TEAK YIELDS IN THE DRY LOWLAND RAIN FOREST AREA OF NIGERIA

S. O. Akindele

Department of Forestry and Wood Technology, Federal University of Technology, Akure, Nigeria

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AKINDELE, S. O. 1989. Teak yields in the dry lowland rain forest area of Nigeria. The yield of teak plantations established by taungya in the dry lowland rain forest area of Nigeria was assessed. The study involved the examination of the stand volume - age relationship for plantations ranging from 9 to 25 years in age. The teak plantations maintained a fairly linear increment pattern during the first 25 years, averaging 27 m^3 ha^{-1} y^{-1}.

Keywords: Teak - yield - increment - Nigeria

Introduction

In Nigeria, the natural forest ecosystem is being degraded because of the increased demands on land for agriculture, urban development, and timber production. This degradation has reached such an alarming rate that by the end of the century the remaining pockets of tropical rain forest in Nigeria may be completely exploited (Okojie *et al.* 1988). One major effort to lower the pressure to convert forest land to agricultural land has been the introduction of the taungya system of farming (Evans 1982). With this system, agricultural crops are grown between rows of trees during the first three years of the tree plantation's existence. Plantations of several tree species are being established in Nigeria using the taungya system. Of these tree species, *Gmelina arborea* and *Tectona grandis* are well-favoured and they together occupy more than 85% of the planted forest area now rapidly replacing the natural forest ecosystem in Nigeria (FORMEU 1984). While *G. arborea* is grown mainly to provide raw material for the pulp mills in the country, *T. grandis* (teak) is regarded as a very suitable species for the rapid production of large volumes of timber, fuelwood and poles of uniform and desirable quality.

Even though it is desirable to accommodate peasant farmers in view of the increased competition for land use, yet, the primary goal of ensuring the optimum use of forest land for the production of desirable tree species should not be jeopardized. In view of this, the present study aims at examining

THINNING AND SPACING GUIDELINES FOR BLUE MAHOE (*HIBISCUS ELATUS* SW.)

P. M. S. Ashton, J. S. Lowe & B. C. Larson

Tropical Resources Institute, 205 Prospect Street, School of Forestry & Environmental Studies, Yale University, New Haven, CT 06511, United States of America

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ASHTON, P. M. S., LOWE, J. S. & LARSON, B. C. 1989. Thinning and spacing guidelines for blue mahoe (*Hibiscus elatus* Sw.). Preliminary thinning and spacing guidelines using blue mahoe (*Hibiscus elatus* Sw.) from the moist limestone region of Puerto Rico are demonstrated. These guidelines are shown to be appropriate for recently introduced plantation species that have not passed through successive rotations under intensive management. Our results show that blue mahoe uses growing space more efficiently as the plantation gets older. This means that trees can be planted at a narrower spacing and that thinning should be lighter in older plantations than what is currently being practiced.

Key words: Crown size - *Hibiscus elatus* Sw. - plantation - Puerto Rico - spacing - thinning

Introduction

Blue mahoe (*Hibiscus elatus* Sw.) is a relatively new tree to be cultivated in plantations. Few have been planted on a commercial scale except in Jamaica and that was primarily during the period before independence in 1962 (Swabey 1941, Kimber 1970). Blue mahoe has been planted experimentally in Puerto Rico since the 1940s (Marrero 1955, Wadsworth 1945) and in Hawaii in the early 1970s (Whitesell & Walters 1976). Cuba also has plantings but little written information has been published there except for some brief general statements by the National Institute of Development and Approved Forest Management based in Havana.

Blue mahoe is a fast growing timber species with a wood that is easy to work, durable and has a beautiful grey blue lustre. Because of these attributes, it has great potential as a highly priced wood for international markets in furniture, turnery and panelling similar to that of teak (*Tectona grandis* L.). Blue mahoe grown in plantations can reach taller heights at smaller diameters than most trees. Little *et al.* (1974) state that it can grow over 25 *m* tall, while only 36 *cm* in diameter at breast height (DBH). Marrero (1955) recorded 10-y-old trees over 30 *m* and 25 *cm* DBH. We observed this growth form throughout the plantations we studied. For products such as poles and pulp, this growth is suitable, but for the production of high quality lumber, it is not.

