PERFORMANCE OF *SHOREA TRAPEZIFOLIA* (THWAITES) ASHTON SEEDLINGS GROWING IN DIFFERENT LIGHT REGIMES

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ASHTON, P. M. S. & De ZOYSA, N. D. 1989. Performance of *Shorea trapezifolia* (Thwaites) Ashton seedlings growing in different light regimes. Fruits were collected from four parent trees of *Shorea trapezifolia* (Thwaites) Ash. in wet evergreen rain forest of southwest Sri Lanka. They were planted in block design with two light treatments (partial shade 1000 μmols $m^{-2}s^{-1}$; full sun 2000 μmol $m^{-2}s^{-1}$). Measurements were made over a two year period.

Seedlings in partial shade grew significantly taller than those in full sun. Significant height differences also exist between seedlings of differing parent trees. Seedlings showed no difference in number of leaves between partial shade and sun or between parent trees. Taller seedlings had more leaves than shorter seedlings irrespective of light treatment. Rate of flushing of seedlings growing in different light regimes was found to be approximately the same. Flushing was correlated to age and an age prediction table was constructed.

These results are proposed as a basis for a method of evaluating *Shorea* advanced regeneration for use in forest management.

Key words: Advanced regeneration - age - growth - height-indices - leaves - *Shorea* sp. - Sri Lanka - vigour

Introduction

New crops of commercial timber trees in south and southeast Asia depend on advance regeneration for their establishment. Advanced regeneration is defined as natural seedlings, sprouts or coppice that appear before any special measures are undertaken to establish another stand of trees (Smith 1986).

Surveys have been done to evaluate the potential of advance regeneration for producing a future stand. Most of these methods have been developed for *Shorea* species in Malaysia (Wyatt-Smith 1963, Forest Department Peninsular Malaysia 1975). These methods have tended to correlate the frequency and distribution of advanced regeneration in sample quadrats (of varying size depending on regeneration size), to a desired future stocking level. They have favoured these measures because of their simple and easy application. This has been the only way to evaluate whether regeneration is adequate for development of a future stand; it may now be possible to consider other measures such as size, vigour, and age which can also be used as predictors of future regeneration survival and growth. In order to construct a more accurate survey technique, seedling trials were carried out to evaluate these characteristics.

This study examined height, number of leaves and number of internodes as possible measures of size, vigour and age respectively. Measurements were made on seedlings of *Shorea trapezifolia* (Thwaites) Ashton growing in nursery conditions.

S. trapezifolia of section Doona (Dipterocarpaceae) was studied because of its importance as a commercial timber in Sri Lanka and because of its dominance in the Mesua-Doona forest type of the lowland wet zone (de Rosayro 1942).

From personal observations, natural seedling populations of *S. trapezifolia* grow best under conditions of partial shade. These conditions can exist along edges of closed canopied forest, along skid trails, and within logged forest that has been heavily thinned, perhaps removing an estimated 50% of the overstorey basal area. In large openings exposed to full sun, many seedlings appear to grow poorly. These seedlings show little height growth and have chlorotic foliage. Differences in growth performance need not only be because of light effects. Reasons could also be attributed to other microclimatic (relative humidity), edaphic (fertility, moisture) and biotic (mycorrhiza, herbivory) factors.

For this study we hypothesise that light is the main variable effecting growth performance of *S. trapezifolia* seedlings.

Methods

The study was done at the field station in the Sinharaja Man and the Biosphere Forest Reserve in southwest Sri Lanka (latitude 6°N, longitude 80°E). This lowland tropical rain forest has been described by Gunatilleke and Gunatilleke (1981, 1985). The climate is aseasonal, with annual rainfall of between 3500-5000 *mm* and an average temperature of 27°*C*.

Seeds were collected from four parent trees in August 1985. Two hundred seeds from each parent were planted in a nursery at 10 *cm* spacing. To test the observations half of the seeds were placed in a partial shade treatment using coir netting that reduced light intensity but did not alter quality; the other half were placed in a full sun treatment. In both treatments forest top soil with a litter covering was used. At midday, under full sun, light readings were recorded as 1000 μmols m^{-2} s^{-1} (50% shade) and 2000 μmols m^{-2} s^{-1} for the partial shade and full sun treatments, respectively. Measurements were made at intervals over a two year period on seedling height, number of leaves, and number of internodes.

Mean data has been plotted to illustrate the diferences in variation between height, number of internodes, and number of leaves over time. Using data from the individual observations a straight line was fitted by least squares regression (Table 1, Figures 1-3). When doing regression analysis autocorrelation is frequently a problem with data from a time series. The Durban-Watson test revealed no significant effect from autocorrelation in this study.

