PRELIMINARY THINNING GUIDELINE FOR *ACACIA MANGIUM* WILLD. PLANTATIONS IN KEMASUL FOREST RESERVE, PENINSULAR MALAYSIA

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PAUDYAL, B.K. & NIK MUHAMAD MAJID. 1990. Preliminary thinning guideline for *Acacia mangium* Willd. plantations in Kemasul Forest Reserve, Peninsular Malaysia. The determination of an appropriate thinning regime for *Acacia mangium* Willd. plantations in Malaysia is important for management purposes. However, this research is still in its initial stage. A preliminary thinning guideline for *Acacia mangium* plantation based on tree crown diameter and diameter at breast height (dbh) is proposed in this paper. This guideline can be used until more detailed information from the permanent plots are obtained. The results indicate that the trees use space more efficiently with increase in size. The management implication of this would be to have thinnings less intensive as stands mature in size. The guideline can be used to determine the minimum stand diameter needed for a desired product and to determine the initial spacing.

Key words: Thinning - crown diameter - growing space index - disengagement - stand density

Introduction

The determination of an appropriate thinning regime for forest species being grown in plantations for the first time is inadequately known in the tropics. Each individual tree in a stand has a definite amount of growing space. The area potentially available to a tree is defined by its horizontal crown projection (crown canopy area) plus its appropriate share of the uncovered area of the stand. As crown diameter increases with increase in bole diameter, the tree requires more crown canopy area and as such more potential area. This basic relationship (Dawkins 1963, Suri 1975, Larson & Zaman 1985, Ashton *et al.* 1986) has been used in young plantations to evaluate the initial spacing and possible thinning regimes to be used in subsequent rotations.

Acacia mangium, introduced from Queensland, Australia, is a relatively new tree in the forest plantation programme in Malaysia. It appears to be one of the most promising plantation species. In plantations, it grows as fast, or faster than *Gmelina arborea* Roxb. and *Eucalyptus deglupta* Blume, the latter two being popular fast growing trees planted in the humid tropics.

In Sabah, *A. mangium* trees on average grew 23 *m* in height in 9 *y* with a diameter of 23 *cm* (Butt & Sia 1982). In Peninsular Malaysia, MAI (dbh) and MAI (height) of this species, observed in Rantau Panjang and Setul Forest Reserves, ranged from 4.80 to 4.99 *cm* and 4.14 to 4.33 *m* for 3 and 1-*y*-old stand, respectively (Kamis & Mohd. Amran 1984).

Johari and Yuan (1986) have given detailed information about the current plantation management procedures in Compensatory Forest Plantation Project (CFPP). The first pruning is carried out at the time of first weeding to remove any undesirable competing leaders and other abnormally big branches. A second pruning is carried out at the time of second weeding when the tree is pruned to half its height, which is about 2.0 to 2.5 *m* above the ground level. A high pruning will be carried out in the fourth year for about 300 potential final crop trees per hectare. In accordance with the CFPP proposal, thinning is to be carried out at year 8 when about 56 m^3 ha^{-1} of timber is expected to be removed leaving behind about 300 trees ha^{-1} as the final crop trees. However, this is an interim guideline which is not based on any research finding. No thinning and pruning regimes have been formulated yet although some thinning trials are being carried out in the older plantations.

A number of studies have been reported in developing thinning guidelines. Dawkins (1963) proposed using basic relationships between crown and stem diameters as a way to develop thinning guidelines for tropical species. Suri (1975) used this relationship to develop thinning guideline for sal (*Shorea robusta*). Similar work was reported by Hibbs (1984) for red oak (*Quercus rubra*), Larson and Zaman (1985) for teak and Ashton et al. (1986) for blue mahoe (*Hibiscus elatus* Sw.). However this approach will only serve as a guide in planning stand density until mature experimental plots are available. Thus, this approach can be used in the early life of a stand and also where there is an immediate need to develop the thinning guidelines as the case in Malaysia now.

In this paper we used the Dawkins' (1963) approach to present the results of a study investigating crown size and spacing to construct some basis for thinning guidelines for *A. mangium* plantations in Peninsular Malaysia.

Methodology

Study site

The study was conducted at six different aged stands of *A. mangium* plantations in Kemasul Forest Reserve in Pahang, Peninsular Malaysia (Figure 1). The age of the stands are 18, 40, 47, 61, 65 and 99 months. Annual temperature ranges from 21 to 32° *C* and mean total annual precipitation is 1700 *mm*, rain fall occurring mainly from April to May and September to December.

