EFFECT OF SPACING ON PERFORMANCE OF TEAK AT LONGUZA, TANGA, TANZANIA

G. Sibomana, F.B.S. Makonda, R.E. Malimbwi, S.A.O. Chamshama & S. Iddi

Faculty of Forestry, Sokoine University of Agriculture, P.O. Box 3009, Morogoro, Tanzania

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SIBOMANA, G., MAKONDA, F.B.S., MALIMBWI, R.E., CHAMSHAMA, S.A.O. & IDDI, S. 1997. Effect of spacing on performance of teak at Longuza, Tanga, Tanzania. The performance of teak (*Tectona grandis*) planted at four square spacings (1.5, 2.0, 2.5 and 3.0 m) at Longuza, Tanga, in Tanzania was assessed. The variables studied were diameter at breast height (dbh), total height and height to the first live branch, survival, number of branches, basal area and volume production at ages 1, 3, 7 and 9 y, and basic density and some strength properties at the age of 14 y. Results showed that dbh, number of branches, total height, basal area, basic density and some strength properties were significantly affected by spacing ($p = 0.05$). The diameter at breast height and number of branches increased with increasing spacing, while basal area decreased. All other variables were not significantly affected by spacing. A spacing of 3.0 m resulted in large diameter trees and later thinnings, with less total volume per hectare. The current spacing of 2 m resulted in higher volume per hectare of small sized trees which could be improved by thinning. It is recommended to continue with this spacing and the current thinning schedule until information on the economic implications of alternative regimes is available.

Key words: *Tectona grandis* - spacing - growth - basic density - strength

SIBOMANA, G., MAKONDA, F.B.S., MALIMBWI,R.E., CHAMSHAMA, S.A.O. & IDDI,S. 1997. Kesan penjarakan terhadap prestasi pokok jati di Longuza, Tanga, Tanzania. Kajian dijalankan terhadap prestasi pokok jati (*Tectona grandis*) yang ditanam di empat penjarakan (1.5, 2.0, 2.5 dan 3.0 m) di Longuza, Tanga, Tanzania. Pembolehubah yang dikaji ialah diameter aras dada (dbh), jumlah ketinggian, ketinggian sehingga ke dahan pertama, kemandirian, bilangan dahan, luas pangkal dan pengeluaran isi padu pada umur 1, 3, 7, dan 9 tahun, dan ketumpatan asas serta beberapa ciri kekuatan pada umur 14 tahun. Hasil kajian menunjukkan dbh, bilangan dahan, jumlah ketinggian, luas pangkal, ketumpatan asas dan beberapa ciri kekuatan dipengaruhi oleh penjarakan ($p= 0.05$). Diameter aras dada dan bilangan dahan bertambah dengan bertambahnya penjarakan manakala luas pangkal berkurangan. Pembolehubah yang lain tidak dipengaruhi oleh penjarakan. Jarak 3.0 m mengakibatkan diameter pokok yang besar dan kemudiannya penjarangan dengan jumlah isi padu sehektar yang kecil. Penjarakan semasa sebanyak 2 m mengakibatkan isipadu sehektar yang lebih besar dalam pokok bersaiz kecil yang dapat ditingkatkan melalui penjarangan. Disyorkan supaya jadual penjarakan dan penjarangan semasa ini terus diikuti sehinggalah maklumat mengenai implikasi ekonomi bagi regim alternatif diperoleh.

Introduction

Teak (*Tectona grandis* L.f.) is one of the world's most valuable tropical timbers. It is native to India, Burma, Thailand, Indochina and Indonesia (particularly Java), and is cultivated extensively in plantations within its natural range as well as in tropical areas of Africa and Latin America (Chudnoff 1980). It is a tree species of moist to dry tropical regions, growing at elevations from sea-level to 1300 m above sea-level (FAO 1983).

Teak wood is used in general construction, furniture as well as in wharfs, bridges, ship decking, flooring, cabinet work, panelling, turnery, tanks, vats and fixtures requiring high resistance to acids. It is also used as poles for building and communication purposes and furniture (Wangaard & Muschler 1952, Abdelkariem 1980).

Teak was introduced to Tanzania by Germans as far back as 1906, and from promising research findings and the ease with which it can be raised, commercial plantations were started in the 1930s and 1950s at Mtibwa, Rondo and Longuza (Wood 1967). Teak has high commercial value which is comparable only to a few indigenous hardwoods. The heartwood of teak has high durability, good strength properties (Rajput *et al.* 1983) and has excellent figure (Donaldson 1984).

