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STANDARDISATION OF PLANTATION TECHNIQUES OF MAHOGANY WITH PARTICULAR REFERENCE TO SOIL NUTRITION AND SHOOT BORER INCIDENCE

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STANDARDISATION OF PLANTATION TECHNIQUES OF MAHOGANY WITH PARTICULAR REFERENCE TO SOIL NUTRITION AND SHOOT BORER INCIDENCE

(Final report of the project KFRI 396/03)

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July 2012

PROJECT PROPOSAL

1. Project code	: KFRI 396/03
2. Title of the project	: Standardisation of nursery and plantation techniques of mahogany with particular reference to soil nutrition and shoot borer incidence
3. Objectives	: 1. To conduct manuring trials in pots and nursery beds to get tall healthy seedlings 2. To standardise management practices (spacing and manurial regimes) that can boost biomass production as well as reduce shoot borer incidence 3. To ascertain the comparative resistance of the two species of mahogany, namely, *Swietenia macrophylla* and *S. mahogany* to the shoot borer attack
4. Date of commencement	: April 2003
5. Duration	: 5 +1 year
6. Funding agency	: KFRI Plan Grant
7. Investigators	: Thomas P. Thomas K. Mohanadas P. Rugmini

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ABSTRACT

Mahogany is one of the most valuable timbers of the tropics. In spite of excellent growth potential and adaptability to a wide range of conditions including degraded sites, the tree is susceptible to shoot borer attack by Hypsipyla species. Trials conducted in many countries to control the pest met with little success. Plantation trials with *Swietenia macrophylla* in Kerala, though on a small scale, also met with the same fate. An experiment was hence conducted with different spacing and manuring levels at the Field Research Centre of the Institute at Velupadam to ascertain the benefits of these in reducing the attack by the shoot borer and/or encouraging faster recovery after attack. The experiment was laid out in split plot design with spacing as the main plot factor and manuring as the sub plot factor. Two spacing levels of 2x2m and 3x3m were provided and the manuring treatments consisted of cowdung, compost, sterameal and NPK at 3 levels each along with control. Results conclusively proved the benefit of lateral shade provided through closer spacing in improving the growth as also in reducing shoot borer incidence. Manuring did bring about moderate effects only and cowdung at 1.5kg per plant and compost at 300g per plant resulted in better growth as compared to sterameal and NPK application. Another trial was conducted with two species of mahogany, namely, *Swietenia macrophylla* and *S.mahogany* in the same design to ascertain the comparative resistance of these species to *Hypsipyla robusta*. *S.mahogany* was found to be extremely slow growing and with greater susceptibility to the shoot borer when compared with *S.macrophylla*.

GENERAL INTRODUCTION

Trees of the genus Swietenia are commonly named mahogany (Nzokou and Harris, 2002) but other related species such as Khaya (African mahogany), Cedrela (Cedar), Lovoa, Toona, Entandrophragma and Chukrasia are also referred to as mahogany (Newton *et al.*,1993) and all of these are attacked by shoot borers. Most of these species have the potential to reach 30-40 m height and up to 2m diameter at breast height (Pennington and Styles, 1975; Ahmad Zuhaidi *et al.,* 2003) at good sites.

Swietenia macrophylla King, one of the prominent species in the group is widely distributed in India, Pakistan, Bangladesh, Philippines, Indonesia, Java, West Indies, Fiji, New South Wales, Costa Rica, Mexico, Brazil, Ecuador, Peru, Honduras, Central America, Amazon etc., at elevations ranging from sea level to about 1350 m asl with an annual rainfall of 1500- 5000 mm and a temperature regime of 11 to 40^{o}C.

In India, it was originally introduced in 1872 from British Honduras; it was planted chiefly in Southern India at low elevations with 1500 – 5000 mm rainfall and it grows well at elevations from sea level to 900 m asl. It grows well on tropical soils and is considered suitable to the lateritic soil of the West Coast which are poor in nutrients.

In Kerala, it was introduced during 1879-81 in gaps within teak plantations, but was abandoned later due to heavy damage caused by the shoot borer, *Hypsipyla robusta.* It was again tried as under plant in teak plantations during 1886-96 period at a spacing of 15m x 15m but was severely damaged by deer. Underplanting in 6, 10, 30 and 40 year old teak plantations was again attempted but without any success.

Trees planted in 1872 in the Royal Botanic Gardens, Calcutta reached 6.1m height in 12 years. A tree planted in 1873 at Chathumborai, Nilambur reached a height of 29 m and girth of 2.16 m at 35 years and a height 30.5 m and gbh of 2.57 m at 39 years of age representing a mean annual increment of 6.5 cm. Trees planted at Pookode and Edakode near Nilambur were also found to record 5cm mean annual increment.

It is a moderate shade tolerant species and overhead shade in early growth stages have been found to reduce attack by the shoot borer, *Hypsipyla robusta*. Mahogany has been reported to grow well under light shade (Nelson Smith, 1941; Anonymous, 1951; Chinte,1952; Mohanadas, 2000), requires a shade crop in the early stages of development to escape the shoot borer (Anon, 1942) and attacks were less severe under shade than in the open and in unweeded than in weeded stands (Dourojeanni, 1963).

Establishment of mahogany on a plantation scale has been deferred due to its susceptibility to the shoot borer, *Hypsipyla robusta* in several countries (Beeson,1919; Roberts, 1966; Entwistle, 1967; Lamb, 1968; Grijpma, 1971; Morgan and Suratmo, 1976; Vega, 1976; Newton *et al.,* 1993; Mahroof, 1999; Floyd and Hauxwell, 2001). Loss of apical dominance and consequent lateral branching caused by repeated attack decrease the quantity and value of timber (Lamb,1966; Lyhr, 1992; Rodan *et al.,* 1992; Yamazaki *et al.,* 1992; Newton *et al.,* 1993; Mo and Tendon,1995). The cryptic habit and overlapping generations of the shoot borer (Girijpma, 1976; Griffiths, 2001) and the nature of mahogany that produces multiple leaders once the apical shoot is broken are major factors that dissuade the establishment of plantations of mahogany. Chemical control is both economically and environmentally unviable because repeated applications are needed to prevent frequent outbreaks.

Silvicultural interventions include planting vigorous seedlings at good sites, interplanting with suitable species (Siregar and Djaingsastro, 1991; Penafiel and Botengan, 1985) and mixed planting with indigenous tree species (Mohanadas,2000). It is in this context that a field experiment was undertaken to standardise silvicultural techniques that may help in improving the growth of mahogany and also reduce the shoot borer infestation. The major objectives were:

1. To produce tall healthy seedlings in the nursery
2. To standardise management practices such as spacing and manuring that can boost biomass production as well as reduce shoot borer incidence
3. To assess the comparative resistance of the two species of mahogany, namely, *Swietenia macrophylla* and *S. mahogany* to shoot borer attack.

1. NURSERY TRIALS

1.1 INTRODUCTION

Healthy seedlings are the first and foremost consideration while raising plantations of any species. Potting media and its nutrient supplying ability are of prime concern in this respect. Combinations of materials that can provide good aeration and water holding capacity as well as facilitate easy root penetration and proliferation are necessary to ensure optimum growth of seedlings. Different proportions of sand, soil and organic matter provide ideal conditions for plant growth. Potting medium with at least 50% organic matter along with sand and soil are supposed to have low bulk density, good aeration and water holding capacity. Traditional potting medium used in India consist of sand, soil and farm yard manure in 2:1:1 ratio (Rai, 1990).

In India, Annapoorna (2002) tried several combinations of sand, soil, compost, cocopeat, burnt rice husk and charcoal as root trainer medium and found that a mixture of sand, soil and compost in the ratio 4:1:5 produced best overall growth with firm plug formation after 7 months. A mixture of sand and compost in 25:75 ratio produced seedlings with better height growth, but with poor root:shoot ratio. Deoiled neem cake and superphosphate were added in all treatments to provide nutrition. Neem cake is helpful in controlling soil borne pathogenic fungi and pests, particularly nematodes and also in reducing loss of nitrogen (Korah and Shigte, 1968; Schmutterer, 1995). Improved growth of seedlings using decomposed coir pith or cocopeat as a potting medium has been reported in *Swietenia macrophylla* (Woods *et al.,* 1998). Considering the importance of potting medium containing nutrients, different combinations were experimented to select the best combination that yields optimum growth of seedlings.

Swietenia macrophylla, is considered to be shade tolerant to certain extent. Partial shade has been reported to promote growth and help in evading shoot borer infestation (Nelson Smith,1941;Madras,1942; Mahroof *et al*., 2002). Recovery of seedlings after simulated damage by *H. robusta* was also reported to be high under greater shade (Mahroof *et al.,* 2001). A trial with different combinations of potting media was conducted in poly pots as well as in beds to produce tall healthy seedlings. Another trial with different levels of shade was also conducted in the nursery to see the effect of shade on growth of seedlings.