The area can generally be described as flat to slightly undulating with slopes ranging from 1 to 20% (Nik & Kamaruzaman 1986). The average elevation of the area is 60 *m* above sea level. The parent material is mainly of sedimentary and low grade metamorphic rocks. The trees were planted at a distance of 3 × 3 *m*, and the number of trees ha^{-1} is 1110, except for the 65 and 99-*mth*-old stands which were planted at a spacing of 2.4 × 2.4 *m* with 1724 trees ha^{-1}.

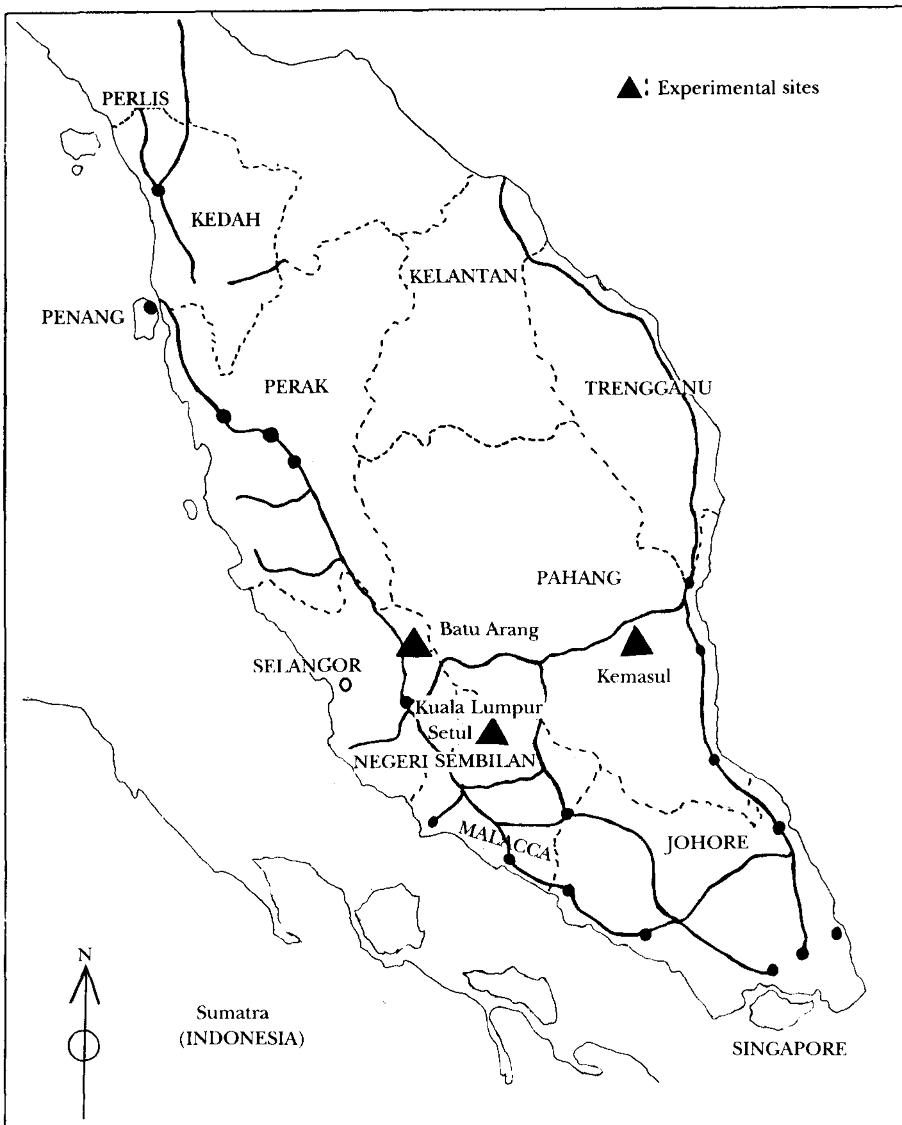

Figure 1. Map of Peninsular Malaysia showing the experimental sites

The general information about the stands regarding age, number of trees per hectare, dominant height, mean height, mean diameter and basal area is given in Table 1. Dominant height was calculated on the basis of 100 largest trees per hectare.

