36.1
	DBH	33.8	40.0	44.4	54.0
	D_7m	24.7	30.9	35.3	44.9
	D_4m	29.7	35.9	40.3	49.9
Medium	H	20.7	23.6	25.6	29.9
	DBH	27.0	32.0	35.6	43.2
	D_7m	18.0	22.9	26.5	34.1
	D_4m	22.9	27.9	31.5	39.1

H = Total height (m), DBH = diameter at breast height (cm), D_7m = stem diameter (cm) at tree height of 7 m, D_4m = stem diameter (cm) at tree height of 4 m.

The results suggest that the third pruning (up to 7 m high) must be executed when the stand reaches a total height of 12 m. On high quality sites, this would be between the fourth and the fifth year on plantations with an average DBH of 13 cm and a diameter of 7.3 cm at the pruning height. Considering the previous mentioned defect-core criterion, the actual diameter at the height of 7.0 m should reach at least 21.9 cm at the final rotation. According to the projections of Table 1, this diameter is feasibly obtained on high quality sites with 15 years or more.

On medium quality sites, the third pruning was estimated for the fifth or sixth year, when DBH reaches 12 cm and the stem diameter at the height of pruning is 6.3 cm. In this case, the diameter at pruning height should reach 18.9 cm by the time of harvesting, which can be obtained at rotations of 20, 25 or 30 years. These projections were based on initial plantation densities of 1111 trees ha^{-1}. Plantations under different densities may present important variations.

Conclusions

Regardless of the site quality, the first pruning in *T. grandis* must be carried out when the stand reaches a total height of 4 to 5 m, eliminating the branches up to a height of 2 to 3 m respectively (50–60% of the total height). After reaching a total height of 5 m, teak trees considerably increase their growth rate. Therefore, it is strongly recommended to carry out the first pruning before this time.

A second pruning can be carried out when the stand reaches 9 to 10 m of total height, pruning up to 4–5 m respectively (40–50% of total height).

A third intervention should eliminate all the branches up to a height of 7 m when the stand reaches 12 m of total height (60% of total height).

On medium and high quality sites, the pruning of *T. grandis* in Costa Rica can be economically feasible for rotations of 15 years and more, if performed adequately and at a precise time. Measurements of plantations with varying densities should be carried out to improve results since spacing will certainly have an effect on crown biomass/structure and on tree growth.

Acknowledgements

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