This study was carried out to assess the performance of teak planted at square spacings of 1.5, 2.0, 2.5 and 3.0 m. The variables studied were diameter at breast height (dbh), volume production, survival, basic density and some strength properties. Currently, teak is planted at a square spacing of 2.0 to 2.5 m. This spacing has no research backing in Tanzania. It was adopted from the major industrial species *Pinus patula* and *Cupressus lusitanica*,which can be traced back to South Africa (Malimbwi *et al.* 1992a,b).

Materials and methods

Study area

The experiment was located in Bulwa, Longuza, in Tanga, Tanzania at 5° 5' S and 38° 7' E. The altitude ranges from 150 to 400 m above sea-level. The slope is between 15 and 20% and the soil is reddish-brown to brown clay loam with patches of black cotton soils. The soil pH ranges from 5 to 6. The natural vegetation was dominated by *Acacia* spp., *Albizia* spp., *Antiaris toxicaria, Antiaris usambarensis, Khaya anthotheca, Milicia (Chlorophora) excelsa, Sterculia* spp., *Trema guinensis* and *Trichilia emetica.* The mean annual rainfall is 1180 mm. The climate is monsoonal with rainfall falling in two periods: the long rains from March to May and short rains from October to December. The mean annual maximum and minimum temperatures are 27.6 °C and 21.1 °C respectively.

Experimental layout

The experiment was established during the long rains of 1979 after clearing and burning the original vegetation. Teak stumps of about 25 - 30 cm long were planted at four square spacings of 1.5, 2.0, 2.5 and 3.0 m in a randomised block design experiment replicated three times. The distances between blocks and plots were 10 m and 6 m respectively. Each plot covered 30 × 30 m and the planted numbers for each spacing were therefore as follows:

Spacing (m)	Number per plot	Number in 3 blocks
1.5	400	1200
2.0	225	675
2.5	144	432
3.0	100	300

Data collection

The height of all trees was measured at ages 1, 3 and 6 y. At the ages of 7 and 9 y, the diameter at breast height (dbh) of all trees and the height of randomly selected trees in each plot were measured. Additionally, the following data were also collected.

- number of live branches at the age of 7 y
- height to first live branch at the age of 9 y
- survival count at each time of measurement

At the age of 14 y, the experiment was assessed for basic density and some strength properties. In each plot, two dominant trees with good visual quality (defect free, straight bole, good crown) were selected for the basic density determination. The 1.5 m spacing was not subjected to this test because it was considered practically unimportant. A total of 18 trees were selected for the purpose. The dbh of the selected trees were measured and increment cores taken at breast height using an increment borer. Basic density was determined using the maximum moisture content method.

The same trees selected for basic density determination were felled for strength properties assessment. A 3 m long billet cut at 1.3 m upwards was taken from each tree. The billets were sawn to produce clear specimens following the procedure described by Lavers (1969). The following strength properties were determined:

- static bending: - modulus of rupture (MOR)
  - modulus of elasticity (MOE)

- compression parallel to the grain (ultimate stress)
- shear parallel to the grain (ultimate stress)

As for basic density, the closest spacing was not assessed for strength properties because it was considered impractical.

Data analysis

Tree volume estimation

Using the height-diameter data collected for each plot, simple regression equations for each spacing were fitted in order to estimate the heights of the trees which were not measured. The form of the equation used was (Kozak & Yang 1978):

$$H = a + b \log D$$

where

H = height, m
a,b = regression coefficients
D = diameter at breast height (dbh), cm

The Tanzania standard volume tables for teak (Ackhurst & Micski 1971) were then used to determine the volume for each tree.

Stand parameters

From the tree measurements several stand parameters were calculated at each time of measurement and subjected to analysis of variance (ANOVA) and/or used in the development of trends. These parameters were: mean height, mean height to first live branch, mean dbh, mean branch count per tree, survival percentage, basal area per hectare, volume per hectare, mean values for the strength properties. Prior to ANOVA, arcsine transformation was applied to the survival percentage data. Least significant difference (LSD) was used to identify significant differences between two means for all variables. Furthermore, development trends with age were determined for mean height, mean dbh, survival percentage, basal area and volume per hectare.

