THINNING GUIDELINES FOR TREE SPECIES OF DIFFERENT SUCCESSIONAL STATUS

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SAMARASINGHE, S. J., ASHTON, P.M.S., GUNATILLEKE, I.A.U.N. & GUNATILLEKE, C.V.S. 1995. Thinning guidelines for tree species of different successional status. Four species of different successional status (*Albizia falcataria* = *Paraserianthes falcataria*, *Alstonia macrophylla*, *Michelia champaca* and *Swietenia macrophylla*) were surveyed to construct spacing and thinning guidelines for their establishment in plantations in central and southwest Sri Lanka. The species selected are commonly planted as shade trees in Kandy district and all have desirable timber properties. Tree measurements taken were diameter at breast height and crown width. These parameters were sampled on trees located in stands of different density. Sixty individuals were selected that represented all size classes and stand densities for each species. Data of diameter breast height and crown width were used to construct spacing and thinning guidelines that were compared among species. Results showed that each species uses growing space differently under contrasting size classes. Guidelines based on these relationships are appropriate for species that are being introduced into new plantation systems where spacing and thinning information from permanent plots is not available. Maximum crown width can also be used to evaluate appropriate plant spacing of successionally compatible mixtures of tree species in a plantation.

Key words: *Albizia falcataria* - *Alstonia macrophylla* - *Michelia champaca* - *Swietenia macrophylla* - thinning - spacing - Sri Lanka - succession

SAMARASINGHE, S.J., ASHTON, P.M.S., GUNATILLEKE, I.A.U.N. & GUNATILLEKE, C.V.S. 1995. Panduan-panduan penjarangan spesies pokok yang mempunyai status sesaran yang berbeza. Empat spesies daripada status sesaran (*Albizia falcataria* = *Paraserianthes falcataria*, *Alstonia macrophylla*, *Michelia champaca* dan *Swietenia macrophylla*) telah dikaji untuk menyediakan panduan-panduan penjarakan dan penjarangan bagi penubuhannya di ladang-ladang di bahagian tengah dan barat daya Sri Lanka. Spesies yang dipilih biasanya ditanam sebagai pokok-pokok naungan di daerah Kandy dan kesemuanya mempunyai ciri-ciri kayu yang diingini. Ukuran pokok yang diambil adalah diameter aras dada dan kelebaran silara. Parameter-parameter ini telah dibuat pensampelan pada pokok-pokok yang ditempatkan di dirian-dirian yang mempunyai ketumpatan yang berbeza. Enam puluh pokok yang dipilih mewakili semua kelas-kelas saiz dan ketumpatan dirian bagi setiap spesies. Data diameter aras dada dan kelebaran silara telah digunakan untuk menyediakan panduan-panduan penjarakan dan penjarangan yang dibuat perbandingan di antara spesies-spesies. Hasilnya menunjukkan bahawa setiap spesies menggunakan ruang yang berbeza untuk membesar di bawah kelas-kelas saiz yang kontras. Panduan-panduan berasaskan perkaitan ini adalah sesuai bagi spesies yang diperkenalkan untuk sistem-sistem perladangan baru di mana maklumat-maklumat mengenai penjarangan daripada plot kekal tidak diperolehi. Kelebaran maksimum silara juga dapat digunakan untuk menilai penjarakan penanaman yang sesuai bagi spesies pokok yang mempunyai gabungan yang serasi di sebuah ladang.

Introduction

Stem diameter is directly related to a tree's crown size (Berlyn 1962, Seymour & Smith 1987). Crown size can be affected by spatial and temporal changes in stand density (Larson & Mohammed Nuruz 1985, Ashton *et al.* 1989). Quality and high yield of timber therefore depend on growing trees to critical diameters quickly and efficiently according to a spacing and thinning regime (Larson & Mohammed Nuruz 1985, Ashton *et al.* 1989). Planting trees at suitable spacing is therefore a prerequisite for the creation of a productive plantation for dimensional timber.