Stem diameter is directly related to stand density and thinning regimes. Producing high priced lumber depends on growing trees to critical diameters quickly and efficiently according to a stand density regime for spacing and thinning.

Most blue mahoe plantations have been established at 2.5 × 2.5 *m* spacing based on custom but without adequate thinning guidelines to support or even modify this policy. In this paper we propose a preliminary thinning guideline for blue mahoe based on crown size. This system can be used until better information from permanent plots and thinning experiments is obtained.

In general, all quantitative guidelines are based on a measure of stand density so that spacing can be described as a function of tree size. Dawkins (1963) proposed basic relationships between crown size and stem diameter as a way to construct preliminary guidelines. Hibbs and Bentley (1984) used these relationships to produce a model for stem/crown growth based on the assumption that expansion rates for crown growth proportionally correspond to diameter growth rates and that this relationship does not change after thinning. Using this model and Dawkins' relationships, thinning guidelines have been constructed by Suri (1975) for sal (*Shorea robusta* L.), and by Larson and Zaman (1986) for teak (*T. grandis* L.). In this paper we use Dawkins' approach to present the results of a study investigating crown size and spacing in order to construct some basis for thinning and spacing guidelines of blue mahoe. We also examine the relationships between crown sizes through measures of live crown ratio and crown class.

Procedure

The study was located in the Rio Abajo State Forest in the northern limestone region of Puerto Rico. This forest has been classified as subtropical moist evergreen (Ewel & Whitmore 1973). Originally cleared for farming, tree plantations were established by the Commonwealth in the 1930s and 40s in the valleys and on the shallow slopes for watershed protection of the Dos Bocas Reservoir. Valley soils were well formed alluvial sandy clays, deep to bedrock. Rainfall averages 2000 $mm\ y^1$ with two moderately dry seasons; the major one in February and a smaller in August. Temperature remains in the mid-20°*C* with minor daily and annual fluctuations.

Eighteen 10 x 20 *m* plots were laid out in 15 mahoe stands of known thinning history and age. Data describing the plots (stands) concerning age, height, and diameter are shown in Table 1. Altogether 306 trees were measured for DBH, height, live crown ratio, crown size and crown class. Crown size was measured in the same way done by Larson and Zaman (1986). The widest horizontal axis of the crown and the axis perpendicular to this were measured. Because crown shape was close to circular these two measures of crown size did not differ significantly, and the two were averaged. Assuming circular crowns this average diameter was then used to estimate crown area. Live crown ratio was expressed as a percentage of the length from the top of the tree to the branch collar of the lowest live branch as compared to the total height of the tree. Crown class was done by the standard method of categorizing the tree by its crown position and health within the stand using dominance classes (dominant, codominant, intermediate, suppressed).

Table 1. Plot descriptions [age, number of trees/plot, mean tree DBH (*cm*), and mean height (*m*)]

Plot number	Age	Number of trees/plot	DBH (*cm*)	Height (*m*)
10	26	8	62.8	22.7
7	28	9	93.3	32.4
15	26	9	84.0	33.5
5	25	9	81.5	29.5
4	28	11	81.4	28.1
2	24	11	73.1	29.9
11	23	11	77.9	30.2
9	26	12	62.4	24.8
6	25	13	77.1	33.9
12	28	16	79.0	29.0
1	24	16	73.0	24.2
18	24	18	50.8	23.6
14	28	19	44.7	26.3
16	24	19	32.6	12.0
13	28	26	46.1	29.1
8	19	29	20.2	13.4
3	24	34	50.8	25.5
17	10	36	31.2	15.6

The relationship between crown diameter and DBH was estimated by linear regression using the least squares method (Ray 1982). This was done on an individual tree basis both in stands that had no history of thinning and in stands that had. The results for the thinned and unthinned were then compared.

The means and the standard errors of live crown ratio's for the plots were tabulated for each crown class.