Results and discussion

Survival

Figure 1 shows the effect of spacing on the survival trend of teak at Longuza. Up to age 6 y, there were only slight differences in survival, implying that spacing did not influence survival. At the age of 9 y, the closest spacing showed the lowest survival but differences between treatments were not statistically significant (Table 1). This is likely to be due to competition. The low survival associated with closer spacing observed in this study is in agreement with results reported by Ola-Adams (1990). The lack of significant differences in the survival rate indicates some degree of shade tolerance of teak.

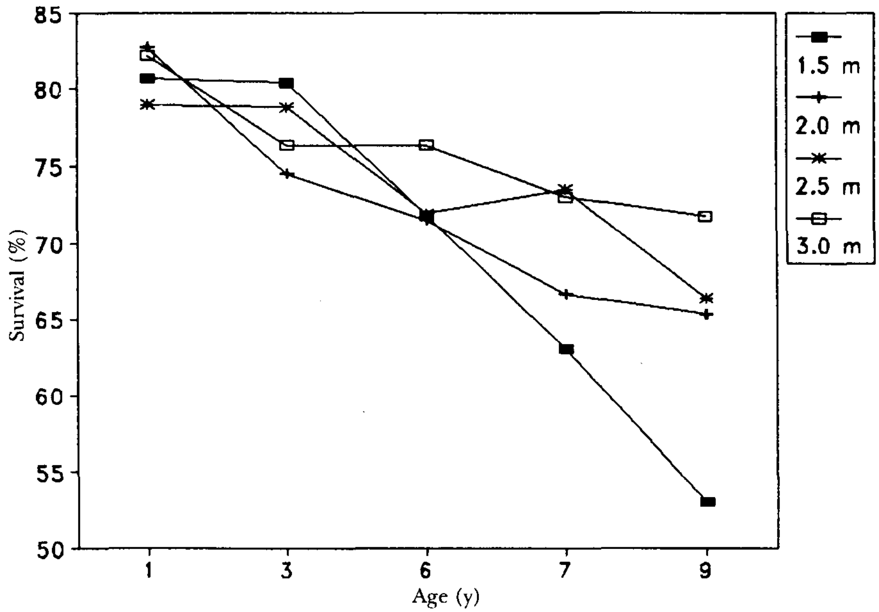

Figure 1. Survival trend for different spacings of teak at Longuza

Diameter

The effect of spacing on diameter is shown in Table 1. It is clear that the mean breast height diameter increased significantly with increasing spacing ($p<0.05$). This is in agreement with results from other investigations, e.g. William & Thomas (1981), Kalaghe (1981), Adegbehin (1982), Earle (1989), Ola-Adams (1990), Malimbwi *et al.* (1992a,b). The results suggest that wide spacing could be justifiable in order to produce bigger logs during first and successive thinnings. Figure 2 shows the effect of spacing on dbh development. It is apparent that at both ages, wide spacing favours diameter growth. Unfortunately there are no dbh data below the age of 7 y to show the time of the onset of competition. But this could probably be between 4 and 5 y of age. An ongoing thinning experiment established when the plantation was 4 y of age at the same site is likely to provide this information.

Table 1. Effect of spacing on mean survival, breast height diameter, number of branches (age 7 y), total height, height to first live branch, basal area and standing volume of 9-y-old teak at Longuza

Spacing (m)	Survival (%)	dbh (cm⁺)	Number of branches	Total height (m)	Height to first live branch(m)	Basal area ($m^2 ha^{-1}$)	Volume ($m^3 ha^{-1}$)
1.5	52.1	9.1a	10a	11.6a	4.8	18.0a	103
2.0	64.9	10.9ab	14b	13.0ab	5.7	17.3a	106
2.5	67.6	12.2bc	14bc	12.5a	4.1	14.2b	101
3.0	71.9	13.9c	19d	14.3b	3.6	13.1b	85
ANOVA	ns	*	**	*	ns	*	ns
F-VALUE	1.21	6.40	11.20	5.43	1.99	5.56	4.22

ns = not significant,
* = significant at $p < 0.05$,
** = significant at $p < 0.01$,
\+ = within the same column, values followed by the same letters are not significantly different.