1.2 MATERIALS AND METHODS

The following combinations of potting mixtures were tried in the nursery to boost the growth of seedlings for the production of tall healthy seedlings. Traditional potting medium consisting of sand, soil and cow dung in 2:1:1 ratio was used in the trial. Dried cowdung was mixed with minimum amount of lime and neem cake. This was fortified with the following combinations of nutrients in the respective dosages to make up for possible deficiencies.

1.2.1 Trials in poly pots

Poly pots of 22x18cm were filled almost full with the potting media as already mentioned and added with N, P, K, Mg, Zn and B as supplements. The dosage of mineral nutrients is given in table 1.

Table 1. Dosage of nutrients in different treatments

Treatments	Nutrients (%)					
	N	P_2O_5	K_2O	$MgSO_4$	$ZnSO_4$	BoO_3
T1	0.05	0.05	0.05	0.05	0.005	0.005
T2	0.1	0.1	0.1	0.1	0.005	0.005
T3	0.15	0.15	0.15	0.15	0.005	0.005
T0	-	-	-	-	-	-

n=30

Seedlings raised in trays filled with vermiculite were pricked out after a week when the seedlings developed two leaves. The seedlings were dibbled in polypots containing potting medium with added nutrients. Each treatment was administered in thirty polypots which were incubated for ten days. Seedlings raised in trays were transplanted into these pots and kept in the nursery. Watering was carried out once a day to maintain adequate soil moisture. Height and collar girth were measured at the end of six months.

1.2.2 Trials in nursery beds

Trials were also conducted in nursery beds prepared with the same media of sand, soil and cow dung in 2:1:1 proportion and supplemented with nutrients in the following dosage (Table 2).

Table 2. Dosage of nutrients in different treatments

Treatments	Nutrients (%)					
	N	P_2O_5	K_2O	$MgSO_4$	$ZnSO_4$	BoO_3
T1	0.10	0.10	0.10	0.10	0.005	0.005
T2	0.20	0.20	0.20	0.20	0.005	0.005
T3	0.30	0.30	0.30	0.30	0.005	0.005
T0	-	-	-	-	-	-

n=30

Seedlings in the nursery bed.

Beds of 3m x1m x 0.15m were prepared with potting mixture containing similar proportion of sand, soil and cow dung along with nutrients mentioned in table 2. Four treatments including control were replicated thrice. Seeds of *S.macrophylla* were spread at about 5cm distance and a thin layer of potting mixture sprinkled over it. Height of seedlings were measured at the end of 6 months to assess the impact of treatments on growth of mahogany seedlings.

1.2.3 Shade net trials

Three levels of shade were provided in the nursery by spreading shade nets of different mesh size. Shade levels of 25%, 50% and 75% were provided to poly potted seedlings of both *Swietenia macrophylla* and *S. mahogany* along with control. Observations on height and collar girth of the seedlings were recorded periodically upto 265 days.

1.3 RESULTS AND DISCUSSION

1.3.1 Selection of potting medium for polypots

Effect of manuring on growth of polypotted seedlings of mahogany (*S macrophylla*) is given in table 3.

Table 3. Growth of *S.macrophylla* seedlings in poly pots

Treatment	Height (cm)	Collar girth (cm)
T0	42.25 ± 4.0	3.20 ± 3.5
T1	48.38 ± 4.5	3.29 ± 4.3
T2	62.95 ± 4.2	4.12 ± 4.4
T3	60.31 ± 5.2	3.74 ± 4.0

n=30

Height and collar girth measured at the end of six month's growth showed that treatment T2 with 0.10 % each of N, P_2O_5, K_2O and $MgSO_4$ and 0.005% each of $ZnSO_4$ and BoO_3 supported maximum growth with seedlings attaining 62.95 cm height with 4.12 cm collar girth. Sturdiness quotient calculated by dividing height by collar diameter was found to be 15.28 which was the highest among all the treatments indicating that this treatment can be adopted to obtain tall healthy seedlings in polypots in the nursery.

1.3.2 Selection of best medium for nursery beds

Growth of seedlings in nursery beds as influenced by manurial treatments is given in table 4. Height and collar girth measured at the end of six month's growth indicated that treatment T2, which supplied 0.20% each of N, P_2O_5, K_2O and $MgSO_4$ along with 0.005% each of $ZnSO_4$ and BoO_3 produced maximum height growth. The seedlings on an average recorded 69cm height and 4.5cm collar girth. The next higher dosage of nutrients did not cause any appreciable change over the second treatment.

Table 4. Growth of *S.macrophylla* in nursery beds

Treatments	Height (cm)	Collar girth (cm)
T0	46.47 ± 5.14	3.52 ± 0.36
T1	53.21 ± 5.20	3.61 ± 0.41
T2	69.24 ± 6.80	4.53 ± 0.47
T3	60.31 ± 7.20	4.15 ± 0.45

n=200

Growth of seedlings vary depending on seed quality, nursery medium, nutrient supply, soil conditions etc. but on an average they reach 30cm at 4 months and 60cm at 6 months growth. Such results were recorded in Puerto Rico by Holdridge and Marrero (1940) and in Solomon Islands by Oliver (1992). Seedlings are ready for planting once the stem base has become woody (Streets,1962). A root collar diameter of 0.8 – 1.3cm was recommended by Lamb(1966) for good survival. Though all these are positive features to be considered, vigorous growth after planting that promotes recovery after shoot borer attack is probably more important than height of planting stock.

1.3.3 Effect of different shade levels on growth of mahogany seedlings

Effect of different shade levels on growth of mahogany seedlings is given in tables 5 and 6. Both the species of mahogany were kept under different grades of shade nets and growth monitored upto 265 days.

Table 5. Mean height (cm) of mahogany species under different shade levels

Period (days)	*S. macrophylla*				*S. mahogany*			
	Shade (%)							
	25	50	75	Control	25	50	75	Control
24	29.30	30.03	30.59	21.00	24.00	24.69	24.40	23.60
70	34.40	32.08	31.51	24.80	25.65	24.83	24.59	24.00
146	45.04	42.48	40.70	30.40	30.27	29.51	27.60	25.64
183	52.00	50.20	45.40	35.83	35.25	34.77	32.10	25.80
217	60.22	60.00	49.98	43.56	45.62	44.00	38.00	27.20
265	88.67	85.04	64.65	53.43	64.28	58.40	53.10	47.26

The growth of *Swietenia macrophylla* seedlings was better under shade (Table.5) and was directly proportional to the extent of period under shade. All the three shade levels of 25, 50 and 75 % were seen to prompt height increment as compared to control, though height was more under 25 % shade. Lesser heights were recorded in 50 % and 75 % shade treatments. Percentage increase in height under 25% shade over control was 39, 38, 48,45, 38 and 66% respectively at 24, 70, 146, 183, 217 and 265 days of growth indicating consistent effect of shade over the periods.

Seedlings of *S.mahogany* also showed a similar growth trend under different grades of the shade net. Maximum height was obtained with 25% shade which was followed by 50 and 75% shade. Increase in height with 25% shade over control at 24, 70, 146, 183, 217 and 265 days were 1.7, 6.8, 18.0, 36.6, 33.4 and 36 percent respectively indicating consistent effect of shade over the periods. . Effect of shade on height growth was lesser in *S. mahogany* when compared to *S. macrophylla*

Table 6. Mean collar girth (cm) of two species of mahogany under shade

Period (days)	*S. macrophylla*				*S. mahogany*			
	Shade (%)				Shade (%)			
	25	50	75	Control	25	50	75	Control
24	0.44	0.42	0.41	0.35	0.34	0.32	0.32	0.35
70	0.57	0.53	0.52	0.44	0.36	0.38	0.34	0.36
146	0.81	0.75	0.68	0.60	0.45	0.41	0.38	0.40
183	0.90	0.80	0.71	0.71	0.49	0.45	0.43	0.40
217	0.97	0.90	0.85	0.75	0.51	0.50	0.45	0.45
265	1.03	0.93	0.93	0.84	0.56	0.56	0.48	0.48

The collar girth of the seedlings of *S.macrophylla* was not as much influenced by shade as in the case of height. However, an increase of 25.7, 29.5, 35.0,26.7, 29.3 and 22.6% was observed by 25% shade over control. Collar girth of *S.mahogany* was still less influenced by shade levels. There was no impact in the initial period upto 70 days. The increase from the third stage (146 days) onwards were 12.5, 22.5, 13.3 and 16.6% over control.

Effect of shade on height and collar girth of both species of mahogany is evident from the study; lighter shade was more effective in prompting height growth; shades heavier than 50% did not cause any appreciable difference. *S.mahogany* was less responsive to shade as compared to *S.macrophylla*. Size of leaves can be a reason for the difference; *S.macrophylla* has larger leaves that allow greater photosynthesis. The increase in height over control at 265 days' growth was 66 percent and the increase in collar girth was 23%.

1.4 SUMMARY

Potting mixture of sand, soil and cow dung in the ratio of 2:1:1 fortified with nitrogen, phosphorus, potassium, magnesium, zinc and boron was effective in producing tall healthy seedlings both in poly pots and nursery beds. Overhead shade had a positive impact on height and collar girth of seedlings. Partial shade of 25% was found to exert maximum influence in this respect. The increase in height at 265 days of growth was 66% and collar girth registered an increase of 26% over control.