Results

Using least squares regression an equation was found to predict crown diameter, CD (*m*) of unthinned trees from diameter at breast height, DBH (*cm*). The correlation coefficient (r) was 0.55 and the F statistic of the model was significant at the 0.0001 level. These are reasonable statistics and indicate considerable variation between individual trees. A t-test was used to investigate the significance of the parameters. The intercept was not significantly different from 0.0 on the level of $\alpha = 0.9999$, while that of the slope was significantly different from 0.0 on the level of $\alpha = 0.0001$.

When trees from the thinned plots only were regressed the correlation coefficient (r) was 0.46, the F statistic and the t-test having the same significance as previously. Figure 1 shows the different slopes for each regression and Table 2 lists their equations and statistics.

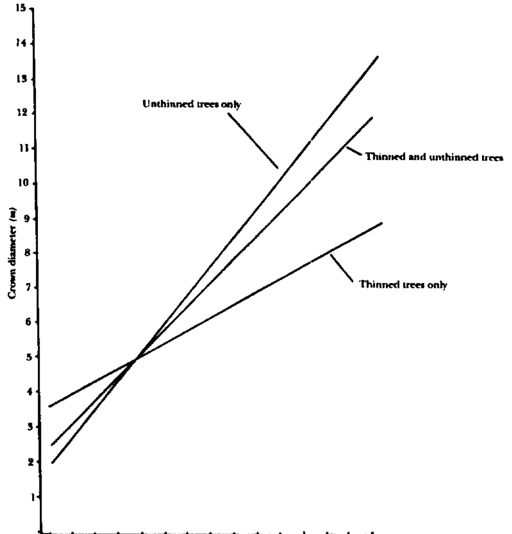

Figure 1. Regression lines predicting crown diameter (CD *m*) from diameter at breast height (DBH *cm*) for thinned trees, unthinned trees, and thinned and unthinned trees.

Table 2. Regression statistics and equations predicting crown diameter (CD *m*) from diameter at breast height (DBH *cm*) for thinned trees, unthinned trees, and thinned and unthinned trees (r = correlation coefficient, n = number of trees in sample)

	Equation	r	n
Thinned trees only	CD = 3.000 + 0.100 (DBH)	.46	134
Unthinned trees only	CD = 1.272 + 0.209 (DBH)	.55	172
Thinned and unthinned trees	CD = 1.810 + 0.170 (DBH)	.51	306

Usually this thinning guideline technique is based on unthinned and thinned trees having the same stem/crown diameter relationships (same slopes), when clearly they do not for blue mahoe. To avoid this assumption both thinned only and unthinned only regression equations must be used.

The growing space index (GSI) was then calculated for both conditions using Suri's (1975) method of the ratio of crown diameter to DBH of the bole (CD/DBH) measured in the same units (Table 3).

Table 3. Crown diameter (CD *m*), crown area (m^2) and growing space index (GSI) for thinned and unthinned stand conditions

DBH (*cm*)	CD (*m*)		Crown area (m^2)		GSI (CD/DBH)	
	Prethinned	Thinned	Prethinned	Thinned	Prethinned	Thinned
10	3.36	4.00	8.86	12.56	33.60	40.00
14	4.20	4.40	13.85	15.20	30.00	31.43
18	5.03	4.80	19.86	18.09	27.94	26.66
22	5.87	5.20	27.05	21.23	26.68	23.64
26	6.71	5.60	35.34	24.62	25.81	21.54
30	7.54	6.00	44.63	28.26	25.13	20.00
34	8.38	6.40	55.13	32.15	24.65	18.82
38	9.21	6.80	66.59	36.30	24.24	17.89
42	10.05	7.20	79.27	40.69	23.93	17.14
46	10.89	7.60	93.09	45.34	23.67	16.52
50	11.72	8.00	107.83	50.24	23.44	16.00
54	12.56	8.40	123.84	55.39	23.26	15.55
58	13.39	8.80	140.74	60.79	23.08	15.17

Ground cover as a percentage of land area can be found by using a constant $\pi/4$ (Dawkins 1963), which assumes that trees are planted at a square spacing and have circular crowns. Dividing the total land area by the crown area and multiplying by the constant computes the number of trees per unit area for each diameter class (Table 4).