This study formulated spacing and thinning guidelines for four tree species. Three tree species are considered pioneers (*Albizia falcataria* (L.) Fosb. = *Paraserianthes falcataria, Alstonia macrophylla* Wall. ex G. Don, *Swietenia macrophylla* King) and one is considered climax *(Michelia champaca L.)* using the terminology of Swaine and Whitmore (1988). However, Hartshorn (1978) and Denslow (1987) would classify these species differently (pioneer - *A. macrophylla;* large gap specialist - *A. falcataria, S. macrophylla;* small gap specialist - *M. champaca).*

All species have desirable but different timber uses in Sri Lanka. *Albizia falcataria* was originally introduced at the turn of the century to provide shade for tea *(Camellia sinensis)* (Worthington 1954). Its wood is used for the manufacture of matches, tea chests and packing cases. *Alstonia macrophylla* was introduced from Malaysia by the Royal Peradeniya Botanical Garden (Corner 1988). Its bole is clear and straight with little taper, making it suitable for poles, posts and paneling. However, the wood requires treatment with preservative. *Swietenia macrophylla* was introduced by the forest department in the 1930's from Belize for its durable high quality timber for use as furniture and housing construction (Lamb 1966). *Michelia champaca* was introduced from India several centuries ago. Its timber is durable and used for furniture and turnery.

Methods

The study was located at four sites (Hantana, Bowalawatte, Udawattekele and Ampitiya) in the Kandy district of Sri Lanka (7°15'N, 80°00'E). The soils of the area are red-yellow podsols (FAO/UNESCO 1979) or alfisols (USDA 1975), and are derived from residual archian rocks (Moorman & Panabokke 1961, Cooray 1967). Kandy district has a mean temperature of 24 °C and an annual rainfall of 2000 mm.

In 1991, species were surveyed and measurements taken on individual trees of diameter at breast height (DBH) and crown width (CW). Measures of the widest horizontal part of the crown and its perpendicular axis were used to calculate mean CW. Observations showed that crown shapes of all species were approximately circular and measurements perpendicular to each other did not differ significantly. Sixty individuals of each species were selected for measurement. Individuals represented a range of DBH size classes (*A. falcataria* 5 - 175 cm; *A. macrophylla* 5 - 45 cm; *S. macrophylla* 5 - 60 cm; *M. champaca* 5 - 120 cm) and were taken from different stand development stages and densities (mature-open 50 - 200 trees ha^{-1}; mature-dense 200 - 500 tree ha^{-1}). Using the regression procedure of SAS (Ray 1982), quadratic equations predicting CW (m) from DBH (cm) for each species were developed.

Results

In all cases the correlation coefficients (r and F statistics of the models were significant at the 0.0001 level (Table 1). However, the relatively low r for *Alstonia macrophylla* was largely because of greater variability in CW with measures of DBH as compared to the other species. The predicted relationship between CW and DBH for each species is shown in Figure 1. The ratios of CW to DBH of the bole (CW/DBH), measured in the same units, were calculated (Table 2). This ratio has been termed by Suri (1975) as the growing space index (GSI).

Table 1. Regression statistics and equations predicting crown width [CW(m)] from diameter at breast height [DBH(cm)] from pooled stand density data for each of the four species

Species	Equation	r	n
Alstonia macrophylla	$CW = 2.2673 + 0.1471\ (DBH)\ - 0.0017(DBH)^2$	0.34***	60
Albizia falcataria	$CW = 0.4474 + 0.2721\ (DBH)\ - 0.0005(DBH)^2$	0.96***	60
Swietenia macrophylla	$CW = 0.7466 + 0.2125\ (DBH)\ - 0.0006(DBH)^2$	0.94***	60
Michelia champaca	$CW = -0.0005 + 0.2958\ (DBH)\ - 0.0011(DBH)^2$	0.86***	60