2. PLANTATION TRIALS

2.1 INTRODUCTION

Mahogany, especially *Swietenia macrophylla* was tried as inter crops, under crops and mixed crops in forest plantations of Kerala, though on a small scale, but without much success. Failure was always due to attack by the shoot borer, *Hypsipyla robusta* larvae which tunnel down the apical shoot causing breakage. Mahogany has the added weakness of putting forth multitude of branches on repeated attack by the pest on the apical portion. This leads to loss of straight boles and consequent economic loss. It is common observation that shade helps to some extent in reducing the severity of infestation by the shoot borer. Trials conducted in the nursery stage has indicated that shade and nutrients improve the growth of seedlings. A field trial was thus initiated by laying out experimental plots to assess the impact of spacing and manuring on growth of trees and the consequent reduction in shoot borer infestation, if any, especially when raised as pure plantation.

2.2 MATERIALS AND METHODS

The experiment was carried out at the field research centre of the Institute situated at Velupadam. The design was split plot with spacing as the main plot and manuring as the sub plot factors. Two different spacings of 2m x 2m and 3m x 3m constituted the main plots. Three levels of cowdung, compost, sterameal and NPK constituted 12 treatments and along with control formed 13 sub plot treatments. Sterameal is a mixture of bone meal, blood meal, ground nut cake, neem cake and ammonium phosphate marketed by Shaw Wallace company. Ammonium phosphate and muriate of potash were used as the source of nitrogen, phosphorus and potassium. Each plot receiving a particular treatment had 25 plants in it. Three replications were provided. *S.macrophylla* seedlings were planted in 2003 to study the growth pattern.

Measurements on height and girth at breast height were recorded twice a year. Girth measurements started from the second year onwards. Incidence of shoot borer was monitored throughout the year. The data obtained were statistically analysed using ANOVA for each period and for pooled data set after transforming the data to logarithmic scale.

Table 8. Dosage of manures in different treatments

Treatments	Manure	Treatments	Manure
T1	Cow dung 500g	T8	Sterameal 200g
T2	Cow dung 1000g	T9	Sterameal 300g
T3	Cow dung 1500g	T10	NPK 125g
T4	Compost 100g	T11	NPK 250g
T5	Compost 200g	T12	NPK 375g
T6	Compost 300g	T13	Control
T7	Sterameal 100g		

2.3 RESULTS AND DISCUSSION

2.3.1 Effect of spacing and manuring on growth of mahogany

Growth of *S. macrophylla* was found to be influenced by spacing (Table 9). It can be seen that both height and girth at breast height were more in 2x2m spacing than in 3x3m spacing throughout the growth periods. These differences were significant from the fifth period onwards (Tables 14 & 15). Taking the latest figures in the eighth period, it is seen that there was an increase of 33% in height and 21% in gbh in the closer spacing of 2x2m compared to 3x3m spacing. Percentage increase in height by 2x2m spacing over the 3x3m spacing from the third period onwards were 11, 12, 16, 17, 28 and 33% respectively. Girth at breast height measured from the third period onwards was seen to be higher by 53, 22, 28, 31, 24 and 21% respectively over the wider 3x3m spacing. The trees attained an average height of 7.24m and a gbh of 24.07cm with the 2x2m spacing and 5.46m height and 19.87cm gbh with the 3x3m spacing at 5 years of age.

Table 9.Growth of *S. macrophylla* as affected by spacing

Period	Spacing			
	Height (cm)		GBH (cm)	
	2m x 2m	3m x 3m	2m x 2m	3m x 3m
1	0.62	0.65	-	-
2	102.91	102.5	-	-
3	190.35	171.5	2.84	1.85
4	270.48	241.22	7.68	5.83
5	454.2^a	390.93^b	13.88^a	10.81^b
6	473.66^a	403.66^b	15.76^a	12.01^b
7	569.25^a	445.46^b	19.93^a	16.05^b
8	724.42^a	545.96^b	24.07^a	19.87^b

Figures superscribed by dissimilar letters indicate significant difference

S. macrophylla in 3x3m spacing

S. macrophylla in 2x2m spacing

Among the manuring treatments, T3 (cow dung 1.5kg) and T6 (compost 300g) were found to appreciably improve height growth in 2x2m spacing. In 3x3m spacing also T3 and T6 exhibited greater effects though T12 (NPK 375g) was found to increase height growth appreciably in the latter periods. All other treatments differed only slightly between themselves. When the girth of trees were considered, T3 (cow dung 1.5 kg), T5 (compost 200g) and T6 (compost 300g) showed appreciable influence in girth in 2x2m spacing while it was T5, T6 (compost 300g) and T12 (NPK 375g) that recorded greater impact on girth increment in 3x3m spacing especially in the latter stages. Mean height and gbh of trees over different periods (Tables 18 & 19) also supported the above observation. Treatments T3 (cow dung 1.5kg) and T6 (compost 300g) were always found to influence growth of *S. macrophylla* irrespective of spacing levels.

Table 10. Mean height (cm) of trees at different periods as influenced by treatments in 2x2m plots

Treat-ments	Periods							
	1	2	3	4	5	6	7	8
T1	0.60	103.00	193.84	269.88	417.55	441.50	566.37	650.54
T2	0.62	105.37	205.64	293.44	444.90	461.84	569.74	715.18
T3	0.61	107.53	209.20	311.44	493.21	507.71	596.70	802.09
T4	0.58	93.66	183.15	260.38	461.55	483.17	596.33	774.41
T5	0.64	96.18	182.92	288.23	488.90	507.41	629.73	797.46
T6	0.64	106.13	196.11	296.42	496.11	513.04	680.26	806.84
T7	0.53	89.40	185.60	250.85	433.82	453.53	534.23	697.32
T8	0.58	96.16	188.27	252.82	438.79	462.79	550.41	711.18
T9	0.59	105.37	199.33	283.86	450.68	462.52	568.70	724.27
T10	0.62	93.10	164.34	253.69	446.64	465.50	534.89	666.52
T11	0.65	95.12	172.44	265.36	447.24	465.74	538.75	698.97
T12	0.68	109.41	190.72	269.25	469.47	494.80	561.46	725.73
T13	0.52	87.36	164.34	230.55	416.30	433.31	472.66	646.75

Periods 1 to 8 are at six months interval

Table 11. Mean GBH (cm) of trees at different periods as effected by treatments in 2x2m plots

Treatments	Periods			
	5	6	7	8
T1	12.13	14.11	19.84	19.89
T2	13.53	15.24	21.02	23.00
T3	15.83	17.62	21.91	26.33
T4	14.26	16.31	20.51	25.39
T5	15.62	17.62	21.76	27.33
T6	15.96	17.91	23.57	27.58
T7	12.87	14.63	18.27	22.13
T8	13.11	15.13	18.49	23.09
T9	13.53	15.27	19.00	23.27
T10	13.44	15.27	19.92	22.71
T11	13.58	15.36	20.02	23.95
T12	14.64	16.92	20.64	23.53
T13	11.99	13.49	14.13	15.00

Table 12. Mean height (cm) of trees at different periods as effected by treatments in 3x3m plots

Treatments	Periods							
	1	2	3	4	5	6	7	8
T1	0.63	83.38	142.76	200.42	355.43	363.74	389.39	457.96
T2	0.65	109.99	198.36	266.57	359.20	392.22	450.68	529.59
T3	0.67	120.22	210.94	297.87	410.62	415.78	520.43	632.39
T4	0.65	100.96	170.93	246.40	404.16	411.69	439.93	539.33
T5	0.69	108.24	179.55	247.85	408.10	415.46	443.59	542.76
T6	0.69	112.03	185.69	261.54	413.34	426.93	461.30	561.61
T7	0.60	90.60	148.14	201.43	382.52	395.08	401.52	507.59
T8	0.64	102.31	173.71	232.71	388.51	397.50	423.29	527.38
T9	0.65	103.09	183.03	251.01	411.50	423.09	453.06	550.68
T10	0.64	102.59	139.58	216.86	382.30	391.93	450.74	559.68
T11	0.66	103.46	173.36	251.23	394.74	407.72	474.36	581.19
T12	0.67	103.83	181.14	256.88	409.29	424.24	483.69	600.33
T13	0.60	81.76	132.27	200.05	352.44	362.23	379.03	450.05

Table 13. Mean GBH (cm) of trees at different periods as effected by treatments in 3x3m plots

Treatments	Periods			
	5	6	7	8
T1	9.17	10.03	12.73	15.54
T2	9.38	11.39	14.33	17.94
T3	11.75	12.66	16.17	19.87
T4	11.37	12.38	17.37	20.74
T5	11.60	12.62	17.59	22.04
T6	11.95	13.33	18.32	23.08
T7	10.39	11.58	15.16	18.36
T8	10.71	11.67	15.50	19.36
T9	11.70	12.94	17.46	21.93
T10	10.33	11.34	15.18	18.66
T11	10.96	12.19	16.52	20.07
T12	11.69	13.08	17.82	22.25
T13	9.03	10.00	12.44	17.05

While the difference in height increased gradually from period 1(11%) to period 8 (33%), the difference in gbh decreased gradually from 53% in period 3 to 21% in the 8th period. The mean annual increments were 1.45m and 1.09m respectively over the five year period. The mean annual increment in gbh was 4.8cm in 2x2m spacing while it was 4.0 m in 3x3m spacing.