Table 1. Linear regression statistics of seedlings growing in partial shade and full sun (regressions) are for height, number of leaves and number of internodes of seedlings plotted against time from germination)

	Intercept	Slope	r	Significance
Partial shade				
Height	0.8621	0.0730	.9934	$p = < 10^{-6}$
Leaves	-2. 6183	0.0576	.9806	p = .00009
Internodes	1.5872	0.0145	.9829	p = .00007
Full sun				
Height	1.4623	0.0503	.9725	p = .00005
Leaves	-1.5305	0.0427	.9460	p = .00126
Internodes	1.6266	0.0134	.9678	p = .00035

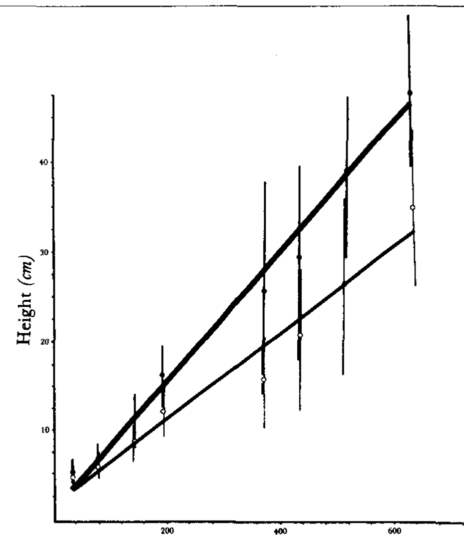

Figure 1. The increase in seedling mean height (X) for partial shade and full sun light treatments over time from germination [seedling means are bound by their standard deviations (• = X for partial shade treatment; o = X for full sun treatment; same notations for all figures)]

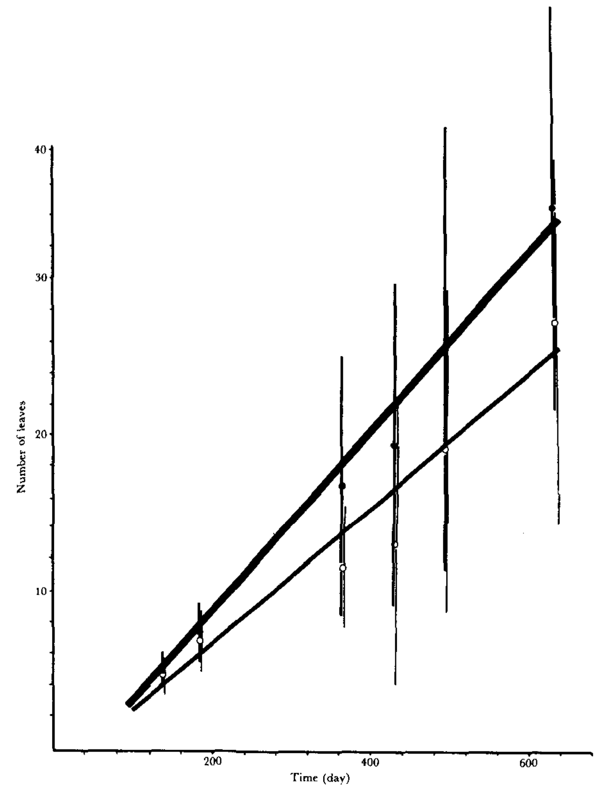

Figure 2. The increase in seedling mean number of leaves ($\bar{X}$) for partial shade and full sun light treatments over time from germination [seedling means are bound by their standard deviations]

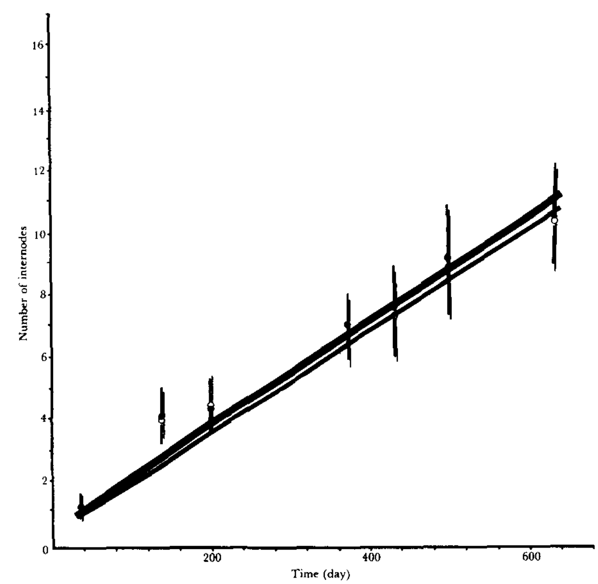

Figure 3. The increase in seedling mean number of internodes ($\bar{X}$) for the partial shade and full sun light treatments over time from germination [seedling means are bound by their standard deviations]

Mixed model nested ANOVA's have also been calculated to find the significance, if any, of between group (partial shade *vs.* full sun treatments), and between subgroup variation (seedlings from four different parent trees), as compared to within group variation. This was done for all three variables and is shown in Table 2.