Table 4. Stand densities (trees ha^{-1}) and basal areas (m^2 ha^{-1}) of fully stocked stands in thinned and unthinned conditions by 2 *cm* mean stand diameter classes (Assuming square spacing and circular crowns Dawkins constant = .785)

DBH (*cm*)	Trees ha^{-1}		Basal area (m^2 ha^{-1})	
	Prethinned	Thinned	Prethinned	Thinned
10	886	625	6.96	4.90
14	567	516	8.73	7.94
18	395	434	10.05	11.04
22	290	370	11.02	14.06
26	222	319	11.79	16.93
30	176	278	12.44	19.64
34	142	244	12.89	22.14
38	118	216	13.38	24.48
42	99	193	13.71	26.72
46	84	173	13.96	28.74
50	73	156	14.33	30.61
54	63	142	14.43	32.50
58	55	129	14.53	34.06

The information can then be combined graphically to construct two thinning guidelines for thinned (derived from thinned only regression) and prethinned plantations (derived from unthinned only regression). These guidelines are a family of crown disengagement curves that are extrapolated from a single guide curve (zero disengagement). This guide curve is constructed after knowing the maximum number of trees that can occupy a stand at various mean stand diameters. Thinning moves a stand to a lower disengagement curve. After thinning, crown closure will move a stand back to zero disengagement (Figures 2 & 3). For practical reasons, because some Caribbean countries still use Imperial units, each guideline has been constructed using both metric and Imperial units. It is important to remember that the two guidelines should be used in the correct plantation conditions. The guideline for unthinned stands (Figure 2) should be used for the period from plantation establishment to the time of first thinning and the second guideline (Figure 3) for use in plantations after their first thinning.