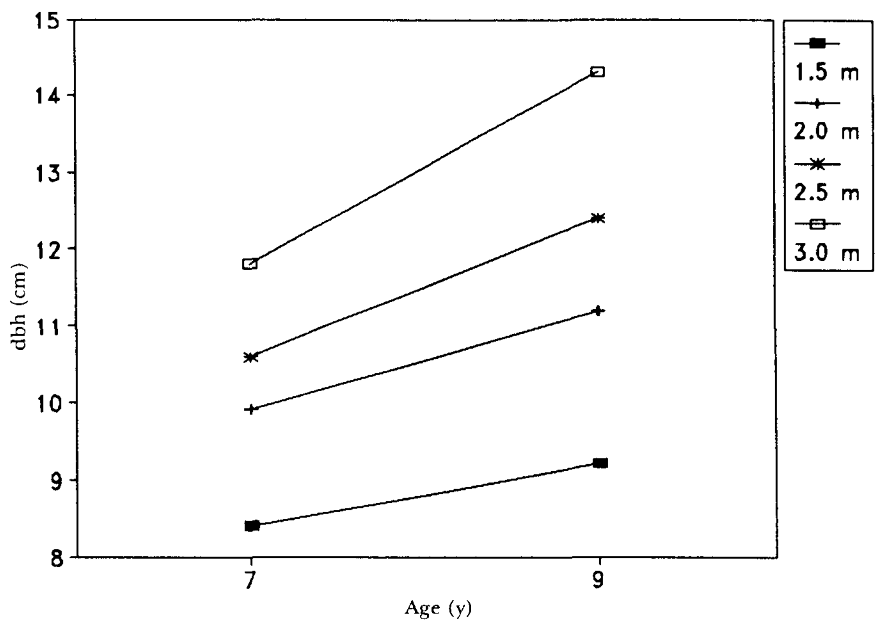

Figure 2. Dbh growth for different spacings of teak at Longuza

Basal area

As shown in Table 1, basal area decreased significantly with increasing spacing. The results are in agreement with those of Adegbehin (1982) for 7-y-old teak and Ola-Adams (1990) for 18-y-old teak. The results, however, contrast with those reported by Malimbwi *et al* (1992a) for 19-y-old *Pinus patula* grown at

Rongai. These researchers found a highly significant increase in basal area with increasing spacing. This further indicates the shade tolerance nature of teak, a trend which is similar to that for cypress (Malimbwi *et al* 1992b), and in contrast to that for *P. patula* which is more sensitive to shade. Figure 3 shows the effect of spacing on the development of basal area of 7- to 9-y-old teak grown at Longuza. While basal area changed very little between ages 7 and 9 y in the closest spacing, the change in the wider spacings was considerable due to increased diameter growth of single trees.

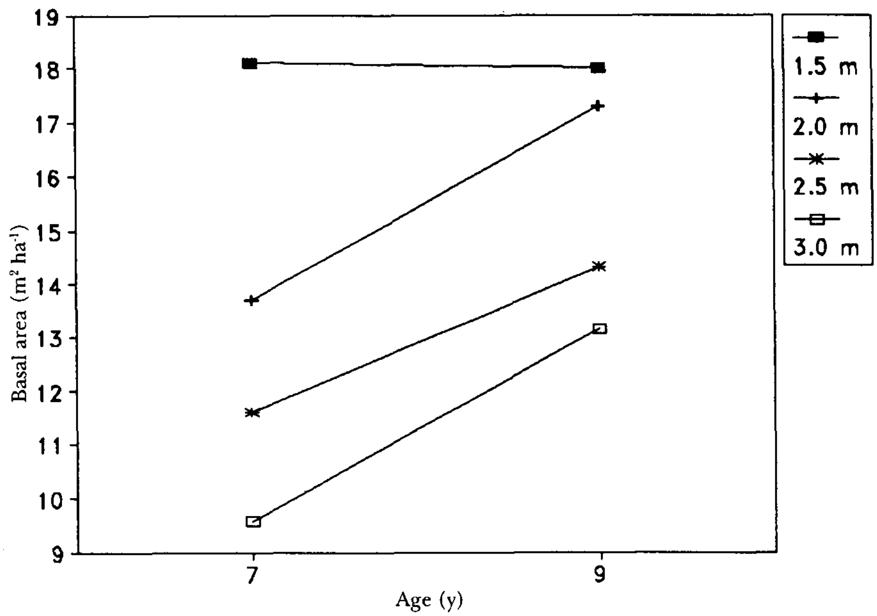

Figure 3. Basal area growth for different spacings of teak at Longuza

Height

Table 1 shows the height of *Tectona grandis* at the age of 9 y while Figure 3 shows the effect of spacing on the development of height. Statistical analysis showed a significant ($p<0.05$) effect of spacing on height at the age of 9 y. Between ages 1 and 7 y, there was no consistent trend of the effect of spacing on height development. With closer spacing the trees may compete for light (severe competition) and the proportion of trees occupying positions in the lower canopy is greater, resulting in the lowering of the mean height of the plot (Malimbwi *et al.* 1992b). This becomes more apparent with increasing age.

