



**Government of the Union of Myanmar**  
**Ministry of Forestry**  
**Forest Department**  
**Forest Research Institute**



**Site Preparations, Species and Spacing Trials**  
**For Pulpwood Plantations**

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## ပျော့ဖတ်သစ်စိုက်ခင်းအတွက် မြေပြုပြင်မှု၊ သစ်မျိုးနှင့်ပန္နက်အကွာအဝေးစမ်းသပ်ခြင်း

ဦးမြဝင်း၊ B.Sc (For.) (Ygn.)၊ သုတေသနလက်ထောက်၊ သစ်တောသုတေသနဌာန  
ဦးစောဝင်း၊ B.Sc. (For.) (Ygn.), Grad Dip.Sc. (For.) (ANU)  
ဒုတိယညွှန်ကြားရေးမှူး၊ သစ်တောဦးစီးဌာန

### စာတမ်းအကျဉ်းချုပ်

စစ်တောင်းစက္ကူစက်သို့စက်မှုကုန်ကြမ်း ဖြည့်ဆည်းပေးသည့် စိုက်ခင်းအတွက် မြေပြုပြင်မှု (၂)မျိုး၊ သစ်မျိုး(၃)မျိုးနှင့် ပန္နက်အကွာအဝေး(၄)မျိုး စမ်းသပ်ခြင်းကို အောက်မြန်မာပြည် မိုးများသောဒေသ မြေဩဇာညံ့သော ဂဝံနှင့်ဂဝံမြေစေး အမျိုးအစားများရှိသည့် စစ်တောင်းစက်အနီးတွင် စမ်းသပ်ခဲ့ပါသည်။ မြေပြုပြင်မှု စမ်းသပ်ချက်အရ မြေထွန်ယက်စိုက်ပျိုးခြင်းသည် မြေမပြုပြင်ဘဲ စိုက်ခြင်းထက် သစ်ပင်များပိုမို အောင်မြင်ရှင်သန်မှုများစေပြီး အမြင့်၊ လုံးပတ် ပိုမိုကြီးထွားစေကြောင်း တွေ့ရပါသည်။ သစ်မျိုး စမ်းသပ်ချက်အရ အော်ရီးရှားနှင့်မင်ဂျင်ယမ်ရှားသည် ယူကလစ်ထက်အမြင့်၊ လုံးပတ်နှင့် တစ်ဧက ရင်စို့ ဖြတ်ပုံဧရိယာ ကြီးထွားမှုတွင်လည်းကောင်း၊ ရှင်ပင်%တွင်လည်းကောင်း သိသာစွာ မြင့်မားကြောင်းတွေ့ ရပါသည်။ ပန္နက်အကွာအဝေး စမ်းသပ်ချက်အရ သက်တမ်းပတ်တိုပြီး၊ အကြီးမြန်သစ်မျိုးအတွက် ရင်စို့ အချင်း (၂)လက်မအား ပျော့ဖတ်သစ်အဖြစ်အသုံးပြုနိုင်ပါက ပန္နက်စိတ်စိတ်စိုက်ပျိုးခြင်းဖြင့် တစ်ဧကတွင် ရရှိသည့် ရင်စို့ဖြတ်ပုံဧရိယာ ပိုများကြောင်း တွေ့ရပါသည်။ ပန္နက်အကွာအဝေး စမ်းသပ်ကွက်ရှိ အပင်တို့၏ အမြင့်ကြီးထွားမှု ကွာခြားမှုမရှိခြင်းကြောင့် တစ်ဧကတွင် ပန္နက်စိတ်စိတ် စိုက်ပျိုးခြင်းဖြင့် တစ်ဧကထူထည် အထွက်နှုန်းသည်လည်း များလာနိုင်မည်ဟု ခန့်မှန်းရပါသည်။

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### **Abstract**

Site preparation, species and spacing trials were carried out with fast growing exotic species on poor laterite and clayey lateritic soils type at heavy rainfall area of lower Myanmar to supply raw material for Sittaung paper mill. It is observed that survival percentage and rate of growth can be raised by plowing the site of the plantation. According to the species trial, survival%, height, diameter and basal area per acre of *Acacia auriculiformis* and *A. mangium* are significantly higher than *Eucalyptus camaldulensis*. According to the spacing trial, it is observed that basal area per acre could be raised by planting the trees in a closer spacing for short rotation and fast growing species of 2" d.b.h.o.b can be used for pulpwood. Hence if the height and diameter growth are not significantly different, it can be estimated that yield of pulpwood per acre can be raised by planting the trees at a closer spacing.