Table 1. Stand description of *Acacia mangium* plantations, Kemasul, Peninsular Malaysia

Age (*mth*)	N ha^{-1}	Hdom (*m*)	Mht (*m*)	Mdbh (*cm*)	B.A. (m^2 ha^{-1})
18	1000 (p1)	9.30	6.09	8.80	7.92
	925 (p2)	9.12	6.01	8.40	7.52
40	1050 (p1)	16.45	12.43	13.80	18.11
	1025 (p2)	16.25	12.49	12.80	17.83
47	1110 (p1)	19.20	15.40	15.10	22.72
	1100 (p2)	18.98	15.36	14.50	22.52
61	1100 (p1)	19.43	16.97	17.30	30.14
	1075 (p2)	18.21	15.89	17.10	29.78
65	1607 (p1)	25.52	19.26	17.20	30.08
	1500 (p2)	25.20	19.20	17.40	30.52
99	1178 (p1)	30.28	25.00	20.25	41.42
	1142 (p2)	29.75	24.86	19.95	41.08

N ha^{-1} - number of trees per hectare; Hdom - dominant height; Mht - mean height; Mdbh - mean diameter; B.A. - basal area; Note: p1 = plot no. 1; p2 = plot no. 2

Experimental layout and calculation

Two plots of 20 × 20 *m* (0.04 *ha*) were established for each age group, making a total of 12 plots for the study. Crown diameter and dbh of 199 trees comprising all the diameter classes in the plantation were measured. The trees were selected to cover a wide range of diameters, from 8 to 21 *cm*, in the different age stands. Crown diameter was measured using the method adopted by Larson and Zaman (1985). The widest horizontal axis of the crown and the axis perpendicular to this were measured and the two values were averaged. This average diameter was used to estimate crown area, assuming a circular crown. The relationship between crown diameter and dbh (Dawkins 1963, Suri 1975, Larson & Zaman 1985) was estimated by linear regression using the least squares method (Ray 1982).

The growing space index (GSI) was then calculated based on the method of Suri (1975) by using the ratio of crown diameter to dbh (CD/dbh) measured in the same units. Table 2 shows the calculated crown diameter, crown area and the resultant GSI for a range of bole diameters. Ground cover or crown projection area as a percentage of stand area was calculated by using a constant (0.785) derived from Dawkins (1963), which allows for the assumption that trees are planted at square spacing and have circular crowns. Dividing the total land area by the crown and multiplying by the constant computes the number of trees per unit area and hence the basal area per unit area for each diameter class. The formula for determining number of trees per unit area for each diameter class is given below.

$$\text{Number of trees/unit area (for each diameter class)} = \frac{\text{Total stand area/unit area}}{\text{Average crown projection/unit area}} \times 0.785$$

$$\text{Basal area } (m^2\ ha^{-1}) = \frac{d^2 \times N}{10{,}000} \times 0.785$$

where d = dbh (*cm*); N = number of trees ha^{-1}.

Results and discussion

It was found by least squares linear regression that crown diameter (CD) can be predicted from bole diameter (dbh) of a given tree by the following equation:

$$CD = 1.89425 + 0.17822 \times dbh.$$

The coefficient of determination (R^2) was 0.63 and the F statistic of the model was highly significant (d.f. = 1197; S.E. = 0.3755; F-value - 346.372; P<0.01). These are reasonable statistics and indicate considerable variation between individual trees. A t-test was used to evaluate the significance of the parameters. The probability that the intercept was significantly different from zero was 0.0001 and the probability that the slope was significantly different from zero was 0.0001. Figure 2 shows the regression slope.