The length of bole to the first live branch is important since it determines the quality of timber to be produced in terms of knots. At age 9 y, the height to the first live branch increased between spacings 1.5 m and 2.0 m and then decreased up to spacing 3.0 m. Statistical analysis, however, showed that height to the first live branch was not significantly affected by spacing (p>0.05). The number of branches also affects the quality of timber in terms of knots. Table 1 shows that the number of branches increased significantly with spacing. To reduce knots in timber, pruning of the widely spaced trees may be necessary.

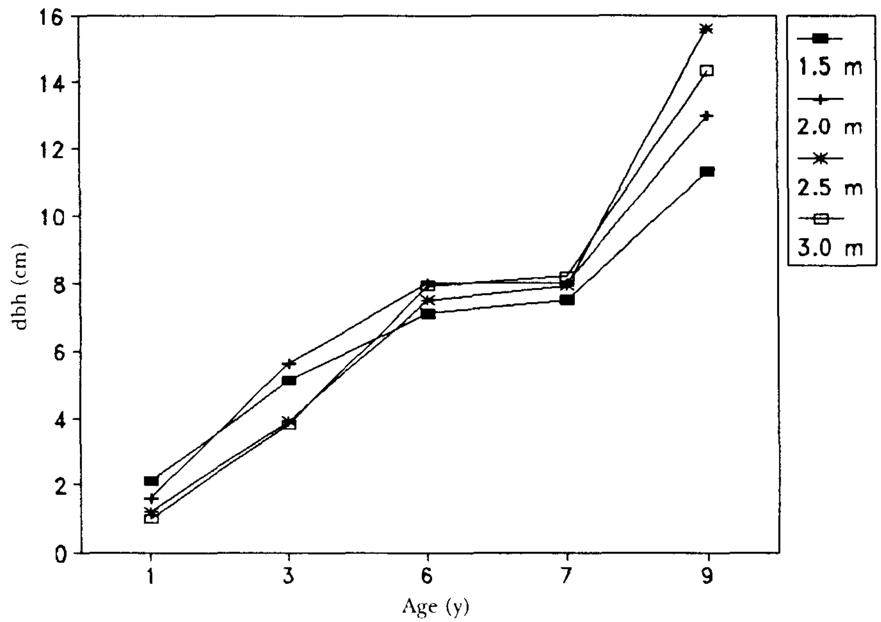

Figure 4. Height growth for different spacings of teak at Longuza

Volume production

Table 1 shows that volume production has a decreasing trend with increasing spacing similar to the basal area trend. Statistical analysis, however, showed that the decrease was not significant (p>0.05). This trend is in agreement with reports by Adegbehin (1982), Ola-Adams (1990) and Malimbwi *et al.* (1992b). Figure 5 shows the volume growth from the ages of 7 to 9 y. The trend is "more volume with closer spacing". At the age of 9 y, however, the closest spacing of 1.5 m has less volume than the next closest spacing of 2 m. This suggests the effect of competition as it can be seen in Figure 1 where mortality in the closest spacing has increased. Thinning would reduce mortality due to competition and boost dbh growth. This could economically be an incentive for adopting closer spacing because in Tanzania there is a ready market for small-sized thinnings of teak.