Growth of *S.macrophylla* in response to manuring is given in tables 18 and 19. It could be seen that cowdung at 1.5kg per plant and compost at 300g per plant produced maximum height in 2x2m spacing throughout the growing period. T2 (1kg cowdung) and T9 (300 g sterameal) also had notable influence in 2nd , 3rd and 4th periods. Similar was the pattern in the case of gbh also; cowdung and compost at the highest levels exhibited greater influence. The next lower dose of compost (200 g) also was comparable in its effect on girth increment. The greatest value of 8.07m height and 27.58cm girth was obtained with 300g compost per plant in 2x2m spacing. Cow dung and compost were thus found to influence height and gbh of *S.macrophylla* throughout the study period.

Increase in height due to the best treatment, compost 300g in comparison with control was 23, 21, 19, 28, 19, 18, 44 and 24 percent respectively over the 8 periods. Girth also was influenced maximum by the same treatment and the respective increase in different periods were 118, 74, 33, 33, 67, and 84 percent.

Response to manuring did not exhibit comparable patterns in 3x3m spacing plots as was obtained in the case of 2x2m spacing. Cow dung at 1.5 kg per plant was seen to influence height growth more than all other treatments. This was true throughout the periods.

Treatment T6 (compost 300g) was also effective in boosting height growth in most of the periods. NPK at 375g per plant exhibited notable effect during the latter sixth, seventh and eighth periods. Increase in height brought about by the third level (300g) of cow dung over control was found to be 12, 47, 59, 49, 16, 15, 37 and 40 percent respectively in the 8 periods.

Girth was measured from the third period only. It was seen that gbh was influenced more by compost in most of the periods, though cowdung recorded higher values in 3rd and 4th periods. Similarly NPK at 375g per plant produced maximum gbh in the latter periods of 6, 7 and 8. Increase in gbh by the best treatment, compost 300g, was to the tune of 118, 32, 33, 47and 35 percent in the latter periods.

Table 16. Pooled analysis of variance on height

Source of Variation	Sum of Squares	Degrees of freedom	Mean sum of squares	F-ratio
Spacing	2.60	1	2.60	52.73 **
Error (a)	0.20	4	0.05	
Manuring treatments	1.03	12	0.09	1.18 ns
Manuring treatments x Spacing	1.03	12	0.09	1.21 ns
Error (b)	3.49	48	0.07	
Period	2809.55	7	401.36	33448.31 **
Period x Spacing	1.87	7	0.27	22.29 **
Period x Manuring treatments	0.99	84	0.01	0.98 ns
Period x Spacing x Manuring treatments	0.92	84	0.01	0.91 ns
Error (c)	4.37	364	0.01	

** Significant at p=0.01; ns=non significant

Pooled analysis of variance on height growth of *S.macrophylla* (Table.16) showed that spacing had a highly significant effect. Periods also differed significantly and the interaction between spacing and periods was also highly significant.

Pooled analysis of variance of girth measurements over different periods also gave similar results (Table.17) as was the case with height. Spacing, periods and the interaction between spacing and periods were highly significant. Manuring treatments did not produce any significant effect.

Table 17. Pooled analysis of variance on GBH

Source of Variation	Sum of Squares	Degrees of freedom	Mean sum of squares	F-ratio
Spacing	4.40	1	4.40	80.90**
Error (a)	0.22	4	0.05	
Manuring treatments	1.41	12	0.12	1.55 ns
Manuring treatments x Spacing	0.95	12	0.08	1.05 ns
Error (b)	3.63	48	0.08	
Period	15.80	3	5.27	1025.95**
Period x Spacing	0.07	3	0.02	4.24 **
Period x Manuring treatments	0.25	36	0.01	1.36 ns
Period x Spacing x Manuring treatments	0.24	36	0.01	1.28 ns
Error (c)	0.80	156	0.01	

** Significant at p=0.01; ns=non significant

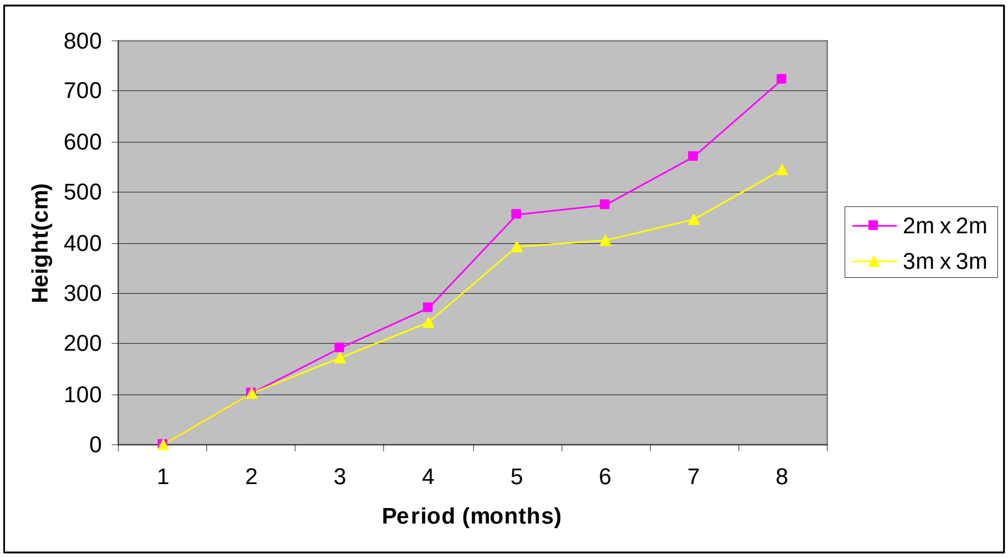

Fig 1. Height growth of *S. macrophylla* as affected by spacing

The pattern of increase in height growth over periods (Fig.1) was linear showing that the rate of increase was consistent with age and closer spaced plants grew taller throughout.

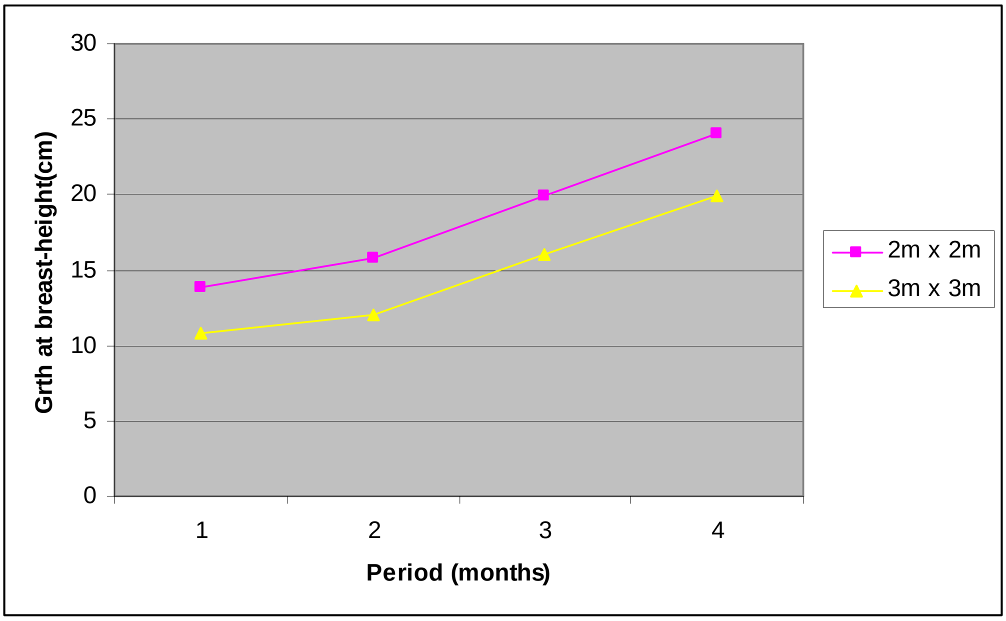

Fig 2. GBH of *S. macrophylla* as affected by spacing

Girth increments were also found to follow a linear pattern over time (Fig.2) indicating consistent increments with age as was the case with height and closer spaced plants grew taller than the wider spaced ones.

