MANAGING SHOOT BORERS BY USING *ACACIA AURICULIFORMIS* AS A NURSE CROP FOR ESTABLISHING MAHOGANY SEEDLINGS

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ABSTRACT

The main factor, which has limited cultivation of mahogany, *Swietenia macrophylla*, King (Meliaceae: Swietenoideae) is damage by shoot borers (*Hypsipyla* spp.). Attack results in destruction of the apical shoot, causing branching of the tree, and significantly reducing the economic value of the timber. Although shoot borers have been intensively investigated no consistently effective control methods currently exist. However, some observations suggested that overhead shade provided by a nurse crop during early growing phase of mahogany seedlings might reduce the attack. Yet much of the information available is anecdotal. Although shade reduces attack by shoot borer, mahogany being a light demander, shade also may reduce the growth of seedlings. Hence a study was designed to assess the effect of different light availability on survival, growth and attack by shoot borers under different light conditions. This study was done from 1997-99 at three sites, two from Rambukkana and one from Mirigama under a nurse crop *Acacia auriculiformis* A. Cunn. Ex Benth. (Mimosaceae). Each site composed of three plots with different canopy openings of high, medium and low shade obtained by pruning of *Acacia* trees. Within pruned area (5 m x 5 m), 18 mahogany seedlings of similar origin, age and height were planted.

The Photosynthetically Active Radiation (PAR) reaching each plot was measured using a data logger with a PAR sensor. Pattern of flushing and growth of mahogany seedlings were recorded monthly. Number of shoot borer attacks per plant was recorded 14 months after planting. Relative PAR values in the three sites varied from 21.6 ± 1.1 % in the higher shade gap to 93.1 ± 3.3 % in the lower shade gap. Seedling survival a year after planting did not show significant differences between light regimes. Under low shade, seedling height was 57.4 % greater than under high shade, and was highly significant in ANOVA (d.f.=2, P=0.0001). The root collar diameter under low shade was 1.3 ± 0.09 cm, while that under high shade was 0.8 ± 0.04 cm (d.f.=2, P=0.0001). Seasonal variation in shoot phenology showed a similar trend in all shade regimes, with increased flushing observed during the rainy period, but shoot remained dormant during the dry spell. Number of attacks per plant in low shade plot was 112 times higher than under high shade (d.f.=2, P=0.0001). Observations of this study show that high shade (20-30 % PAR) reduces growth of mahogany even though it might reduce attack by shoot borer and the best rapprochement to manage shoot borer problem while achieving reasonably good growth would be medium shade conditions (45-50 % PAR).

INTRODUCTION

Big-leaf mahogany, *Swietenia macrophylla* King (Meliaceae: Swietenoideae) is a highly valued timber particularly for its colour, workability and durability (Mayhew and Newton, 1998). Due to the higher demand for timber however, extensive logging throughout the tropics including Sri Lanka led to the depletion in populations making it necessary for establishment of new plantations. The main factor, which has limited cultivation of mahogany in plantations, is attack by shoot boring moths (*Hypsipyla* spp.) (Newton *et al.*, 1993). The moth larva destroys the growing point of young tree resulting in branching and forking which lower the economic value of the timber (Yamazaki *et al.*, 1992). A number of attempts have been used to reduce the impact of shoot-borer, but many of these have failed. Thus, guidelines, which give effective and consistent shoot borer management methods, are not available (Mahroof, 1999).

Further, it has been suggested that planting mahogany under the shade of a nurse crop may be a possible silvicultural method to reduce shoot-borer damage during plantation establishment (Whitmore, 1978; Hauxwell *et al.*, in press). However, existing evidence was largely anecdotal with trials often un-replicated and results have been inconsistent. Several mechanisms have been proposed with respect to how light availability may affect susceptibility of mahogany to attack by shoot borer larvae (Lamb, 1968). However, the influence of light on the growth of mahogany has not been investigated in any detail. There are few data on the effects of light and nurse crops on the growth and morphology of mahogany to confirm or deny these phenomena (Hauxwell *et al.*, in press; Mahroof *et al.*, in press). In order to develop a practical control method for planting mahogany under a nurse crop, it is therefore necessary to determine the optimum light regime which enables to reduce attack, on the other hand giving acceptable yield of plant growth.