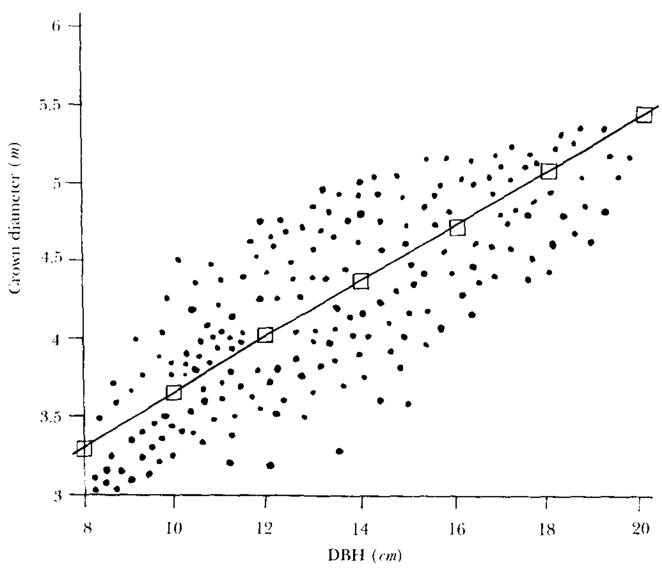

Figure 2. Crown diameter-dbh relationship, Kemasul

Table 2. Calculated crown diameters, crown area and GSI in relation to dbh

dbh (*cm*)	Crown diameter (*m*)	Crown area (m^2)	GSI (CD/dbh)
8	3.32	8.65	41.50
10	3.67	10.60	36.76
12	4.03	12.74	33.58
14	4.38	15.12	31.35
16	4.74	17.67	29.65
18	5.10	20.43	28.34
20	5.45	23.38	27.29

Note: All dbh figures are stand averages

Table 3. Basal area and number of trees in relation to dbh

dbh (*cm*)	Trees ha^{1}	Basal area (m^2 ha^{1})
8	907	4.55
10	740	5.80
12	616	6.96
14	519	7.98
16	444	8.92
18	384	9.76
20	336	10.55

Note: All dbh figures are stand averages

The results of basal area and number of trees in relation to dbh is given in Table 3. The information about the number of trees that can occupy per hectare corresponding to a particular diameter size can then be combined graphically to construct a thinning guideline. This guideline is a family of crown disengagement curves that are extrapolated from a single guide curve (zero disengagement). This guide curve was constructed after knowing the maximum number of trees that can occupy a stand at various stand diameters. Thinning moves a stand to a lower disengagement curve. After thinning, crown closure will move a stand back to zero disengagement. Figure 3 shows the disengagement curve for Kemasul. It shows that for 8 *cm* dbh, the maximum number of trees ha^{1} that can occupy the stand (that is, no thinning or 0% disengagement) is 907. If this stand is thinned to 40% (that is, 40% disengagement level), the number of trees remaining per hectare would be 544. When these trees, after a certain period, attain an average dbh of 16 *cm*, thinning is needed once again as only 444 trees ha^{1} can occupy the stand for the above diameter size. Thus, disengagement curves are simply thinning intensities ranging from zero (no thinning) to 40%.

As the number of trees decreases with increased dbh, there is an increase in total basal area. This indicates that the trees use growing space more efficiently with increase in size. The trend of GSI over dbh was then examined and this is shown graphically in Figure 4. GSI decreases asymptotically, meaning that *A. mangium* requires relatively less crown canopy area compared to its bole size as it matures.

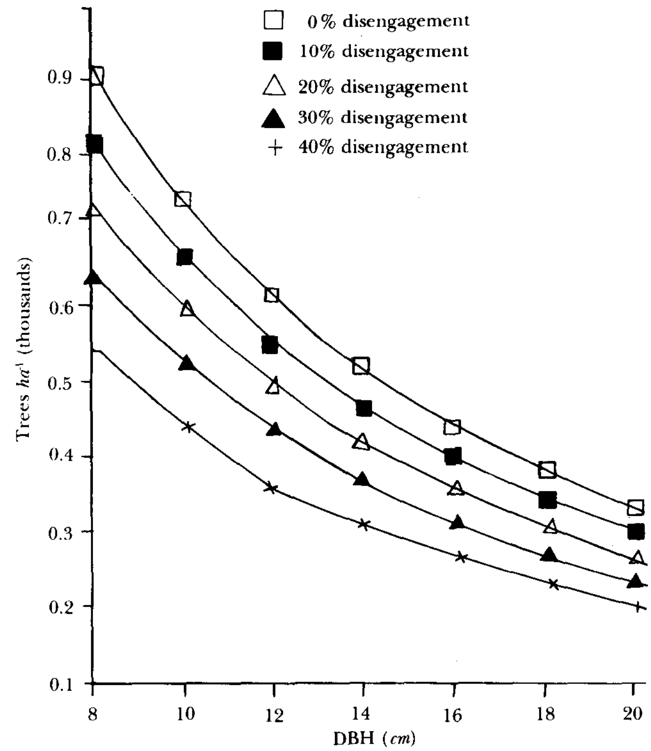

Figure 3. Number of trees ha^{-1} at a given disengagement level and dbh, Kemasul