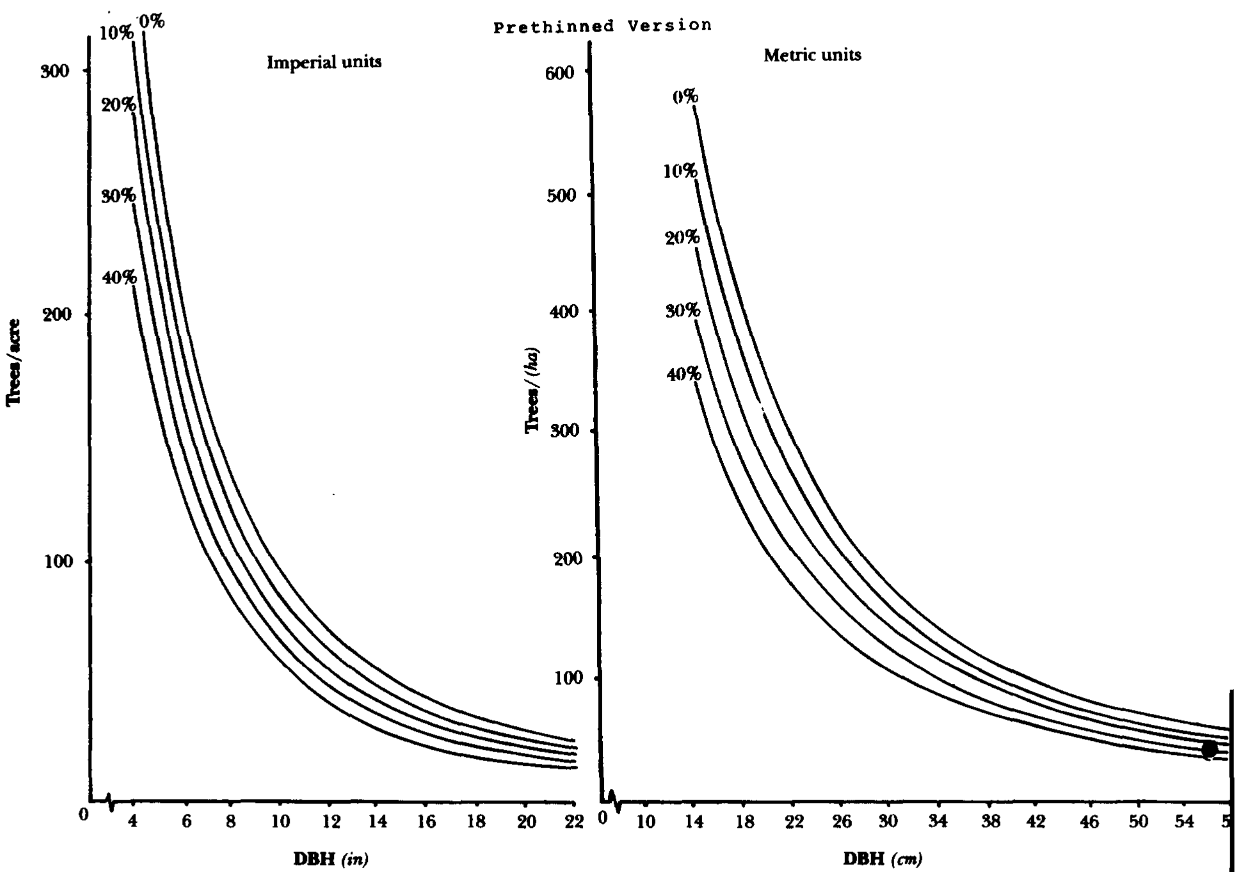

Figure 2. Thinning guideline for unthinned stands - a baseline guide curve is illustrated (0% disengagement) in both metric and Imperial units; it is based on the maximum number of unthinned trees that can occupy a stand at various mean stand diameters [A family of disengagement curves, 10% disengagement (90% stocking), 20% disengagement (80% stocking), 30% disengagement (70% stocking), 40% disengagement (60% stocking), have been extrapolated from 0% disengagement (100% stocking)]