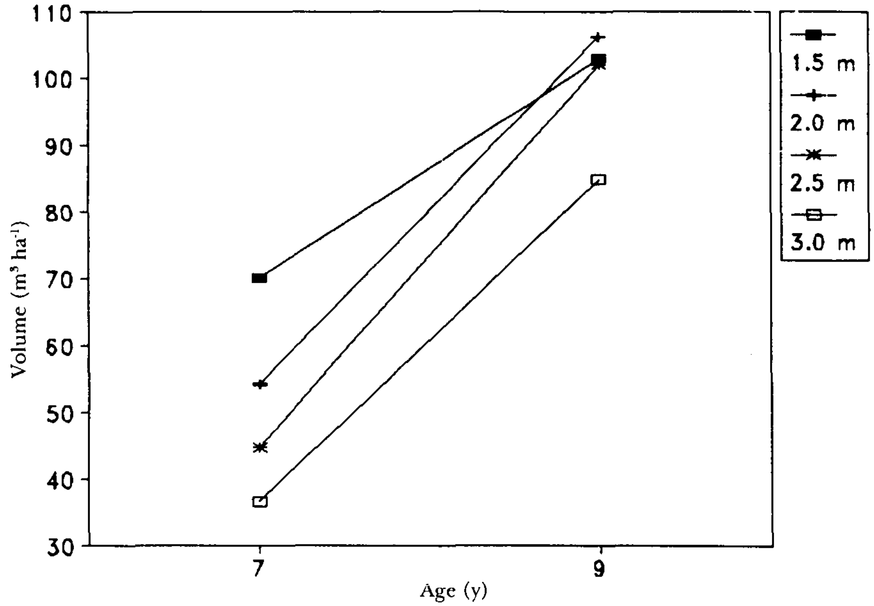

Figure 5. Height growth for different spacings of teak at Longuza

Wood Properties

Basic density

The effect of spacing on basic density is shown in Table 2. It is clear that basic density increased significantly with increasing spacing ($p<0.05$). Ola-Adams (1990) also found an increase in specific gravity with increasing spacing in 18-y-old teak. The increase observed in this study may be due to differences in growth rates of trees between spacings. This is expected for teak in which relief from crowding leads to an increase in growth rate and hence increase in wood density in ring porous hardwoods (Kollmann & Cote Jr. 1968, Desch 1973).

Table 2. Effect of spacing on basic density of 14-y-old *Tectona grandis* grown at Longuza, Tanzania

Spacing (m)	Average volume-weighted basic density ($kg\ m^{-3}$)
2.0	525a⁺
2.5	541b
3.0	587c
ANOVA	**
F-value	23.15

** = significant at $p<0.01$,
\+ = within the same column, values followed by the same letter are not significantly different.

The basic density values are lower than those reported by Steven (1977) and Batulaine (1987). This could be due to differences in age, genetical factors (Bauch 1980) and/or environmental factors (Rydholm 1965). For example, the age of material studied by Batulaine (1987) which had air dry density of 655 kg m^{-3} was from 39-y-old teak trees.

Strength properties

Table 3 shows the effect of spacing on static bending, compression parallel to grain and shear strength parallel to grain. Analysis showed that static bending modulus of elasticity and shear parallel to grain increased significantly ($p<0.05$) with increasing spacing. This is expected since density increased significantly with spacing. Density is positively correlated with most strength properties.

Table 3. Effect of spacing on some strength properties of 14-y-old *Tectona grandis* grown at Longuza, Tanzania

Spacing (m)	Strength (N mm^{-2})			
	Static bending		Compression parallel to grain	Shear parallel to grain
	MOR	MOE		
2.0	89	7185a+	39.68a	8.28a
2.5	96	8119b	42.23b	8.81b
3.0	118	11427c	44.72c	10.56c
ANOVA	ns	*	ns	**
F-value	4.77	17.87	2.56	107.5

ns = not significant,
* = significant at $p < 0.05$,
** = significant at $p < 0.01$,
\+ = within the same column, values followed by the same letter are not significantly different.

Practical significance of the results

The spacing currently used in teak plantations is between 2 and 2.5 m square. The results of the present study indicate that for spacings of 2.5 and 3.0 m square, there are no differences of practical significance in most of the variables studied. As teak is a self pruner, the branchiness currently observed in the wider spacing is likely to be eliminated with the onset of competition. Thus a spacing of 3.0 m square could be adopted in the establishment of *Tectona grandis* in Tanzania as this would result in production of large diameter logs and stronger wood in delayed thinnings. On the other hand, closer spacing of 2 m square results in higher volume per hectare of small dimension trees. With proper early thinning, diameter growth and timber strength could be improved, at the same time realising early returns from sale of the thinnings. The recommendation on the adoption of a particular thinning schedule should be backed up by an economic justification. The ongoing thinning experiment at the site will provide information on different thinning regimes of teak and their economic implications. Until such information is available the spacing of 2 m square and thinning regime currently in practice should continue.

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