Table 18.Mean height (m) of trees under two spacing at the 8th period

Treatments	2m x 2m	3 m x 3m
Cowdung 0.5 kg	6.5 ± 0.7	4.6 ± 0.5
Cowdung 1.0 kg	7.1 ± 0.8	5.3 ± 0.5
Cowdung 1.5 kg	8.0 ± 0.8	6.3 ± 0.7
Compost 100gm	7.7 ± 0.7	5.4 ± 0.6
Compost 200gm	7.9 ± 0.7	5.4 ± 0.6
Compost 300gm	8.0 ± 0.8	5.6 ± 0.6
Sterameal 100gm	7.0 ± 0.7	5.1 ± 0.1
Sterameal 200gm	7.1 ± 0.8	5.3 ± 0.5
Sterameal 300gm	7.2 ± 0.6	5.5 ± 0.6
NPK 125gm	6.7 ± 0.7	5.6 ± 0.6
NPK 250gm	7.0 ± 0.7	5.8 ± 0.5
NPK 375gm	7.3 ± 0.8	6.0 ± 0.5
Control	6.5 ± 0.7	4.5 ± 0.5

Table 19. Mean GBH (cm) of trees under two spacing levels at the 8th period

Treatments	2m x 2m	3 m x 3m
Cowdung 0.5 kg	19.89 ± 2.0	15.54 ± 1.6
Cowdung 1.0 kg	23.00 ± 2.6	17.94 ± 1.6
Cowdung 1.5 kg	26.33 ± 2.8	19.87 ± 1.9
Compost 100gm	25.39 ± 2.6	20.74 ± 2.5
Compost 200gm	27.33 ± 2.9	22.04 ± 2.3
Compost 300gm	27.58 ± 2.9	23.08 ± 2.3
Sterameal 100gm	22.13 ± 2.2	18.36 ± 2.0
Sterameal 200gm	23.09 ± 2.4	19.36 ± 2.1
Sterameal 300gm	23.27 ± 2.4	21.93 ± 2.4
NPK 125gm	22.71 ± 2.3	18.66 ± 1.9
NPK 250gm	23.95 ± 2.5	20.07 ± 2.1
NPK 375gm	23.53 ± 2.4	22.25 ± 2.4
Control	15.00 ± 1.7	17.05 ± 1.9

Infestation by the shoot borer in the year 2005 when the plants were 3 year old is given in Figure 3. It can be seen that maximum attack was during the rainy season though infestation was more than 40 percent in most of the months especially in 3x3m spacing. Maximum infestation of around 60% occurred during the months of August and September 2005. The plants were infested in all the months though attack was less in January, February and March when rainfall was scanty and new flushes few. Infestation was less in 2x2m spacing in all the months.

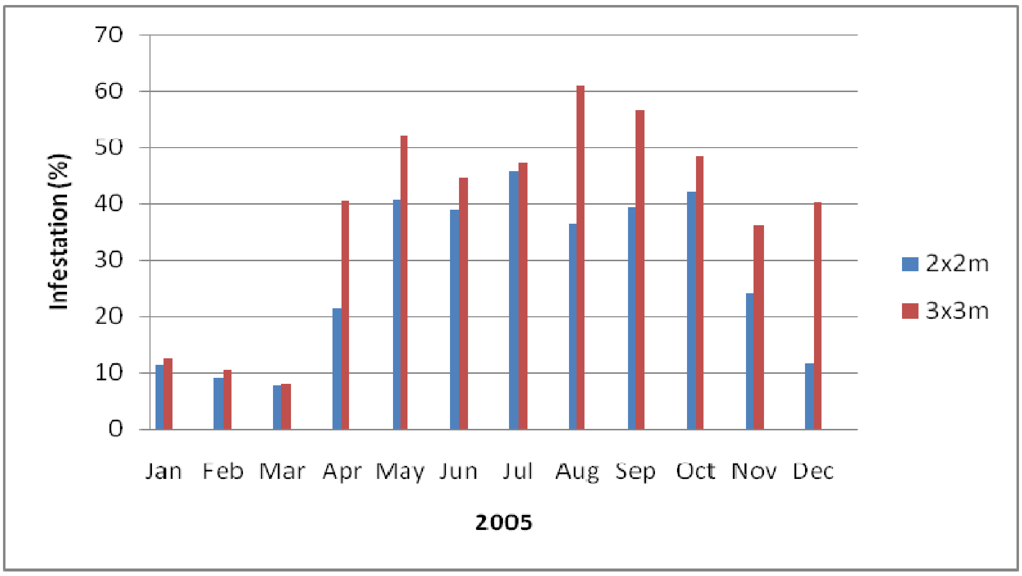

Fig 3. Susceptibility of *S. macrophylla* as affected by spacing in 2005

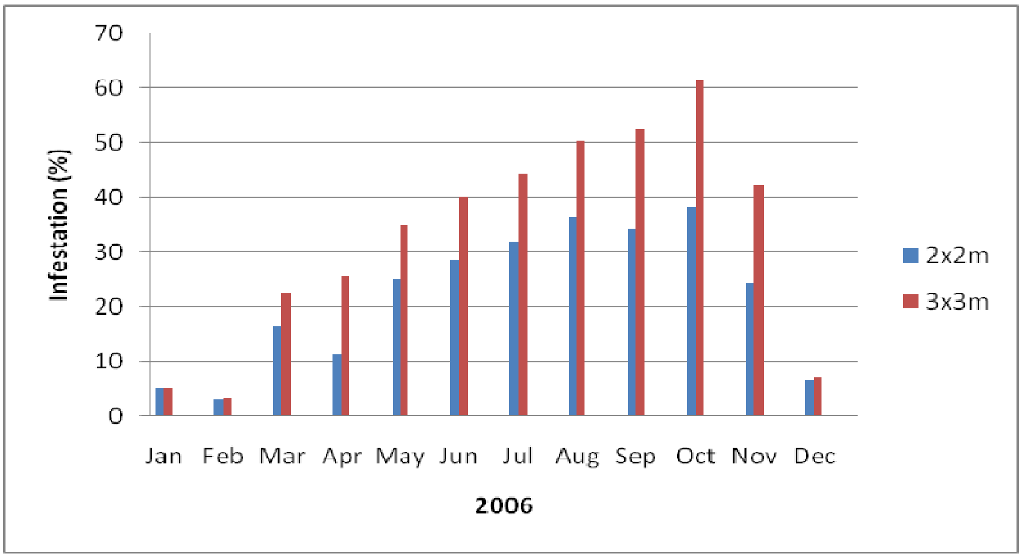

Fig 4. Susceptibility of *S. macrophylla* as affected by spacing in 2006

The pattern of infestation by the shoot borer in the year 2006 (Fig.4) was slightly different with a constant increase from the month of March to October and a reduction thereafter. January and February recorded least infestation. More than 40% plants suffered attack during June to November. Maximum infestation occurred during the month of October when 60% of the plants suffered attack by the pest. Infestation was always less in 2x2m spacing.

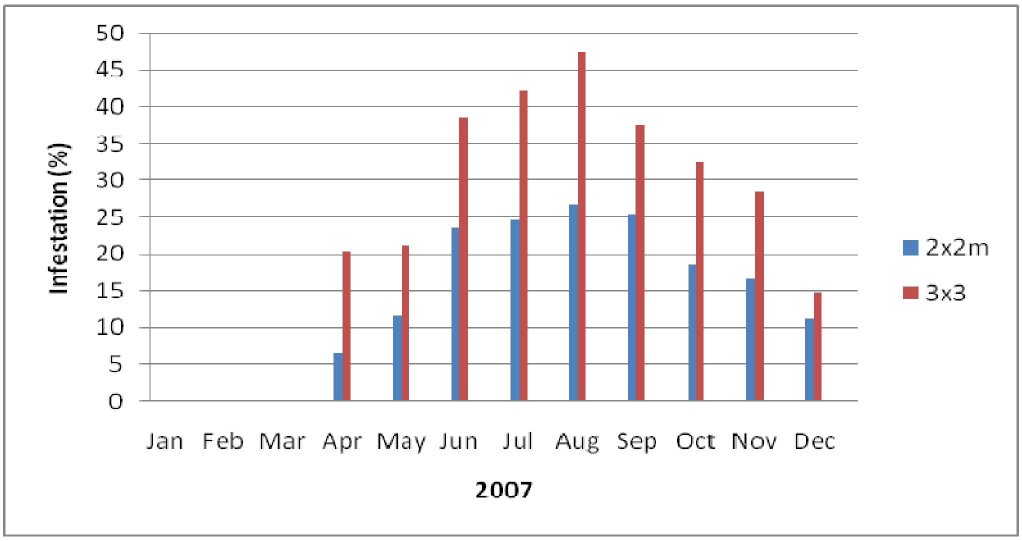

Fig 5. Susceptibility of S. macrophylla as affected by spacing in 2007

The pattern of infestation by the shoot borer was slightly different in the year 2007(Fig.5). It was observed that there was no attack by the pest during January, February and March since there was no rain at all in that year and no flushes available. Infestation started building up from April and maximum attack occurred during June to September. The attack was lesser than the previous year with less than 40% plants infested in most of the months. Infestation was always lesser in 2x2m spacing.