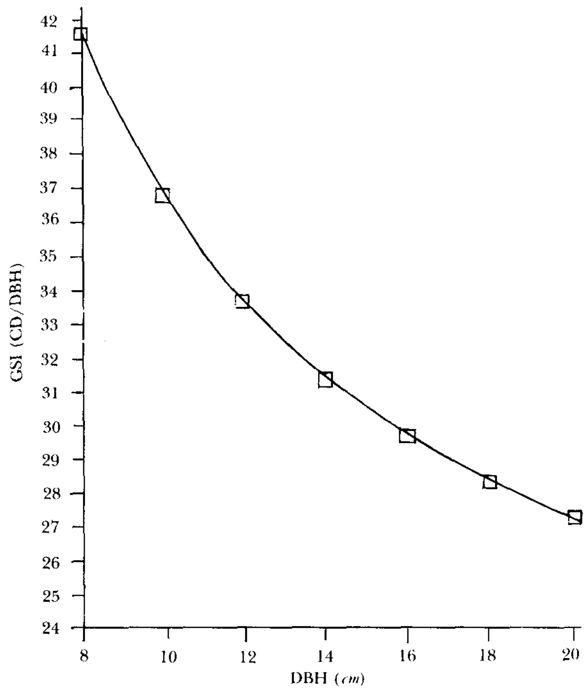

Figure 4. Growing space index (GSI), Kemasul

Four important issues have to be addressed during a thinning operation. These are timing, intensity, frequency and grade of thinning. The results of this study will not answer any of the four questions directly but would provide information for the forester to make thinning decisions. The family of curves in Figure 3 can be combined with local experience and knowledge of growth rates for the particular stand and the forest management objectives for the stand.

The guidelines would determine the minimum stand diameter needed for a desired product: be it pole, post or sawlog. For example, in the case of 16 *cm* boards for poles, one could use the zero disengagement curve to determine the number of trees for this diameter. Figure 3 gives 444 trees ha^{1}. This number is the maximum number of trees that can occupy the growing space for that size and the remaining trees should be thinned.

In a similar way, these curves can be used to determine initial spacing, so as not to plant more than the maximum number of trees that can occupy the stand for a particular diameter size. Adjustments can be made for mortality at planting by increasing the number of trees planted by the estimated number that would die.

The use of these curves for initial spacing is best demonstrated by an example. If a 10 *cm* dbh tree is desired, for example for pulpwood, Table 3 indicates that 740 trees ha^{1} should be planted. If 10% mortality is expected, then about 814 trees should be planted. In other words, about 3.5 *m* spacing would be required for this site if not thinning is planned. However, because of wide spacing at the beginning, there is a possibility of resurgence of weeds, stem branches becoming thicker, and the trees leaning, thus affecting the quality of the stand.

Another aspect that must be accounted for in decision making is time, which has not been incorporated into the guideline. This includes several factors, the most important being growth rate of the trees which depends on site conditions. Growth rate will vary greatly depending on the soil and climatic conditions of the area and it would be virtually impossible for a universal guideline to take this into account. This information should be readily obtainable in future from growth records of permanent plots.

It must also be noted that diameter increase with time is not entirely correlated with crown expansion. This phenomena has been hypothesized by Hibbs (1984) for red oak (*Q. rubra*), and growth form of *A. mangium* seems to support this. It can be shown by the decreasing growing space index (Figure 4). The decrease in growing space index (GSI) indicates that *A. mangium* requires less crown canopy area as the tree matures. This is similar to what Suri (1975) found for Sal and Ashton *et al.* (1986) for blue mahoe. This implies that as trees mature, the ratio between crown and stem size will decrease. Therefore, as the trees mature, the present guideline may not be applicable in thinned plantations. This is because, in all probability, dbh growth for a given crown size will be higher in a thinned stand than in an unthinned stand. Thus, this guideline is especially applicable for first thinning in young stands. A separate guideline has to be developed following first thinning. The use of the curves for different disengagement levels is to facilitate the forester to implement the decision. For example, if a forester thinks that by removing 30% of crown canopy area, the site is not much exposed and is also beneficial for the satisfactory growth of the remaining trees, he should use 30% disengagement level for this purpose.