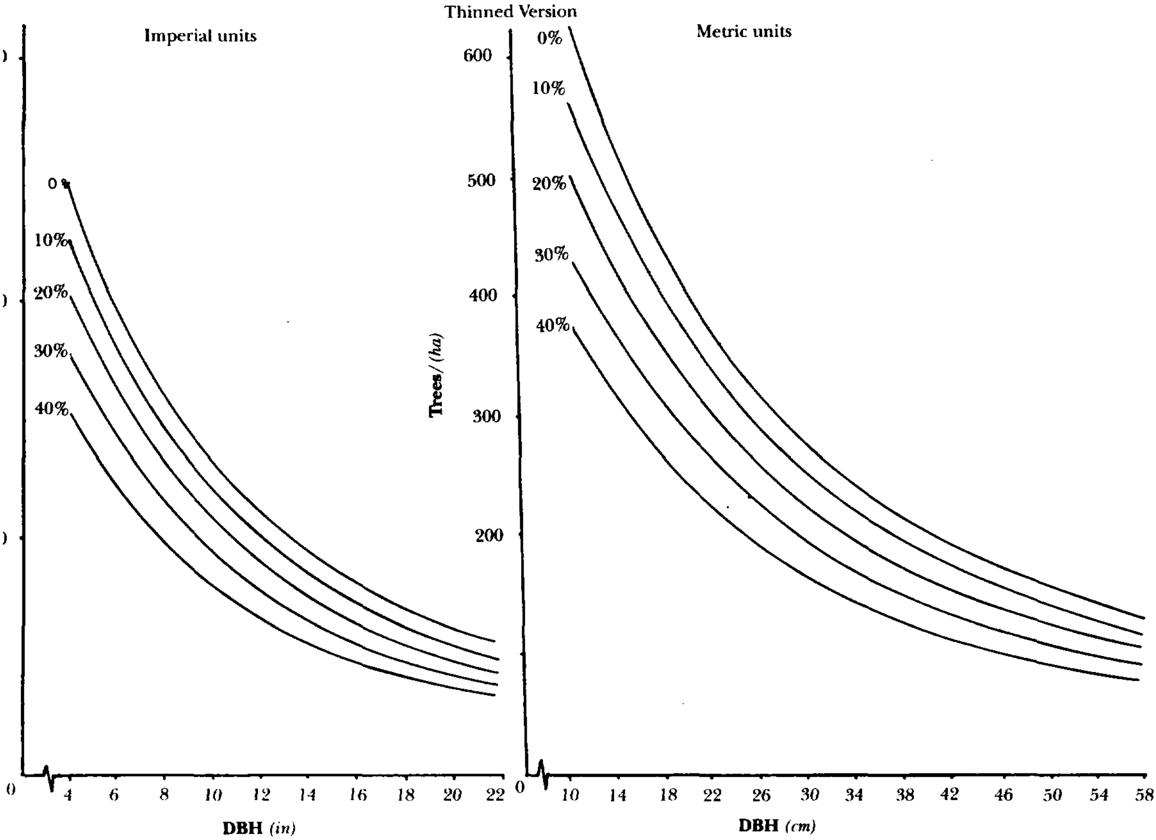

Figure 3. Thinning guideline for thinned stands - a baseline guide curve is illustrated (0% disengagement) in both metric and Imperial units; it is based on the maximum number of thinned trees that can occupy a stand at various mean stand diameters [A family of disengagement curves, 10% disengagement (90% stocking), 20% disengagement (80% stocking), 30% disengagement (70% stocking), 40% disengagement (60% stocking), have been extrapolated from 0% disengagement (100% stocking)]

As the number of trees decreases with increased DBH there is an increase in total basal area. This would indicate that the trees use space 'more efficiently' as they increase in size. The trend of GSI (CD/DBH) over DBH was then examined and this is shown graphically in Figure 4. GSI decreases asymptotically meaning that blue mahoe requires relatively less crown canopy compared to its bole size as it matures.

Another similar method to GSI for measuring crown size to stem size ratio's is by looking at the live crown length (distance between the top of the tree and the branch collar of the lowest live branch on the main stem). By taking the ratio of the length of live crown to the total height of the tree one can look at the crown to stem size ratio from a different perspective. Table 5 shows live crown ratio's are larger for trees of intermediate crown class as compared to dominant crown class. This supports the idea mentioned previously that the smaller trees have on average larger crown sizes as compared to their stem diameter. It is possible that the larger trees with smaller crowns are denser, with more foliage per unit space. This has not been investigated but should be considered.

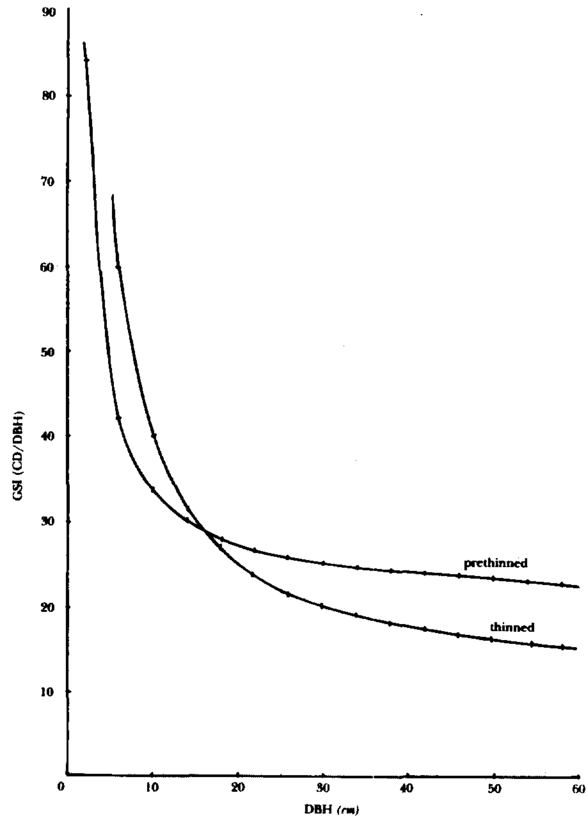

Figure 4. A graph showing the relationships between growing space index (GSI) and diameter breast height (DBH) for unthinned and thinned conditions

Table 5. Mean live crown ratio's (X) and standard errors (S) for dominant, codominant, and intermediate crown classes

	Live crown ratio	
	X	(S)
Intermediate crown class	45.6%	(3.48)
Codominant crown class	31.8%	(2.58)
Dominant crown class	25.8%	(4.51)

X = mean live crown ratio of plots as a per cent
S = standard error of the means of the plots

Discussion

Results of this study will help provide information for the forester to make decisions, but it is important to realize that this information should not be accepted uncritically. For example, the forester must incorporate these guidelines (Figures 2 & 3) with his or her own knowledge of the individual site conditions that the plantation under consideration is in. He or she must know under what circumstances each guideline should be used.