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## **1. Introduction**

Sittaung Pulp and Paper mill depends mainly on fibre of wood and bamboo as raw material. Up to 1992-93 Eucalypt plantations amounting to 26,470 acres were established at Kyeiktho Township, Mon State, where the rainfall is 140 to 180 inches annually. According to the mill capacity, it requires at least one thousand acres of mature plantations annually, (Ohn Lwin, 1993). Determining technical rotation for raw material plantations depends not only on soil and climate but also on silvicultural treatments being given to these plantations. It was found that the eight-year old Eucalypt produces pulp with better strength compared to other Eucalypt pulps of various ages. Even five, six and seven years old Eucalypt are found suitable for making pulp and paper (Win Mar et.al, 1987). However, the productivity of Eucalypt plantation is dependent on site quality, climatic conditions, and silvicultural treatments. Areas with high rainfall and higher elevation, are found to produce pulpwood yield of about 30 stacked tons per acre (Saw Win, 1987).

Industrial plantations were previously established without site preparation, even on heavily compact soil such as laterite and lateritic soil. Neither was it plowed nor pits dug on such adverse soil, and consequently the productivity was reduced resulting in longer rotation. Therefore, it is necessary to observe the effect of plowing on poor soils in heavy rainfall area.

Selection of suitable species fitted to each particular soil and climate with shorter rotation is also required. Preferably species selected should have the ability to resist forest fire, die back phenomena after fire, have high coppicing power. Therefore, fast growing exotic species were tried for pulpwood plantations in this study.

Initial spacing influences the extent of the use of labor, time and money. For example, if the seedlings are planted at close spacing it will require more financial investment in raising seedlings; transporting seedlings to the plantation sites, planting at stake and so on. Moreover, more time and labor force will be required to carry out these tasks. Thus in this paper different spacing were also tried to find out the best optimal spacing for plantation establishment with varying species.

## **2. Materials and Methods**

Experimental design adopted in this research is Factorial Experiment in Randomized Block Design. The experimental area is divided into three replications (blocks) so as to minimize the experimental error. Within each replicate, half of the area was plowed and the other half unplowed. Within each plowed and unplowed plot, three species with four spacings were randomly allotted.

Each plowed and unplowed trial consists of 12 plots (3 species x 4 spacing). The whole experiment therefore consists of 72 plots: e.g., 2 site preparations x 3 species x 4 spacing x 3 replicate. Forty-nine trees (7 x 7 rows) were planted in each experimental plot. Layout of factorial experiment in randomized block design is shown in figure (1). The required seedlings per acre for different spacing are shown in Table (1).