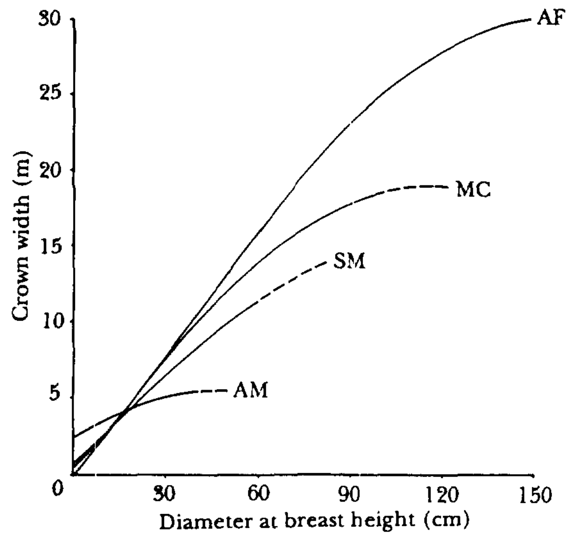

Figure 1. Regression lines depicting DBH and CW relationships of the four species. *A.macrophylla* = AM; *A. falcataria* = AF; *S. macrophylla* = SM; *M. champaca* = MC.

Ground cover as a percentage of land area can be found by using a constant n/4 (Dawkins 1963), which assumes that trees are planted at a square spacing and have circular crowns (Ashton *et al.* 1989). The number of trees per unit area (ha) for each diameter class was calculated by dividing the total land area by the crown area and multiplying it by Dawkins' constant.

This information can be graphically combined to construct spacing and thinning guidelines for each of the four species. These guidelines are a series of crown disengagement curves that are referenced to a single guide curve (zero disengagement). Zero disengagement represents the maximum number of trees that can occupy a stand at various mean stand diameters based on the calculations using Dawkins' constant. Thinning moves a stand to a lower disengagement curve. After thinning, crown closure will move a stand back to zero disengagement (Figure 2).

Table 2. Diameter at breast height (DBH), crown width (CW), crown area (CA) and growing space index (GSI) for the four species

	Alstonia macrophylla			*Albizia falcataria*		
DBH (cm)	CW (m)	CA (m^2)	GSI	CW (m)	CA (m^2)	GSI
5	2.96	6.88	59.21	1.80	2.53	35.91
10	3.57	10.00	35.68	3.12	7.63	31.18
15	4.09	13.14	28.28	4.42	15.31	29.44
20	4.53	16.10	22.65	5.69	25.41	28.45
25	4.88	18.71	19.53	6.94	37.73	27.75
30	5.15	20.82	17.17	8.16	52.27	27.20
35	5.33	22.33	15.24	9.36	68.75	26.74
40	5.43	23.16	13.58	10.53	87.06	26.33
60				14.97	176.00	24.96
80				19.02	283.84	23.77
100				22.66	402.99	22.66
120				25.90	526.56	21.58
140				28.74	643.46	20.53
160				31.18	763.34	19.49
180				33.23	866.53	18.46
200				34.87	954.35	17.43

	Swietenia macrophylla			*Michelia champaca*		
DBH (cm)	CW (m)	CA (m^2)	GSI	CW (m)	CA (m^2)	GSI
5	1.79	2.53	35.88	1.27	1.26	25.30
10	2.81	6.21	28.12	2.69	5.69	26.92
15	3.80	11.21	25.33	4.06	12.93	27.05
20	4.76	17.76	23.78	5.36	22.93	26.92
25	5.63	25.36	22.74	6.61	34.31	26.44
30	6.58	34.00	21.94	7.80	47.73	25.99
35	7.45	43.00	21.28	8.92	62.52	25.50
40	8.29	53.90	20.72	9.92	78.35	24.98
60	11.34	100.89	18.39	13.66	146.40	22.76
80	13.91	151.81	17.38	16.36	210.17	20.45
100	16.00	200.87	16.00	18.11	257.42	18.11
120	17.61	243.34	14.67	18.89	280.25	15.75
140	18.74	275.58	13.38	18.72	275.11	13.37