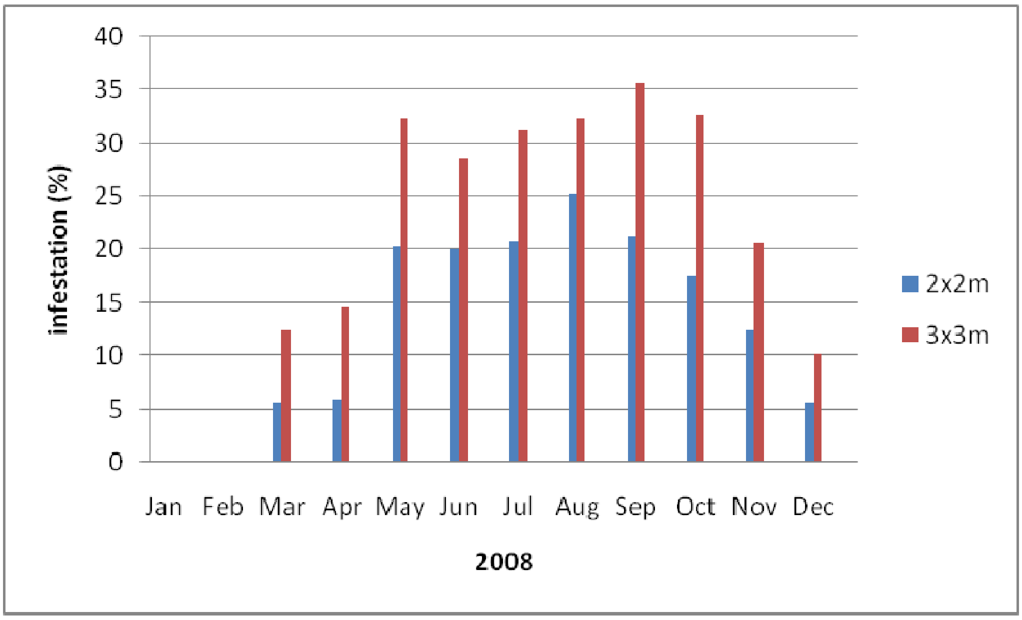

Fig 6. Susceptibility of *S. macrophylla* as affected by spacing in 2008

The mahogany plants were infested with the shoot borer in most of the months in the year 2008 (Fig.6) except January and February. Maximum attack was recorded during the months of May to October but the percentage of infestation was only around 30 to 35 percent. The rate of infestation can thus be seen to have decreased with the growth of the plants. Infestation was always higher in 3x3m spacing compared to 2x2m spacing.

Susceptibility of *S.macrophylla* to attack by the shoot borer *Hypsipyla robusta* was found to be more in the wider spaced plots of 3x3m as compared to 2x2m plots throughout the period of study. It was thus observed that spacing and manuring had a positive influence on improving height and girth of mahogany, *Swietenia macrophylla* in young plantation. High density pure plantations are often spaced at 2x2m to 3x3m and thinning carried out after 5years (Marie, 1949; Bascope'*et al.*,1957). Shade may induce changes in shoot composition that can reduce susceptibility to attack by the shoot borer. In Peruvian Amazon line plantings, pest incidence was found to be higher during flushing (Yamazaki *et al.*,1992). Newton *et al.*,(1998) reported similar observations in Costa Rica. Flushing shoots have different chemical composition and are soft both of which attract oviposition by adult moth and larval burrowing (Grijpma,1976; Vega,1976). Plant defences such as sap tannin content (Lamb,1966), resin flow (Wilkins,1972;Whitmore,1978) or complex secondary compounds such as proanthocyanidins or limonoids that act as antifeedants or insecticides (Adesida andAdesogan,1971; Koul and Isman,1992; Vanucci *et al.*,1992) may be affected by shade.

Fertilizer application is not widely practiced in mahogany plantations due to the adaptability of this species to nutrient poor sites. But it is used in high input plantations upto the sixth year to improve growth over the years. Around 500 – 1000 kg $ha^{-1}yr^{-1}$ of NPK upto the 6^{th} year and 160 kg $ha^{-1}yr^{-1}$of urea thereafter had been recommended by Evans (1992).

Silvicultural treatments that promote faster height growth may enable the trees to evade the pest as also to recover from damage caused by the shoot borer. Closer spacing and manuring has been found to improve growth of *S.macrophylla* in the field (Tables19,20) Shoot borer infestation has also been reduced by a combination of these treatments (Figures 3,4,5,6). Spacing was found to exert maximum influence and the impact was consistent throughout the growth periods. Manuring was found to improve height and girth compared to the control, but its effect was significant only in the seventh period. Manuring can influence tolerance by improving vigour and thus faster recovery after attack. Lateral shade imposed by close growing trees encourage vertical growth (Stevenson,1939; Aubrevilla,1953; Yared and Carpenezzi,1981) and thus help in reducing borer attack.

Results of the present investigation also revealed that taller trees were able to evade attack by the shoot borer as can be evidenced from the reduction in infestation over the growing period. The adult moth has a limited flight ability and is unable to cover large distances (Abe,1983). It may also be inferred from the mode of infestation that the moth rarely flies higher than around 5m since most of the trees above this height has been found to escape the pest. The microclimate associated with closer spacing that has higher humidity assists the proliferation of entomopathogenic fungi (Ferron,1981) and reduction in UV radiation helps in persistence of entomopathogenic viruses (Entwistle and Evans,1983).

Silvicultural techniques that have been successful in one site may not be that effective in another site. Experience suggests that most of the trees will be attacked where the shoot borer is present. Adoption of techniques that help in reducing the attack and also encourage recovery after attack are the only options. Promoting vertical growth and restricting lateral branching is preferred in this respect. High density planting in pure plantations with adequate nutrient supply can help the trees to a considerable extent in reducing Hypsipyla damage. Healthy planting stock and pruning in the initial years are other aspects that have to be taken care of to ensure healthy growth of mahogany in plantations. Since the moths locate their host primarily by olfaction (Morgan and Suratmo,1976; Kareira,1983), planting of non-Meliaceae trees that produce chemical signals in or around a stand may prevent the moth from locating the mahogany trees. Species such as *Azadirachta indica* that are known to have insect repellant properties may be preferred in this respect. Predators, parasitoids and pathogens may be encouraged by providing suitable habitats. Tree species which harbor large populations of ants have potential in this context. Impact of silvicultural treatments on the microclimate such as temperature and humidity and its consequent influence on entomopathogenic fungi and viruses remain largely uninvestigated.

2.4 SUMMARY

Results of the field experiment revealed that closer spacing of 2x2m was very effective in providing lateral shade and was thus significant in boosting growth and reducing pest incidence. Manuring also had its impact, though to a lesser extent in improving growth of *S.macrophylla*.

3. COMPARATIVE RESISTANCE OF MAHOGANY SPECIES TO SHOOT BORER

3.1 INTRODUCTION

Mahogany species, in general, is susceptible to shoot borer infestation. But there can be differences between species in resisting the attack. An experiment was conducted at the same site to ascertain the comparative resistance of *S.macrophylla* and *S.mahogany* to the shoot borer, *Hypsipyla robusta*

3.2 MATERIAL AND METHODS

Both species of mahogany, namely, *S.macrophylla* and *S.mahogany* were assessed for their comparative resistance to *Hypsipyla robusta* infestation by recording pest incidence every month.

3.3 RESULT AND DISCUSSION

Observations on infestation by *Hypsipyla robusta* recorded from 4th year to 7th year revealed that *S.mahogany* was more susceptible than S.macrophylla in all the years over all the months. It was also seen that wider spaced plantations were more susceptible to the borer attack than closer spaced ones. Infestation occurred throughout the year except when there was no rain and no new flushes.

Hypsipyla robusta infestation

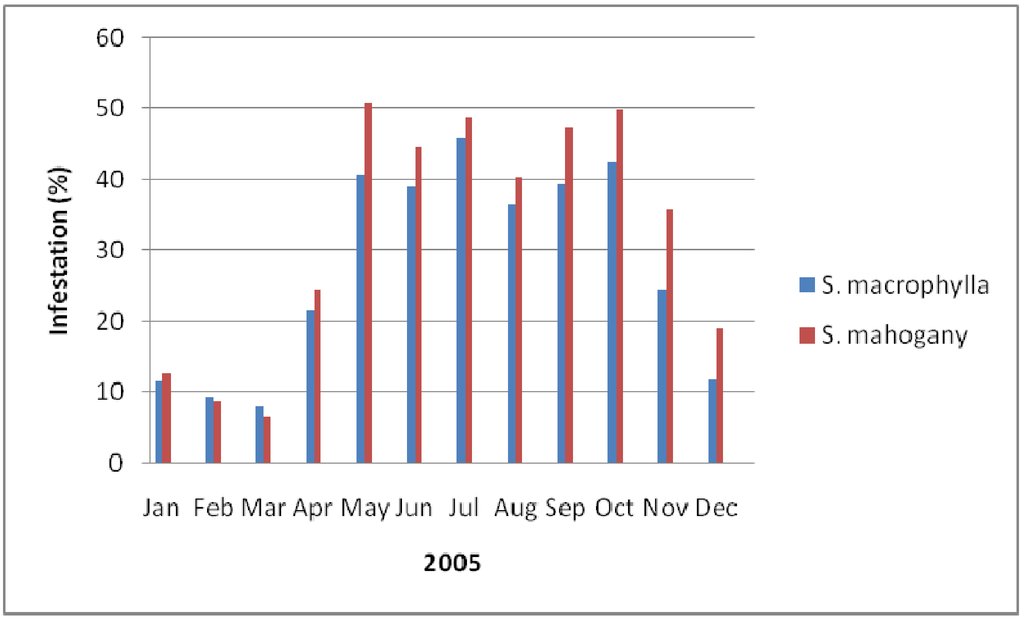

Fig 7. Susceptibility of mahogany to shoot borer in 2x2m spacing

Comparative resistance of the two species of mahogany in 2x2m spacing against the shoot borer during 2005 is shown in Figure 7. It can be seen that *S.mahogany* was always attacked more by the shoot borer *Hypsipyla robusta* except in the months of February and March during which period there was no appreciable difference between the species. Attack was severe during the months of May to October when around 40 percent of *S.macrophylla* and around 50 percent of *S.mahogany* suffered infestation.