Another important factor is the timing of thinning. Timing will depend on the availability of harvesting and processing technology and market conditions. The forester has to decide for thinning within the framework of these factors. Thinning to wastes may be preferable in many of the cases.

This guideline also does not indicate which trees to remove in a thinning operation. The trees to be retained, however, will depend on the growth rate and quality of residual stand after thinning. The time necessary to reach a specific new mean stand diameter will depend on the trees chosen for thinning and on the ability of the remaining trees to respond to release after thinning. The relationship of crown disengagement also assumes a regular spacing of trees left after thinning. If the residual stand is excessively clumped, some trees will grow as if the stand was quite open.

There is the possibility that the relationship between crown diameter and bole diameter changes after the largest of sample trees (that is, 20 *cm* dbh) are measured. However, there is no indication in the smaller diameter trees that the relationship is anything other than linear.

Conclusion

A preliminary thinning guideline for *A. mangium* stands in Kemasul Forest Reserve in Peninsular Malaysia has been constructed based on a linear regression of crown diameter on bole diameter. The thinning guideline is a family of curves constructed from a single guide curve (zero disengagement) which is derived from the maximum number of trees that can occupy a stand at various stand diameters. The guideline can be used by the forester to determine the number of trees to be retained for certain diameter size and this information will indicate the number of trees to remove in a thinning.

It was found that as *A. mangium* trees mature, they use canopy space more efficiently. This trend indicates that as the stands mature, thinnings, if more than one is planned, should be less intensive. Decreasing GSI trend favours narrower spacing if no thinnings are planned and wider spacing if thinnings are planned.

In using this guideline, it must be realized that it is preliminary and, as plantations become older, more substantive information should be collected and this preliminary guideline replaced. This can be done through the collection of data from permanent plots. More emphasis must be given to record the changing relation of crown diameter to bole diameter as trees respond to thinnings. However, if only one thinning is planned, measurements of crown and bole diameters, after first thinning, may not be essential.

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References

ASHTON, P.M.S., LOWE, J.S. & LARSON, B.C. 1986. *Thinning guidelines for Blue mahoe (Hibiscus elatus).* Tropical Resources Institute - Yale School of Forestry and Environmental Studies, Connecticut, United States of America. 23 pp.

BUTT, G. & SIA, P.C. 1982. Guide to site-species matching in Sarawak. 1. Selected exotic and native plantation species. *Sarawak Forest Department, Forest Research Report.* Sarawak, Malaysia. 61 pp.

DAWKINS, H.C. 1963. Crown diameters: Their relation to bole diameter in tropical forest trees. *Commonwealth Forest Review* 42: 318-333.

HIBBS, D.E. 1984. A growth model for red oak in New England. *Canadian Journal of Forest Research* 14: 250-264.

JOHARI BAHARUDDIN & YUAN, C.T. 1986. Review of plantation experiences in Peninsular Malaysia. Pp. 1 - 26 in *Proceedings of the Ninth Malaysian Forestry Conference.* October 13 - 20, 1986. Kuching, Sarawak.

KAMIS AWANG & MOHD. AMRAN MOHD. GHAZALI. 1984. Initial performance of *Gmelina arborea* Roxb. and *Acacia mangium* Willd. under plantation conditions. *Malaysian Forester* 47(4): 255-262.

LARSON, B.C. & MOHAMMAD NURUZ ZAMAN. 1985. Thinning guidelines for teak (*Tectona grandis*). *Malaysian Forester* 48(4): 288 - 297.

NIK MUHAMAD MAJID & KAMARUZAMAN JUSOFF. 1986. The effects of clearing and continuous cultivation on the physical properties of upland forest soils. Pp. 217-293 in Kamis Awang, Yusuf Hadi, Nik Muhamad Majid and Shukri Mohd. (Eds.) *Proceedings of regional workshop on impact of man's activities on tropical upland forest ecosystem.* February 3- 6, 1986. Universiti Pertanian Malaysia, Serdang, Selangor.

RAY, A.A. 1982. *SAS User's guide.* Statistical Analysis System Institute, Cary, North Carolina, United States of America. 172 pp.

SURI, S.K. 1975. Quantitative thinning model with particular reference to sal forests of Madhya Pradesh. *Indian Forester* 101 (1): 80-89.