**Table (1) Seedling per acre for different spacing**

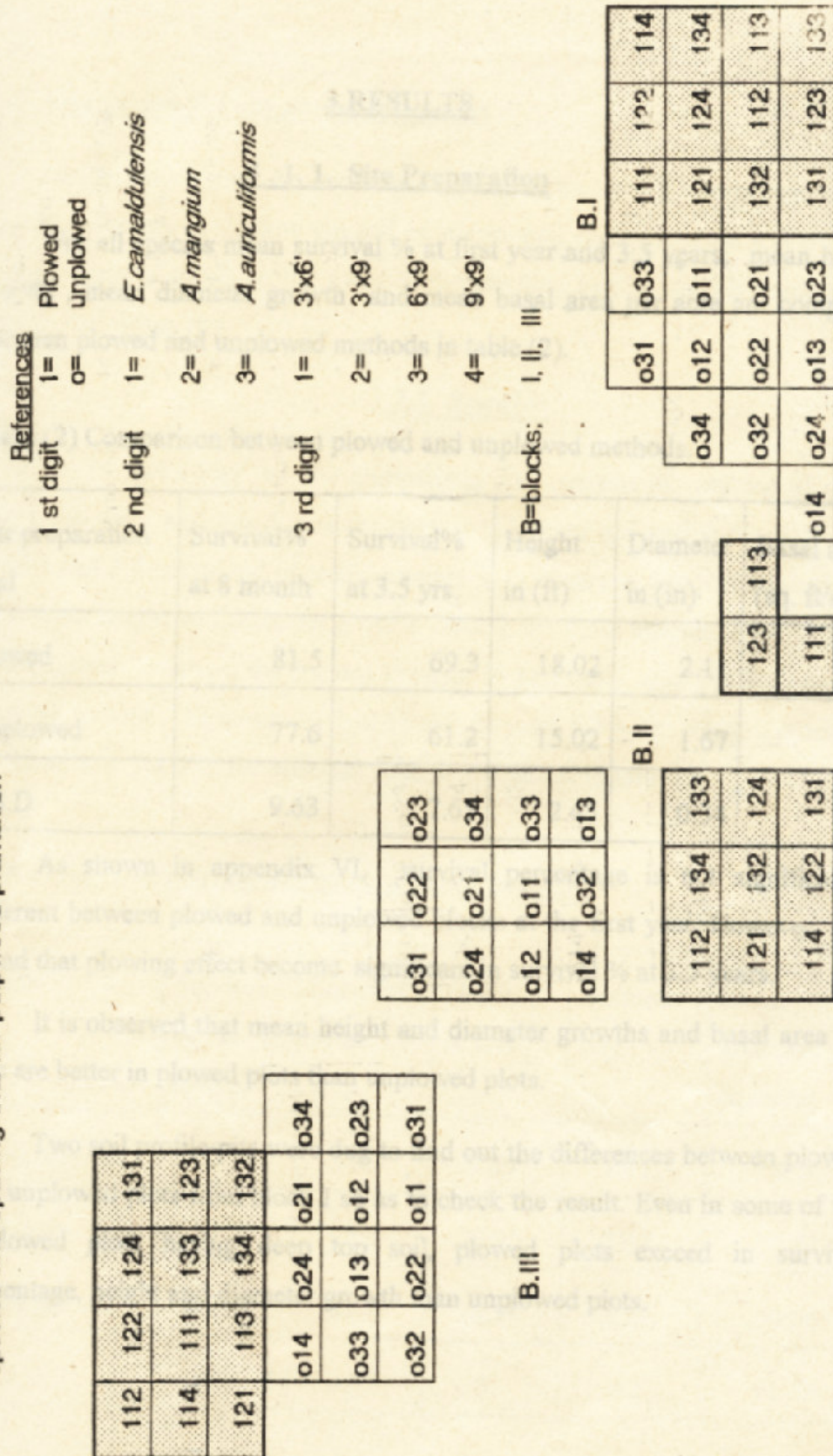
<b>Spacing</b>	<b>Growing space for each seedling (sq.ft)</b>	<b>Area of each spacing trial plot (acre)</b>	<b>Required stakes or seedling/acre</b>
3' x 6'	18	0.02	2420
3' x 9'	27	0.03	1613
6' x 9'	54	0.06	807
9' x 9'	81	0.09	538

Site selection and surveying, taungya fellings and clearing of debris were done in 1990. Then half of each block was plowed down to a depth of 4-8 inches by man power. Staking with four different spacing was done on plowed and unplowed blocks. Seedlings of *E.camaldulensis*, *A. mangium* and *A. auriculiformis* were raised at Theinzayat forest nursery. One hundred and eighty days old seedlings were planted and patching was done one month after planting. Weeding was carried out three times during the first year and two in the second year, and once in the third and fourth year respectively. Fire protection was carried out from February to mid May before the onset of the monsoon.

Survivals % at first year and at 3.5 years were recorded. Top height and diameter at breast height over bark were measured with measuring pole and caliper. Basal area per acre is converted from diameter measurements. These data are shown in appendix I, II, III, IV and V. ANOVA tables are shown in appendix VI. Due to human interference a certain portion of the experimental plots were destroyed. Data of missing plots are projected and calculated by using the standard statistical formula.

Layout of Factorial experiment in randomised block design for site preparation, species and spacing trial for pulpwood plantation

Figure (1)



### 3. Results

#### 3.1.1 Site Preparation

For all species mean survival % at first year and 3.5 years, mean height growth, mean diameter growth and mean basal area per acre are compared between plowed and unplowed methods in table (2).

**Table (2) Comparison between plowed and unplowed methods**

Site preparation trial	Survival % at 8 month	Survival % at 3.5 yrs.	Height in (ft)	Diameter in (in)	Basal area/acre (sq.ft/ac)
Plowed	81.5	69.3	18.02	2.11	26.53
Unplowed	77.6	61.2	15.02	1.67	16.52
L.S.D	9.63	7.65	2.45	0.34	9.02

As shown in appendix VI, survival percentage is not significantly different between plowed and unplowed blocks at the first year. However, it is found that plowing effect become significant in survival % at 3.5 years.

It is observed that mean height and diameter growths and basal area per acre are better in plowed plots than unplowed plots.

Two soil profile-pits were dug to find out the differences between plowed and unplowed plots from block I so as to check the result. Even in some of the unplowed plots having deep topsoil, plowed plots exceed in survival percentage, height and diameter growth than unplowed plots.