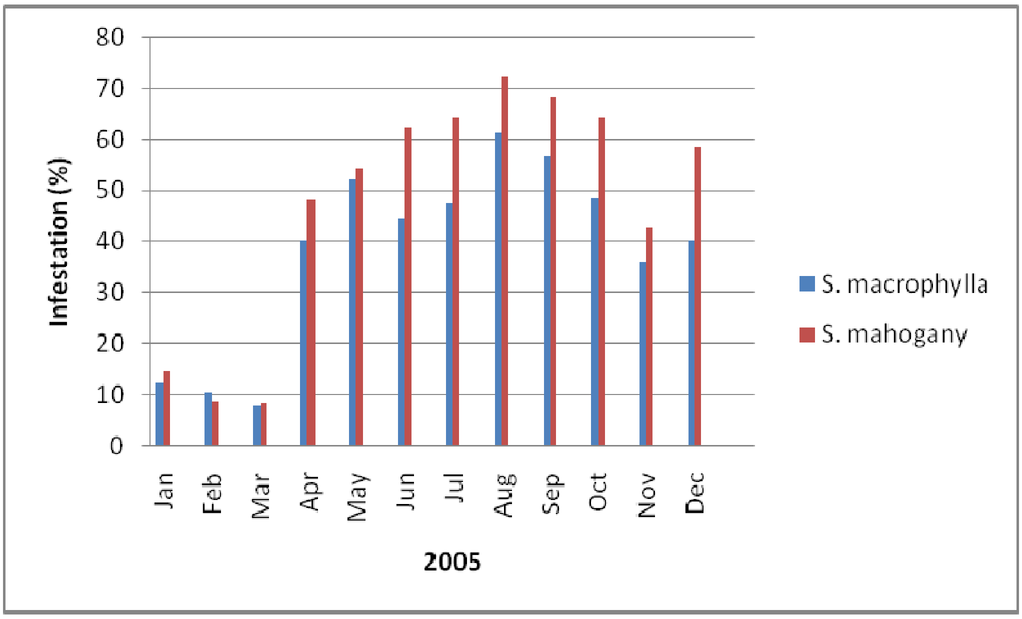

Fig 8. Susceptibility of mahogany to shoot borer in 3x3m spacing

Shoot borer infestation was higher in 3x3m spacing (Fig.8) with more than 60 percent plants suffering attack in the case of *S.mahogany*. *S.macrophylla* suffered slightly less with around 50 percent of the plants infested during the peak season of May to October.

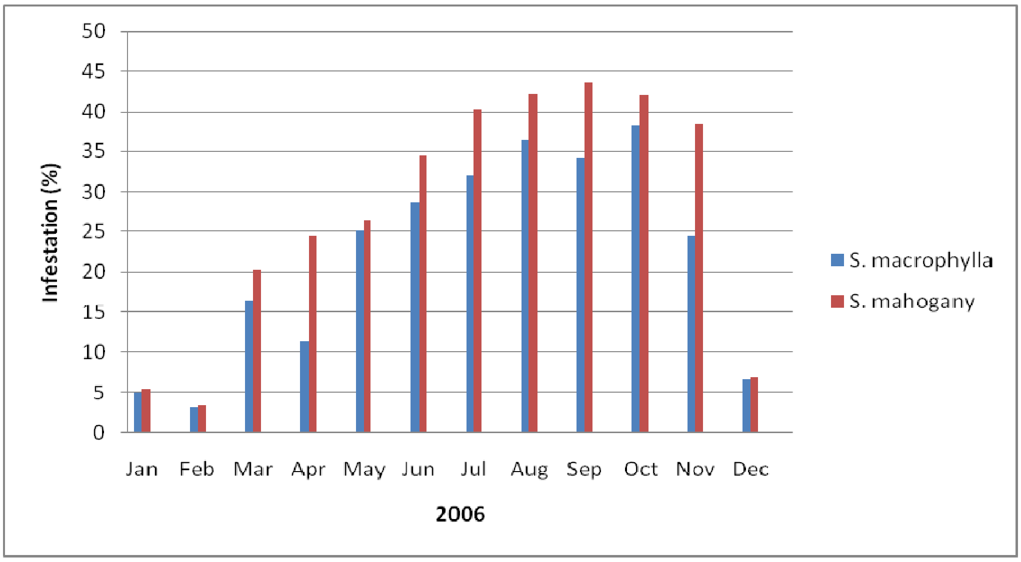

Fig 9. Susceptibility of mahogany to shoot borer in 2x2m spacing

Data on infestation by the shoot borer in 2006 also revealed similar pattern with *S.mahogany* suffering more than *S.macrophylla* in all the months. Around 40 percent of the *S.mahogany* and around 30 -35 percent of *S.macrophylla* plants suffered attack during the months of June to November in 2x2m spacing.

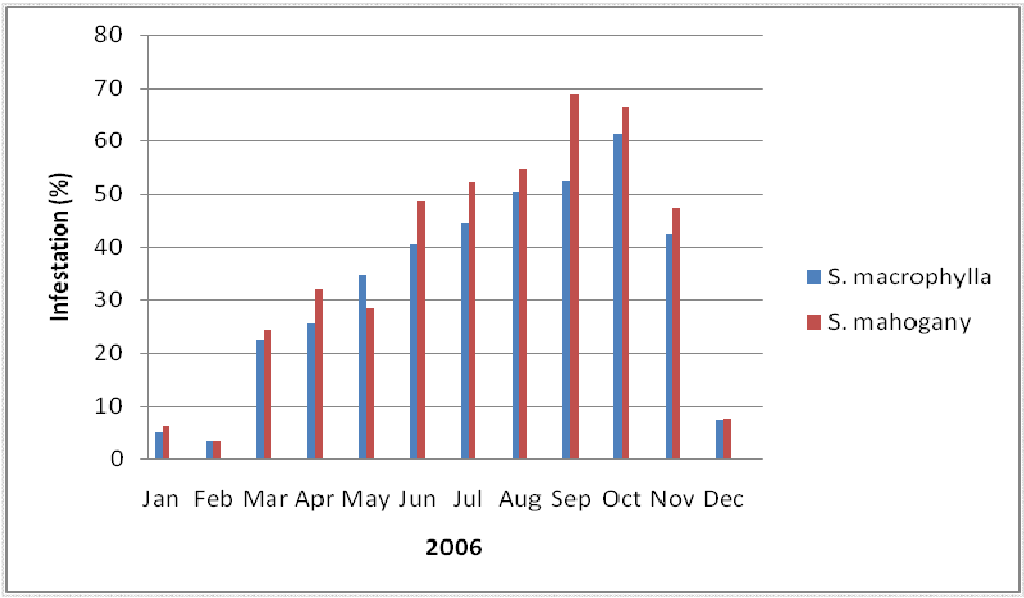

Fig 10. Susceptibility of mahogany to shoot borer in 3x3m spacing

Infestation by the pest was more in 3x3m spacing in the same year 2006 as is shown in Figure 10. Attack was to the tune of 50 to 68 percent in the case of *S.mahogany* compared to 40 to 60 percent in *S.macrophylla* plots during the period of June to November. All the months recorded attack by the pest.