This objective was therefore achieved by creating various degrees of light conditions by pruning a nurse tree *Acacia auriculiformis* A. Cunn. Ex Benth (Mimosaceae), and planting mahogany seedlings underneath these openings. The hypotheses tested were that under high light availability, mahogany: (i) grows more rapidly by producing longer and thicker shoots, (ii) produces a higher number of shoots though increased branching, (iii) flushes more often and (iv) produces more tissues to make plants susceptible to the shoot borer attack.

MATERIALS AND METHODS

Site description

Establishment of mahogany under *Acacia* was carried out in the wet and the intermediate zones of Sri Lanka. The climate at all study sites is seasonal, receiving precipitation from the Northeast and Southwest monsoons and convectional rains between the monsoon periods. The first and the second sites under *Acacia* were established in December, 1997 and April, 1998 respectively, at Nattiyapana, Mawanella, at 116 m above M.S.L. The mean annual rainfall of the location is 1700-2300 mm, average temperature ranges between 25-30° C and the topography of the study sites is of undulating hills with a slope of 30-35°. The two sites were located 1.5 km apart and were separated by a valley.

The plantations had been established in 1989 by the Forest Department and the trees in the area were spaced 2.5 m x 2.5 m apart (Range Forest Office, Rambukkana, Sri Lanka). The third site was established in February, 1998 at Mirigama, Gampaha, at 60 m above M.S.L. under *Acacia* established in 1991 by the Forest Department. The mean annual rainfall, maximum and minimum temperatures of this location are 2650 mm, 35.7° C and 29° C respectively. The mean annual relative humidity of the area is 90%.

Shade treatments

Three different canopy openings were created in each trial, and they were categorised as high, medium and low shade. These were created either by removing branches or entire trees of *Acacia*. Under the different canopy pruning treatments, a 5 m x 5 m plot was demarcated to plant mahogany seedlings. The different canopy pruning treatments were created as follows;

(i) high shaded gap, by removing the central *Acacia* tree within the 5 m x 5 m plot area to ground level
(ii) medium shaded gap, by cutting the central tree within the plot to ground level, and pruning the six trees around the center of the plot to breast height
(iii) low shaded gap, by cutting the central tree and the six trees around the center of plot to ground level, and pruning the nine trees surrounding them to breast height.

Plant sources and planting pattern

Six-month-old *S. macrophylla* seedlings were obtained from the Forest Department nursery in the Kegalle division. These seedlings had been raised from seeds collected from the Marukwathura mahogany plantation established in 1926 (Sandom and Thayaparan, 1995) at Kegalle. Seedlings of similar height (28-32 cm) were selected for planting. Eighteen plants were planted in each plot under different shade regimes on a hexagonal grid with plants exactly 1 m apart. Plant arrays were oriented by compass points and numbered individually starting from the first plant in the northern corner in all cases. Numbered aluminium tags were used for labelling. Seedlings were watered once a week by hand, during dry periods. Plots were weeded manually once a month. Gaps were re-pruned 10-12 months after planting to maintain the degree of canopy opening throughout the experimental period.

Measurements of PAR under different plots

The canopy openings were initially classified by visual observation to give a range of openings and subsequently measured by a light sensor. The Photosynthetically active radiation (PAR) between 400-700 nm in all plots were measured using a data logger with PAR sensor (SDL 2512, 15450, version DH / MM 63, Skye Instruments Ltd., UK) following the method of Rich *et al.* (1993). PAR of a shade opening was calculated as the ratio of PAR associated with a plot to an open area. The mean for each plot was calculated as a percentage mean over the seven-hour period of recording.