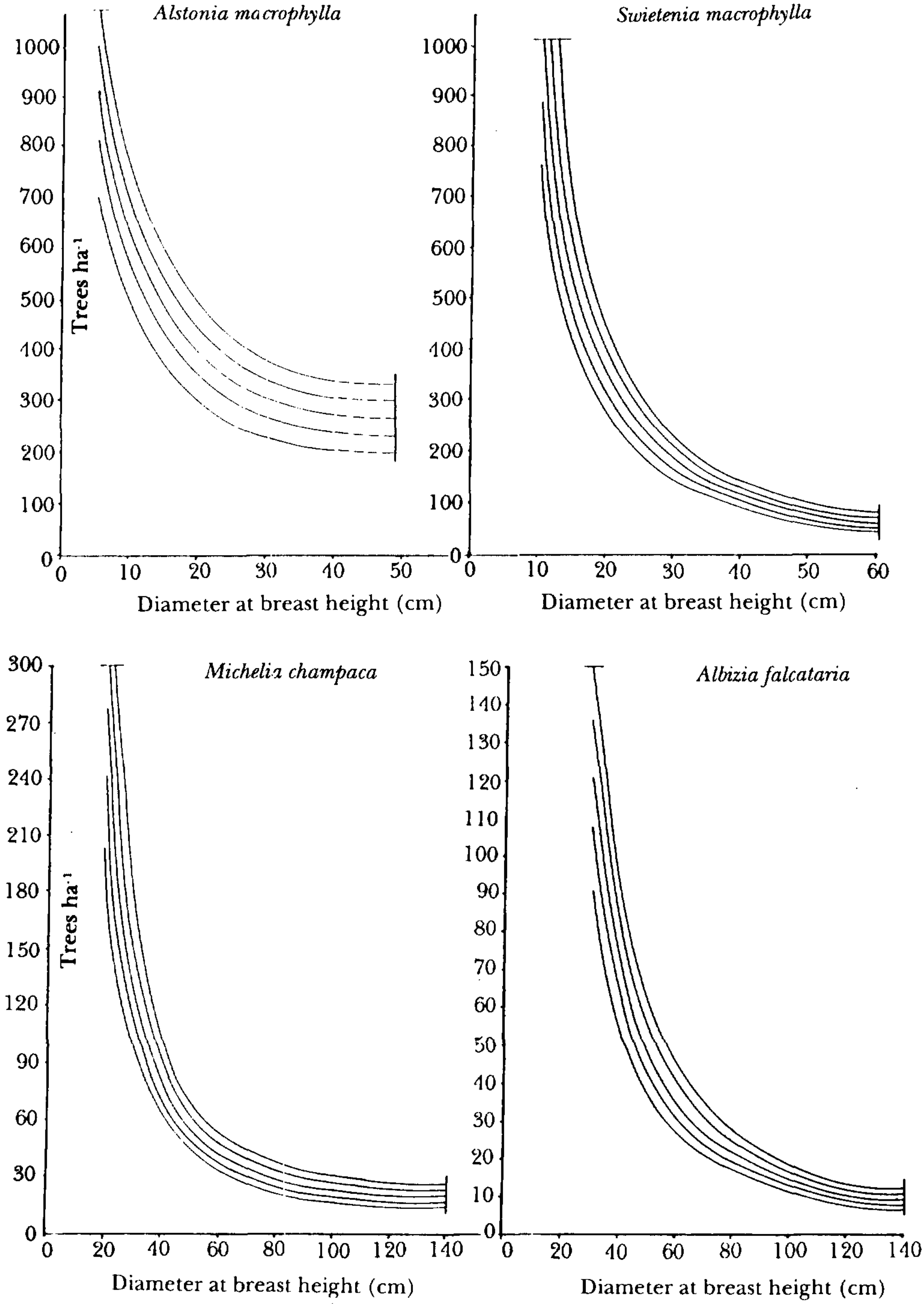

Figure 2. Thinning and spacing guidelines of stands for each species. The reference guide curves (0% disengagement) are based on the maximum number of trees that can occupy a stand at various mean stand diameters. [A series of disengagement curves, 10% (90%stocking); 20% (80% stocking); 30% (70% stocking); 40% (60% stocking) have been extrapolated from the 0% disengagement guide (100% stocking) to gauge thinning intensity].