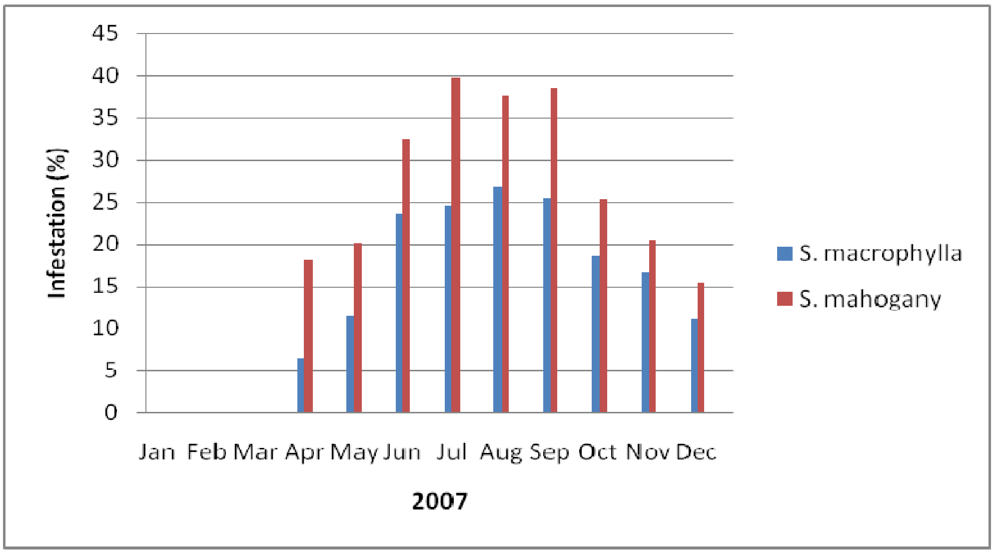

Fig 11. Susceptibility of mahogany to shoot borer in 2x2m spacing

The percentage of infestation in 2007 in 2x2m spacing plots is given in Figure 11. It can be seen that there was reduction in infestation from the previous years but still the pattern was similar. Around 30-40 percent plants of *S.mahogany* were attacked while the plants of *S.macrophylla* suffered attack to the tune of only around 25 percent during the peak period of June to October.

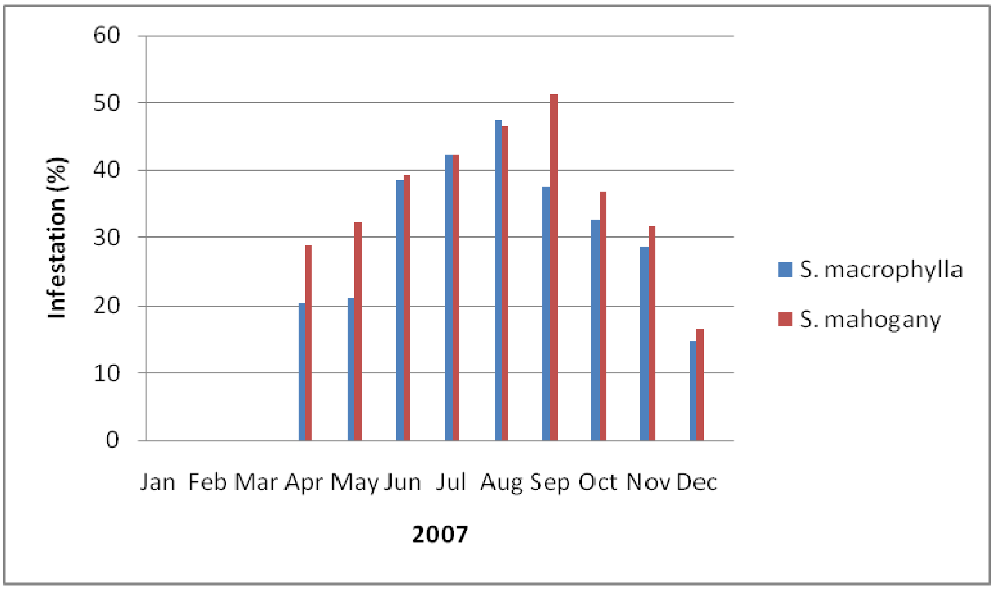

Fig 12. Susceptibility of mahogany to shoot borer in 3x3m spacing

Infestation was more in 3x3m spacing compared to the closer spacing of 2x2m in the year 2007 (Fig.12) and the rate of attack was not much different between the species, though *S.mahogany* suffered more in most of the months. Around 40 percent of both the species suffered infestation during the months of June to Octoober

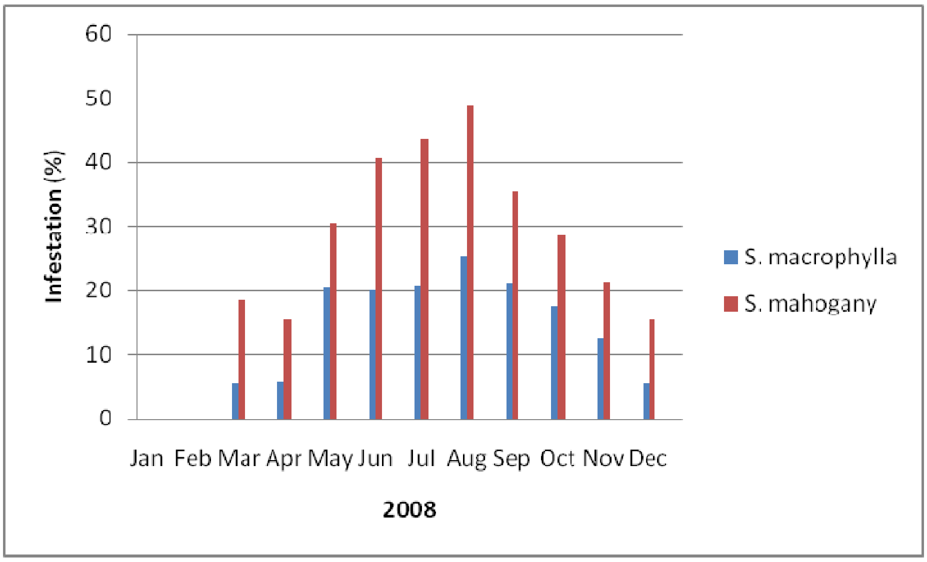

Fig 13. Susceptibility of mahogany to shoot borer in 2x2m spacing

Infestation came down in 2008 as can be seen in the Figure 13 especially in the case of *S.macrophylla*; infestation got reduced to around 20 percent during the peak season of May to October. The rate of attack in the case of *S.mahogany* plots were more than 30 percent and even more than 40 percent during June to August.

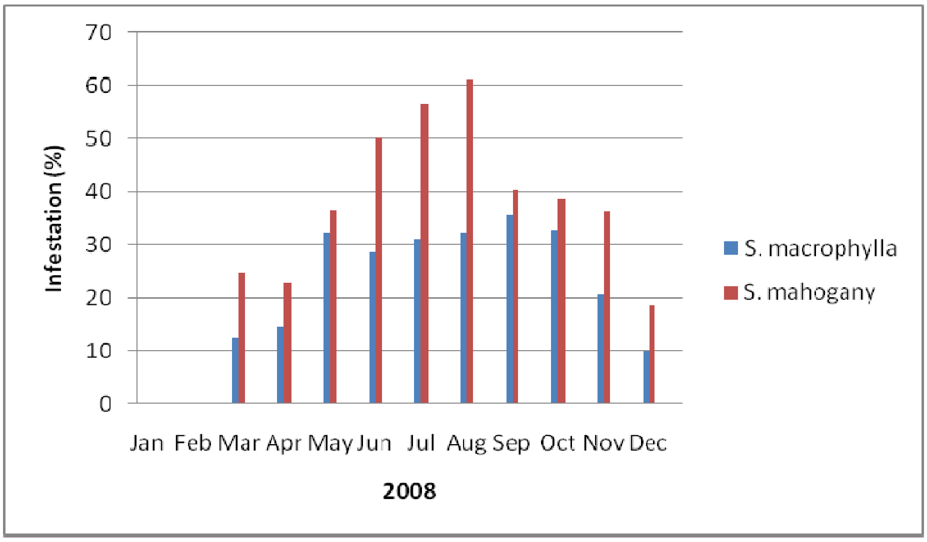

Fig 14. Susceptibility of mahogany to shoot borer in 3x3m spacing

The infestation rate has been found to be more in 3x3m spacing in the same year 2008 (Fig.14) with around 30 percent of S.macrophylla and around 40 percent of *S.mahogany* getting attacked during the period May to November. During June, July and August the *S.mahogany* plants suffered even upto 60 percent infestation.

3.4 SUMMARY

*Swietenia mahogan*y was much more susceptible than *S. macrophylla* throughout the period of study irrespective of spacing though infestation was more in wider spacing. Infestation decreased with age of plants in both the species.

4. GENERAL CONCLUSION

Mahogany is an ideal plantation species in many respects since raising seedlings in the nursery is very easy and seedlings grow fast. The species tolerates wide range of site conditions and grows satisfactorily even on degraded sites. But the tree is almost always infested by the mahogany shoot borer, *Hypsipyla robusta*, that tunnel down the apical shoot causing its breakage and encouraging lateral branching. Loss of the main leader and resultant low branching drastically reduce timber value. Silvicultural techniques that reduce attack by the shoot borer and assist recovery after attack are the only strategies that are feasible. Closer spacing of 2x2m that create lateral shade restricting development of lateral branches and promoting vigorous vertical growth has been found to improve growth of trees and also reduce shoot borer infestation. Manuring has been found to support the plants in this respect, but to a lesser extent as compared to spacing which was shown to have significant impact.

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