Measurement of growth parameters

Seedling survival was recorded monthly after planting in all plots. Twelve months after planting, the proportion of surviving seedlings was calculated. Plant height was measured for seedlings to the nearest 0.5 cm. The root collar of each seedling was marked with paint and the height was measured from the root collar to the tip of the apical shoot. Height measurements were carried out monthly starting from the date of planting to April, 1999. Subsequently, height increment was calculated 51 weeks after planting. Measurement of root collar diameter was made (to the nearest mm using a vernier caliper) at seven and ten months after planting.

The number of live healthy shoots on each seedling was counted and recorded every month until the end of January 1999 before shoot-borer damage was observed in the field. The length of the dominant shoot was measured to the nearest 0.5 cm from the previous growth, indicated by thickening of bark to the tip of the apical shoot. Subsequently, the number of shoots and length of the dominant shoot at 48 weeks after planting were used in analyses.

The various stages of the shoot growth of mahogany seedlings were classified into one of four categories from the beginning of flushing to the mature stage of the shoot. Phenology class 1 was used to describe the very early stage of growth where the shoot was tender and flexible, pink to pale red in colour and the leaves were not fully expanded. Phenology class 2 included shoots which were tender and flexible but green in colour; some leaves were fully expanded while the uppermost leaves were just emerging, the upper surface of the leaf was green, and the lower surface of the leaf was pink to pale red. Phenology class 3 was used to describe the later stage of shoot flush in which shoot elongation was completed, the shoot was inflexible and the leaves were fully expanded and pale green in colour but still soft. Phenology class 4 included non-flush shoots, where the shoot was mature, and the leaves were stiff and dark green in colour.

Shoot borer attack

Attack by shoot borer on mahogany seedlings was assessed 54 weeks after planting although damage was first observed 48 weeks after planting. Each individual tree was assessed for the presence of shoot-borer attack and subsequently the incidence (proportion of trees attacked in each treatment) of shoot borer attack was calculated. Assessments of attack were made by visual inspection of each plant, indicated by the presence of fresh frass.

Statistical analyses

Data were analysed by analysis of variance (ANOVA) procedure using SAS (1986) to detect statistically significant differences in response to shade treatments and site effects. Multiple comparisons among means of different light treatments were carried out using Duncan's new multiple range test at the P level of ≤ 0.05. Owing to some seedling mortality over the period of the study, height, root collar diameter, number of shoots and dominant shoot height data were subjected to an unbalanced ANOVA, using the GLM procedure of SAS (Ray, 1982). Data for survival were transformed to natural log, shoot counts were transformed to $\sqrt{Y+1}$, and proportion of attack was transformed into Arcsin $\sqrt{Y}$ prior to analysis. Graphs were plotted using Excel (Windows 98, version 7.0, Microsoft Corporation, USA). Analyses used transformed data where appropriate, but the graphs were plotted with raw data.

RESULTS

PAR values under different plots

Table 1 shows the PAR in each shade treatment under *Acacia*. The mean percent PAR of high shade plots of the three sites ranged from 25.6 to 54.4, that in medium shade plots ranged from 42.3 to 56.0, and that under low shade ranged from 55.9 to 93.1 μ mol m $^{-2}$ s^{-1}. Significant effects of shade treatments were found on PAR (d.f. = 2, F = 25.8, P = 0.005; ANOVA). Significant site effects were also found under the natural shade regimes of *Acacia* (d.f. = 2, F = 15.5, P = 0.01).

Table 1. Mean percentage PAR of plots under natural shade regimes of *Acacia* measured from 22/07/98 to 27/08/98. Values are means SE, n = 12; percentages were calculated in relation to PAR recorded in an open area nearby.

Treatments	Site 1	Site 2	Site 3
High shade	25.6 2.9	21.6 1.1	54.4 12.1
Medium shade	43.4 3.8	42.3 0.6	56.0 7.0
Low shade	66.0 3.4	55.9 0.8	93.1 3.3

Seedling survival

Overall seedling mortality one year after planting was low and was not significantly different under different shade treatments (d.f. = 2, F = 0.17, P > 0.05). Proportion of seedling survival was 88.8 ± 16.6 (n=47) under high shade, 88.9 ± 12.9 (n=48) under medium shade, and 83.3 ± 6.8 (n=41) under low shade.