There is an increase in total basal area as the number of trees per unit area decreases with an increasing DBH. Equations predicted different maximum CW (CW_{max}) for each species (*A. falcatatia* CW_{max} = 36.00 m at 250 cm DBH; *A. macrophylla* CW_{max} = 5.43 m at 40 cm DBH; *S. macrophylla* CW_{max} = 19.56 m at 180 cm DBH; *M. champaca* CW_{max} ≐18.89 m at 120 cm DBH) (see Figure 1). This demonstrates that different tree species require different amounts of space to grow efficiently and to increase in bole size.

The trend of GSI (CW/DBH) over DBH was then examined for the four different species. For each species GSI is high at the initial stage of establishment and decreases with increasing DBH (Figure 3). Patterns in this decrease are markedly different among species. Compared to the other species *A. macrophylla* has a high GSI for small stem size but dramatically declines as stem size increases. *Albizia falcataria, M. champaca* and *S. macrophylla* trees that have small stems have a smaller CW compared to *A. macrophylla.* Large stemmed trees of *A. falcataria* and *S. macrophylla* have a considerably larger CW than *A. macrophylla.*

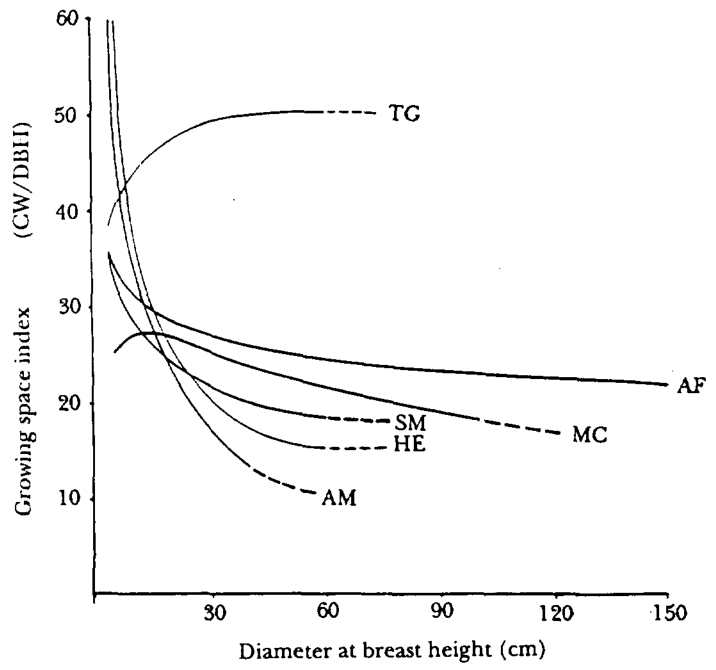

Figure 3. A graph showing the relationship between GSI and DBH for *A. macrophylla* = AM, *A. falcataria* = AF, *S. macrophylla* = SM, *M.champaca* = MC. GSI and DBH relationships have also been depicted for *Tectona grandis* = TG (data from Larson & Mohammed Nuruz 1985), and for *Hibiscus elatus* = HE (data from Ashton *et al.* 1989).

Discussion

The size, shape and branching characteristics of trees can be governed by manipulating the growing space allocated for them. Selecting an initial spacing for each tree species can facilitate the growth of a desired tree diameter for a product (Table 2). However, maximum yield of the plantation depends on the spacing and total number of trees that can be planted per hectare. Maximum number of trees per hectare for a desired tree diameter can be obtained from the zero disengagement curves of each species (Figure 2). The other disengagement curves provide information on the extent of thinning required and is particular for each species.

As an example, these thinning guidelines might be used by the forester to determine the stand diameter desired for trees in the plantation to be harvested for a particular product (e.g. 15 cm boards). Using the guideline for the species concerned, the forester can use the zero disengagement curve to estimate the number of trees ha^{-1} that can be grown to the desired stand diameter for the product. This number is the maximum number of trees that can occupy that growing space at that product diameter. All additional trees can be removed by thinning. The maximum tree number will determine the amount of crown disengagement that would occur if all trees were thinned at the present time. If too much growing space is opened in one thinning, the forester could plan on two or more thinnings over an extended time period instead.