#### 3.1.2 Conclusion for site preparation trail

Site preparation should be done before planting on heavily compacted soil or impervious layers or shallow top soil of laterite and clayey lateritic soil so as to provide a media in which the roots of the seedling can be quickly established and for their longevity.

#### 3.2.1 Species

According to the comparison and analysis of variance of mean height, diameter and basal area per acre at 3.5 years old and survival % at 8 months and 3.5 years, old of tested species, it is observed that *A. mangium* has the highest height and diameter growth among the three species tried. *Acacia auriculiformis* attained the highest survival % and basal area per acre among the three species. The mean survival % at first year, 3.5 years, height, diameter and basal area per acre for different species are shown in table (3).

**Table (3) Comparison of performances among species**

Species	Survival % at 8 month	Survival % at 3.5 yr.	Height in (ft)	Diameter in (in)	Basal area/acre (ft .sq /ac)
<i>E.camaldulensis</i>	62.5	51.3	9.85	1.11	4.4
<i>A. mangium</i>	83.8	63.3	20.95	2.44	29.51
<i>A. auriculiformis</i>	92.4	81.1	18.76	2.12	30.66
L.S.D	11.8	9.37	3	0.42	11.05

The d.b.h.o.b distribution per 1.2 acre among tested species are shown in table (4)

**Table (4) Comparison of d.b.h.o.b distribution per 1.2 acre at 3.5 yr of tested species**

Species	D.B.H.O.B at 3.5 yr	
	1 – 2" (no of tree)	2.1" & above (no of tree)
<i>E.camaldulensis</i>	522	36
<i>A.mangium</i>	308	439
<i>A. auriculiformis</i>	429	465

Comparison of d.b.h.o.b distribution of tested species reveals that *A. auriculiformis* attains the highest number of trees in 2.1" & above d.b.h.o.b class while *E. camaldulensis* attains the highest number of trees in 0.1" to 2" d.b.h.o.b class.

### 3.2.2 Discussion of species trial

The information that should be considered for selecting right species on right site are presented in table (5).

**Table (5) Information to be considered for species selection**

No.	Factors	<i>E. camaldulensis</i>	<i>A. mangium</i>	<i>A. auriculiformis</i>
1.	Drought resistant	survive till to 6 months	survive till to 4 months	survive till to 6 months
2.	pH	salt tolerance varies with seed origin	pH 4.5	pH 3 to 9.5
3.	Rainfall	400-1250 mm	1000-4500 mm	1500 - 1800 mm
4.	Mode of growth	Usually straight bole	branchy	branchy

Source: (Forestry Administration Korea and Edwards Ayensu 1980)

The presence of heart rot and termite attack was noted on the ends of some of the *A. mangium* logs in Malaysia (Chan Hing Hon 1984). Infested trees stay alive and continue to grow, the disease being discovered only when the trees are felled and it becomes evident

that only a thin layer of sap wood remains (Somyos Kijkar). *A. mangium* and *A. auriculiformis* cannot withstand the ground fire and crown fire. They do not have die back phenomenon after the crown fire has occurred. *A. mangium* and *A. auriculiformis* tend to produce very large lateral branches, which often started low on the trunk. *Acacia auriculiformis* produces profuse bundles of nodules and it can survive on land very low in nitrogen and organic matter where eucalyptus and other species fail (Ayes 1980).

Laterite and lateritic soil is found to be slightly acid to acidic condition and poor in nutrients (Tin Tin Ohn, 1993). Species trial on poor sites such as gravelly soil over a lateritic hardpan, in Bangladesh, indicated that the growth of *A. mangium* is still better than several provenances of *E. camaldulensis*. All tested species have coppicing power, however, coppice systems trial is required for them because they can be attacked easily by termites and also succumb to heart rot.

*A. mangium* x *A. auriculiformis* (hybrid *Acacia*) was discovered in 1972. As being leguminous, hybrid *Acacia* grows quickly on several types of soils, is drought tolerant, and resists insects and diseases. For these reasons, hybrid *Acacia* is rapidly gaining acceptance in ASEAN region and shows considerable potential as an industrial plantation species. It coppices well. It grows much faster than either parents (Somyos Kijkar 1992).