Plant height and root collar diameter

The height of seedlings at the time of planting was not significantly different between treatments or sites. The effect of shade on final height of mahogany seedlings at 51 weeks after planting was highly significant in ANOVA (d.f.= 2, F = 25.81, P < 0.0001). Under low shade, height was 57.4 % greater than under high shade (Table 2). Height increment was approximately 2.5 times greater in low shade than in high shade, and differences between treatments were highly significant (d.f. = 2, F = 27.23, P < 0.0001). The analysis of variance showed no significant site effects for final height (d.f. = 2, F = 2.42, P > 0.05), but significant site effects were observed for height increment (d.f. = 2, F = 4.94, P < 0.05).

Table 2. Mean final height and height increment of seedlings of mahogany seedlings 51 weeks after planting under three different degrees of shade at three sites. Measurements are given to the nearest cm. Values presented are means ± se, n = 18. FH; Final Height, HI; Height Increment.

Treatments	Site 1		Site 2		Site 3	
	FH (cm)	HI (cm)	FH (cm)	HI (cm)	FH (cm)	HI (cm)
High shade	40 ± 3	14 ± 2	59 ± 16	27 ± 16	48 ± 3	14 ± 3
Medium shade	69 ± 6	39 ± 6	86 ± 15	54 ± 15	40 ± 2	7 ± 1
Low shade	112 ± 14	80 ± 12	90 ± 8	59 ± 7	48 ± 6	14 ± 5

Mahogany seedlings established in gaps under *Acacia* showed significantly greater root collar diameter and root collar diameter increment under the lower shade treatment by 51 weeks after planting (d.f = 2, F = 32.5, P = 0.0001; d.f = 2, F = 64.3, P = 0.0001). There were also significant site effects (root collar diameter, d.f = 2, F = 15.2, P = 0.0001; root collar diameter increment, d.f = 2, F = 21.6, P = 0.0001), with overall diameter reduced in all plots at site 3. The mean root collar diameter and standard error of plants under high shade regime were 0.8 ±0.04 cm, while those under low shade were 1.3 ±0.09 cm, an order of 62 % greater root collar diameter under low shade.

Number of shoots and dominant shoot height

No significant effect of light on shoot number was recorded (d.f. = 2, F = 1.00, P > 0.05). Also, no significant site effects were found under *Acacia* (d.f. = 2, F = 1.42, P > 0.05). However for dominant shoot height treatment means ranged between 6.5 - 10.0 cm in high and low shade gaps at 40 weeks after planting. Highly significant shade treatment effect (d.f. = 2, F = 12.24, P = 0.0001) was observed with longer shoot in the low shade. Significant site effects (d.f. = 2, F = 12.05, P = 0.0001) were observed in the analysis of variance, with overall height reduced in all plots at site 3.

Phenology

The sites under *Acacia* had a record of a total of 3232 mm rain at sites 1 and 2 in 16 months and 2404 mm in 13 months at site 3. The amount of monthly rainfall ranged from 0-441 mm, with no rains in February 1998, and the peak rainfall in May 1998 at site 1 and 2, corresponding to the Northeast monsoon. The rainfall at site 3 ranged from 90-412 mm, receiving highest rainfall in the Northeast monsoon period. The stage of shoot phenology was related to the amount of rainfall received at the experimental sites. The mean phenology of seedlings was lower (i.e. saplings were flushing) with high rainfall and higher (i.e. saplings not flushing) when lower rainfall was recorded (Figs 1, 2 and 3). The seasonal variation in shoot phenology showed a similar pattern at all three sites. However, no significant shade treatment effects were observed for phenology (ANOVA; d.f. = 2, F = 0.01, P > 0.05).