To use the guidelines for selection of initial spacing at plantation establishment, another example is best for demonstration. If the smallest tree that can be utilized for *S. macrophylla* is 40 cm DBH, then Figure 2 suggests about 145 trees ha^{-1} at zero disengagement be planted at 8.28 × 8.28 m. It is important to recognize that these guidelines do not account for the intervals of time between thinnings. This is because growth rates will vary depending on the particular variation in soil and climate of the stand in question. It is therefore best for the forester to base his decision on when to thin and the time intervals between thinnings on his experience of the area.

The information generated from these guidelines does not have to be solely used for thinning. It can also be used for the determination of seedling spacing in new plantations. Data also suggest species spacing for possible combinations in plantation mixtures. However, the most appropriate mixtures should be successionally compatible. For example, one plantation combination would require a close spacing for the pioneer *A. macrophylla* with *M. champaca* interspersed at wider intervals. Judicious use of the *A. macrophylla* thinning guideline would facilitate the continued growth of residual *A. macrophylla* and *M. champaca*. Over time the complete removal of *A. macrophylla* in thinnings would promote eventual occupation of all growing space by *M. champaca*. At this stage the *M. champaca* thinning guideline would be used until rotation ends. It is important to recognize that for combinations of species in mixture these guidelines are crude at best. This is because the data in this study have not taken into account interspecific competition.

The relationship between GSI and DBH demonstrates that the rate of expansion of CW decreases with increasing DBH (Figure 3). Results suggest that for the pioneer, *A. macrophylla*, more trees can be planted at a closer spacing to obtain larger desired boles than the other species. A similar relationship exists between GSI and DBH for the pioneer or large gap specialists, *A. falcataria* and *S. macrophylla*.

Albizia falcataria, and to a lesser degree *S. macrophylla*, require relatively lower decreases in expansion rate of CW per stem increment increase. Compared to the other species this relationship becomes apparent when trees attain stem diameters greater than 25 cm DBH. When trees of *A. falcataria* and *S. macrophylla* are smaller in stem size, growth allocation appears more efficient with greater decreases in CW expansion per unit increase in DBH than for larger stem sizes. However, the change in relationship between CW or GSI and DBH suggests that species change in their physiological efficiency or that they re-distribute their foliage in different ways as they increase in height and girth.

Other measures of crown size such as live crown ratio (LCR) might be more appropriate to observe allocation change between crown and bole. *Michelia champaca* has been classified as a climax or small gap specialist. It has a relationship between GSI and DBH that shows an initial increase and then a more gradual and/or linear decrease. These differences in the relationship between GSI and DBH among species suggest dramatic species-specific changes in crown morphology with the size of tree.

The changes in GSI among species that dominate the canopy of different successional stages have been documented by Halle *et al.* (1978) and Whitmore (1984). However, though these observations have been observed in a descriptive manner this study is one of a few that has quantified these changes (Dawkins 1963, Suri 1975, Larson & Mohammed Nuruz 1985, Ashton *et al.* 1989). For comparison with our species, the relationships between GSI and DBH for *Tectona grandis* (Larson & Mohammed Nuruz 1985) and *Hibsicus elatus* (Ashton *et al.* 1989) have also been depicted in Figure 3. Three kinds of relationship are shown by: i) *T. grandis*-increase at decreasing rate; ii) *M. champaca* - increase then a nearly linear decrease; iii) other species - decrease at decreasing rate. Patterns suggest species belonging to later seral stages such as *T.grandis* and *M. champaca* are different than species categorized as belonging to early seral stages. These late successional species grow in association with the pioneers. However, the late successional species are generally subordinate in height to the pioneers in early stand development. Over time the late successional species overtop their early successional competitors. The increase in GSI indicates that canopy space is used efficiently as these trees mature. The small crowns of these species therefore show no evidence that they can be grown at a close spacing early because crowns greatly expand later as trees increase in bole size. This growth dynamic might be a reason for differences in GSI and DBH among late and early seral species.

As plantations become older, more data should be collected from permanent plots in order to improve or replace existing guidelines. However, the spacing and thinning guidelines in this study have immediate application for plantation establishment of single species in degraded forests or on other lands suited for reforestation. The relationship between GSI and DBH among species of different successional status also suggests spacings for species mixtures in plantation analogs that emulate the dynamics of natural forest.

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