In general, to use this information there are three aspects of thinning that must always be considered. When to thin? How heavy to thin? Which trees to thin? Larson and Zaman (1986) discuss well these considerations. We have described some examples in using ours.

Firstly, they can be used to determine minimum stand diameter for a desired product, be it a pole, post or sawlog. Using Figure 2 or 3 and taking the zero disengagement curve as a guide would allow the forester to determine the maximum number of trees that would occupy the growing space for the desired tree diameter. Knowing this the forester could then evaluate the particular stand under review and decide whether a thinning is desired and if so the amount of crown disengagement necessary for growth release.

The prethinned guideline can be used to establish initial spacing, so as not to plant more than the maximum number of trees that will give a first thinning that is commercial, rather than precommercial. In the case of blue mahoe planting densities on the high side must be recommended to avoid large epicormic sprouts (Ashton *et al.* 1986a). Adjustments can be made for mortality at planting by increasing the number of trees planted by the estimated number that would die. No extra cost in replanting need then be done. From our experience though, replanting is probably better for blue mahoe as stand spacing irregularities seem partially responsible for persistent epicormic sprouts (Ashton *et al.* 1986a). Here we should mention an important assumption that has been made in the guidelines that the trees removed in thinning are regularly spaced. This is usually the case, but not in improvement thinnings where one is concentrating on removing deformities from the stand. Clumping will make some trees grow as if unthinned and others as if in the open.

Another aspect that must be accounted for in decision making is time, which has not been incorporated into the guideline. This involves several factors, the most important being growth rates of plantations which depend on site conditions (see Ashton *et al.* 1986b for site indices of blue mahoe). This information should be readily obtainable in the future from more reliable data on growth records from permanent plots. Stem analysis might also be an avenue of investigation, though growth rings so far as can be determined at present, are variable with time in this species.

As stated previously, diameter increase with time is not entirely correlated with crown expansion. This relationship has been hypothesized by Hibbs and

Bentley (1984), and from our observations seems very plausible as blue mahoe's growth form suggests this. In addition we have found that the relationship changes with thinning. It can be shown in the decreasing growing space index (Figure 4) and the live crown ratio patterns (Table 5). This is similar to what Suri (1975) found in sal, meaning that as the trees mature, the ratio between crown size and stem size will become less. This leads one to suspect that crown size will not respond dramatically with thinning. We have observed this phenomenon in stands that have been heavily thinned, where crowns have remained relatively small compared to DBH. Knowing this, it is recommended that thinning be of a light nature particularly on older plantations.

This makes the prethinned guideline in Figure 2 conservative in nature because in all likelihood DBH growth for a given crown size will be higher in a thinned than an unthinned stand. This is why once a plantation has had its first thinning it is necessary to use the thinned guideline in Figure 3.

Lastly, there is the time dependent factor related to the unpredictability of market fluctuations and the availability of harvesting and processing technology. A forester will have to make a thinning when he or she has the available technology to do so and when economics allows it.

Conclusions

Following Suri (1975) and Larson and Zaman (1986), preliminary thinning guidelines have been constructed based on relationships described by Dawkins (1963) and Hibbs and Bentley (1984). The thinning guidelines are a family of curves constructed from a single guide curve (zero disengagement) that is derived from the maximum number of trees that can occupy a stand at various mean stand diameters. The guidelines can be used by the forester to predict the number of trees possible at certain diameter size objectives and this information can indicate through crown disengagement the amount of thinning required to achieve this. It is important that the forester remembers that each guideline should be used under the correct plantation conditions and that adjustments must be made accordingly using his or her own experience.

Decreasing GSI trends favour narrower spacing if no thinnings are planned and wider spacing if thinnings are planned. These trends indicate that as stands mature, thinnings should be less intensive.

Using these guidelines, the forester must realise that they are preliminary until more substantive information is made available. This can be done through the collection of data from permanent plots. Special emphasis must be made to record the changing relation of crown size stem diameter as trees respond to thinning.

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