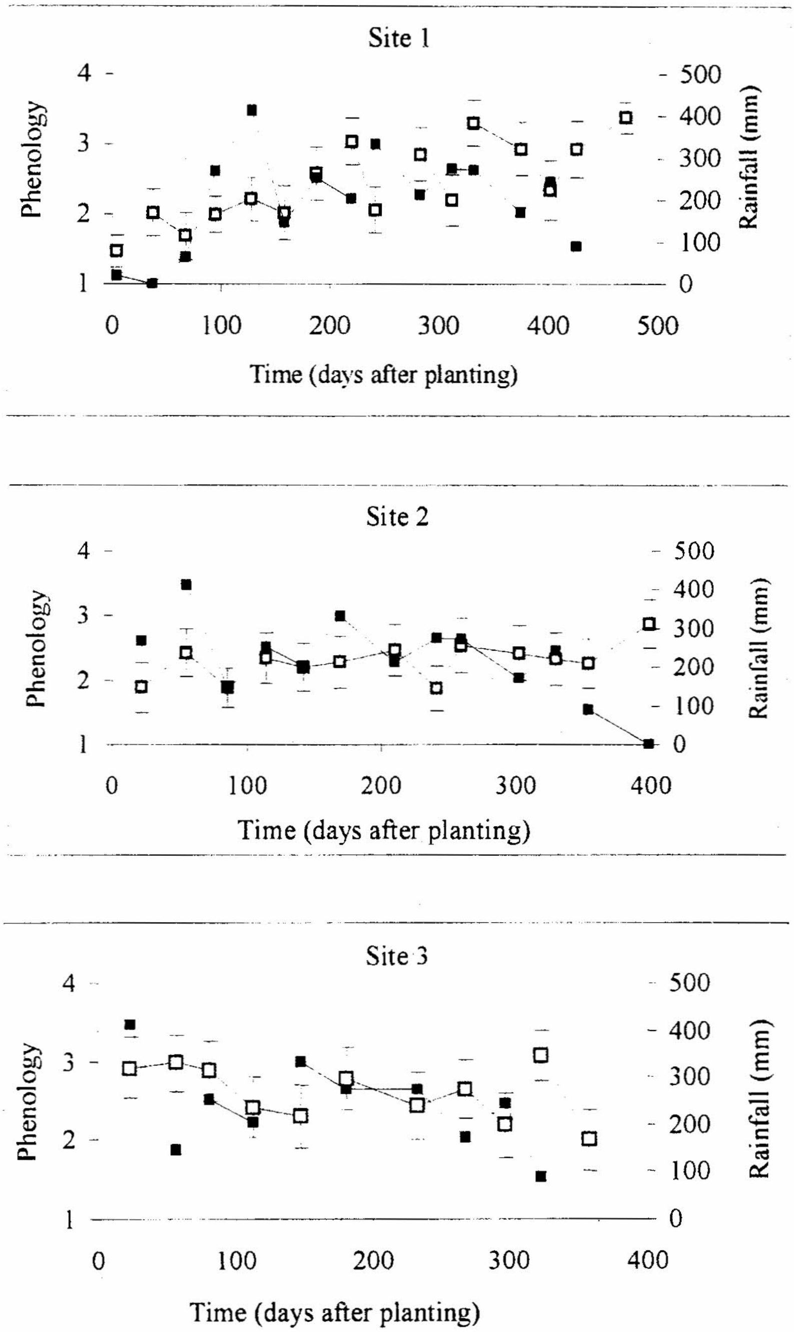

Fig 1, 2 and 3. The pattern of mean phenology of mahogany seedlings under different canopy gap openings. Symbols: (a) open square: mean phenology overtime, (b) closed square: monthly rainfall pattern. Phenology is assessed on a scale of 1-4. Values presented are means at each time point ± SE, n=180 for phenology. Rainfall data obtained from the Department of Agriculture, Sri Lanka

Shoot borer damage

The incidence of attack (proportion of trees attacked) in the low shade treatment was 31 % higher than in high shade plots. Analysis of variance showed that the incidence of damage was significantly higher in the low shade treatments (d.f. = 2, F = 8.57, P = 0.0003). No significant differences were observed between sites under *Acacia*. Fig. 4 shows the proportion of shoot borer attack under different shade treatments.