Table 2. Mixed model nested analysis of variance (ANOVA) for seedlings measured on day 630 for height, number of leaves and number of internodes (seedlings were grown from four parent trees and in two light treatments)

Measure	Significance	Light treatments			
		Sun (n= 105)		Shade (n= 133)	
		X	S	X	S
Internodes	ns	10.29	(0.36)	10.53	(0.53)
Leaves	ns	32.89	(4.18)	37.19	(5.39)
Height	**	38.08	(6.22)	49.28	(6.86)

Measure	Significance	Parent tree treatments							
		Tree 1 (n = 36)		Tree 2 (n = 85)		Tree 3 (n = 52)		Tree 4 (n = 65)	
		X	S	X	S	X	S	X	S
Internodes	ns	10.42	(0.78)	10.55	(0.68)	10.52	(0.22)	10.18	(0.41)
Leaves	ns	30.58	(8.15)	39.68	(7.05)	34.50	(7.73)	32.80	(4.48)
Height	***	39.00	(6.14)	47.74	(7.45)	45.25	(1.74)	42.11	(5.58)

n = Number of seedlings
X = Mean
S = Standard error

Results and discussion

Height

In the case of height, there are significant differences between seedlings because of different light treatments and because of parent tree genotype. Measures are higher for the partial shade treatment. As would be expected from natural seedling populations, the variance for both treatments is large, perhaps because parent trees provide only half the known genotypic difference and/or because of competition for space between seedlings growing in the same environment.

Height has been a measure regularly used by foresters for the construction of species specific indices that evaluate site suitability for trees (Clutter *et al.* 1983). Though there are many differences, we have used some of the same relationships at the seedling level. With this information height can be used to characterize size of seedlings. Where seedlings are of the same age, large sized individuals have shown better past growth than their smaller cohorts. Past growth condition of a seedling can therefore be evaluated by comparing its height with others of equal age.

Leaf number

It might be hypothesized that because of less exposure to environmental extremes of wind, rain and sun, leaves are retained longer in the partial shade treatment and, therefore, seedling leaf number should be higher than those in full sun. An ANOVA showed no significant difference between the two light treatments for the number of leaves on seedlings (Table 2). Reasons for this might be due to the very large variation shown between seedlings within the treatments. This perhaps indicates that competition between individuals from self thinning hides the smaller difference that might exist because of light. Both the size of variation within the treatments and the difference that might be attributed to light are illustrated in Figure 2.

A loose fitting relationship exists between seedling height and leaf number; taller individuals have more leaves than smaller ones of the same age, irrespective of the different light or parent tree treatments (Figure 4). The loose fit can be attributed to the wide variation in leaf number for a given height. Previous work has shown close relationships between tree stem growth and photosynthetic area (Berlyn 1962, Seymour & Smith 1987). These studies suggest that for each species, individuals with larger crowns have higher increments in bole growth than those with smaller crowns. In this study number of leaves is suggested as a measure of photosynthetic area. The most desirable would of course be total leaf area (J. Wyatt-Smith personal communication). The leaf number can used to gauge an individuals vigour vhen in competition with others. Seedlings with more leaves but of the same height as others are assumed to have more vigour and, therefore, are predicted to have better current and future growth. This is illustrated in Figure 4 where seedlings can have many more leaves but are of the same height as others.

This relationship fails if leaf size varies depending upon the environment the seedling is growing in or below ground measures (rootstock size, sprouting capability) do not reflect the above ground measures (leaf number) of seedling vigour. For example, seedlings of some species, that currently have few leaves compared with their cohorts, have the capacity to respond to a favourable change in growing condition by sprouting new growth from the rootstock. This ability to sprout provides a 'second chance' to survive and grow for individuals that ordinarily would probably have died in the self thinning process. Species with these attributes cannot be gauged for vigour based only on above ground measures.