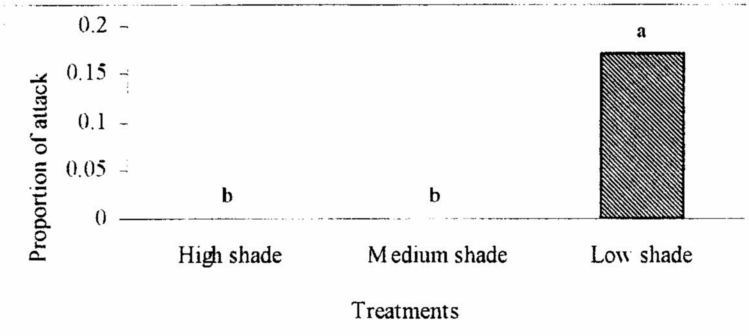

Fig. 4. The effect of shade on mean proportion of attack by shoot borer at 3 sites. Measurements were taken at 54 weeks after planting. Values presented are treatment means produced by ANOVA, DNMRT. n=41 for High and low shade, n= 48 for medium shade. Treatments with the same letter (a or b) are not significantly different from each other (P<0.05). Analysis was carried out on Arcsin √Y data.

DISCUSSION

Results demonstrated that mahogany seedlings had higher survival in all light treatments. In the experiments described here, significant height growth differences were observed between light treatments. Seedlings under low shade were approximately 50 % taller than those under high shade. Similar observations were made by Ashton *et al.* (1997, 1998) in Sri Lanka, who found that *S. macrophylla* was significantly taller in 12 m-wide strip openings than under closed understorey treatments. Smith-Wenban (1993) reported that with full light and abundant moisture *S. macrophylla* seedlings can reach a height of almost 50-100 cm within six months, growing much less under medium light (15 cm), although under such conditions they may persist for many months, growing very slowly. The growth of young *S. macrophylla* seedlings has been thought to be directly proportional to the degree of canopy opening (Lamb, 1966; Bauer, 1991; Gerhardt, 1996) a suggestion potentially supported by the current results.

Apparently, the length of the dominant shoot was greatest in higher PAR values. Lamb (1966) reported that under complete overhead light with side protection, leading shoots might grow at a rate of 30 cm length in 2-3 weeks. No effects of shade on branching were observed. Largest root collar diameter was recorded in the low shade treatments. There is some evidence to support these findings (Stevenson, 1941). *S. macrophylla* had the largest root collar diameter in clear cut opening (2-3 cm) than under planting (1 cm) after 2 years of planting (Ashton, *et al.*, 1998). On the basis of more than a year's observations, flushing of *S. macrophylla* coincided clearly with the onset of rainfall. The reports of Grijpma and Gara (1970) indicate that flushing of trees corresponded with the beginning of the rainy season.

Results of shoot borer damage indicated that a higher incidence of attack was observed under the low shade treatment. Information gained from work described by other authors (Grijpma and Gara, 1970; Howard, 1991; Yamazaki *et al.*, 1992; Newton *et al.*, 1998) are also consistent with the observations of higher incidence of attack in seedlings with new shoots, fresh foliage and taller stems. This suggests that open-grown trees with new growth and longer shoots are more readily infested than shaded stems.

CONCLUSIONS

1. *S. macrophylla* grows more rapidly in the field under high light availability (more than 60 % PAR) by producing longer and thicker shoots providing more susceptible loci for shoot borer attack.
2. The incidence of attack by shoot borer is significantly higher for seedlings grown under high light availability (more than 60 % PAR).
3. An optimum light amount of 40-45 % PAR during initial establishment period could reduce the attack considerably and also enable the plants to attain approximately 50 cm of height growth per year.

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