For *S. trapezifolia* the relationship holds because leaf size does not vary noticeably with environment and because of seedling inability to sprout or coppice. This means that seedlings or saplings below a certain 'critical' limit (leaf number) have a reduced ability to respond to a favourable change in the microenvironment condition. For such species, future growth can be better predicted from above ground measures of current vigour.

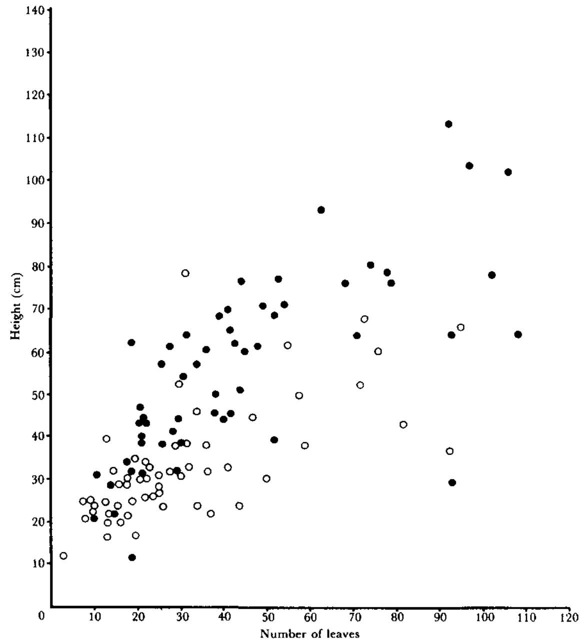

Figure 4. The relationship between seedling height and leaf number for both partial shade and full sun light treatments (data have been pooled from Tree No. 1 & 2)

Internodes

There is no difference in number of internodes between the light or parent tree treatments over time, and the variances are small compared to leaf number and height (Table 2 and Figure 3). This suggests that although rate of flushing is the same between seedlings of different heights their internode lengths must vary: tall seedlings must have longer internodes than short seedlings.. Rate of plant flushing has been found in most previous studies to be related to the total growing environment (McGee 1968, Foster & Farmer 1970, Phares 1971, Farmer 1975). This can include such important factors as light quantity and quality, soil moisture, relative humidity and soil nutrient status. Other studies by Doley (1970), Larson and Whitemore (1970) , and Larson (1980) indicate that flushing can be most closely related to water availability.

Our data supports the latter hypothesis and suggests that rate of flushing in aseasonal everwet climates is little affected by other conditions. Likewise, in the case of seasonal climates where droughts occur and moisture is therefore periodically limiting, flushing rate should be discontinuous and changing. This flushing phenomenon need not necessarily apply to all species in aseasonal climates, but it seems to describe *S. trapezifolia* seedlings growing in light conditions >50% of full sunlight. For *S. trapezifolia* seedlings growing in <50% of full sunlight flushing rate is likely to decrease because at a critical light level seedling growth is retarded. Knowing that flushing rate (number of internodes/per unit time) is relatively independent of environment for *S. trapezifolia* growing in the brighter light regimes allows us to construct an age table based on the fitted regression line for pooled data from both treatments (Table 3). Because of the large variance age can only be estimated approximately.

Table 3. Age of seedlings as predicted from number of internodes counted [age is predicted from a straight line regression of pooled data from full sun and partial shade light treatments (intercept = 1.6069; slope = 0.0139)]

Number of internodes	Age (*y*)
4	0.50
7	1.00
9	1.50
12	2.00
	Projected age (*y*)
14	2.50
17	3.00

Measurements for internodes were discarded if no terminal shoot was evident on the plant. This was done to avoid herbivory and disease confusing the age-internode relationship. Information on internodes together with knowledge that height and number of leaves are good measures of past, current and possibly future growth performance, can be directly used in the development and use of advance regeneration indices (Ashton in preparation).

Conclusions

Seedlings of *S. trapezifolia* in the partial shade treatment grew significantly taller than those in full sun. Height was also significantly different between seedlings of different parent trees. No significant difference in either seedling leaf number or flushing rate could be found between light treatments or parent trees. Findings for these seedlings suggest height can be used to evaluate past growth, leaf number can be used to evaluate current growth and possibly predict future growth, and internodes can be counted to estimate the approximate age. It is important to note that when the forester uses the age table for *S. trapezifolia*, plants with terminal shoot dieback should be discarded.

Further studies under nursery conditions are needed to evaluate *S. trapezifolia* growth performance in light conditions <50% of full sun. Findings from this study can also be used to compare with field surveys of seedlings growing on the forest floor in different environments.

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