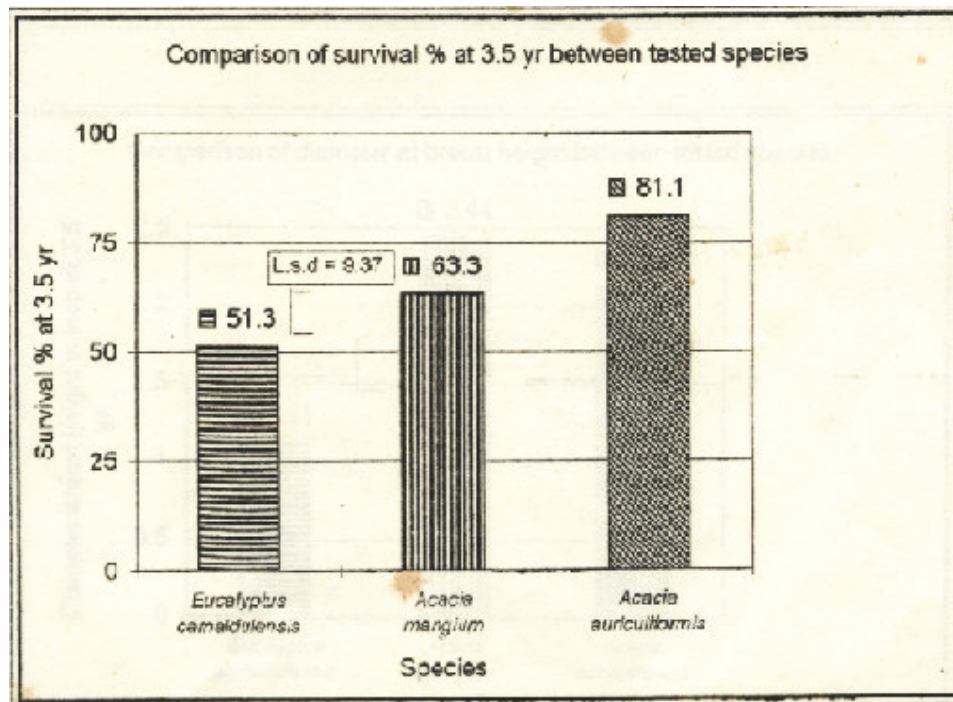
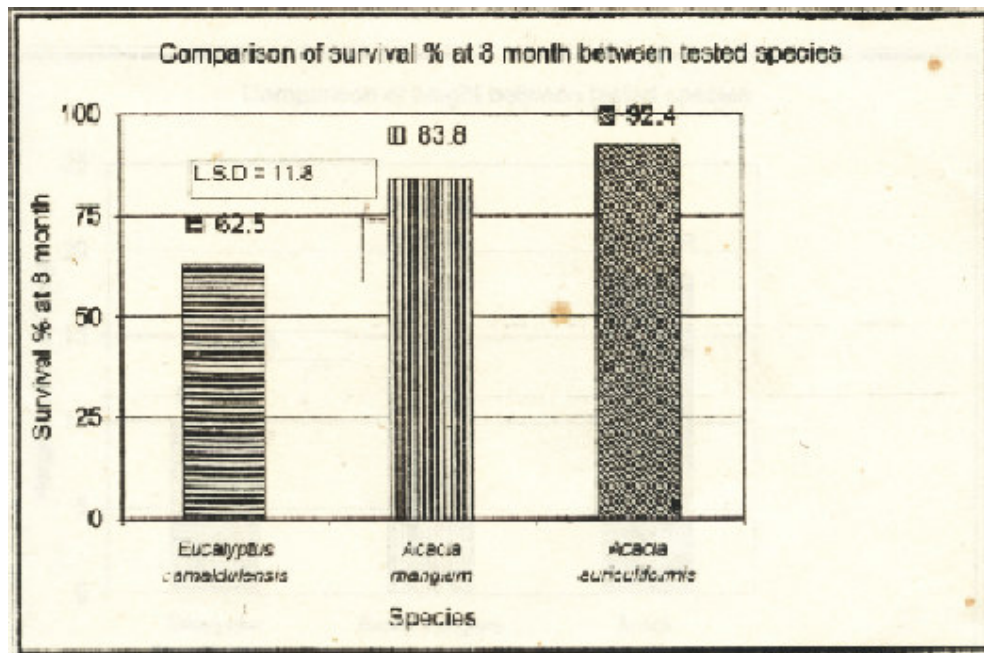
At the Thai/Japan International Cooperation Agency reforestation and training center in Sakaerat, Nakhorn Ratchasima, the hybrid *Acacia* was outplanted with *A. mangium* in relatively dry lateritic clay soil. After only 3 months, the hybrid was twice as high as *A. mangium* (Somyos Kijkar 1992).

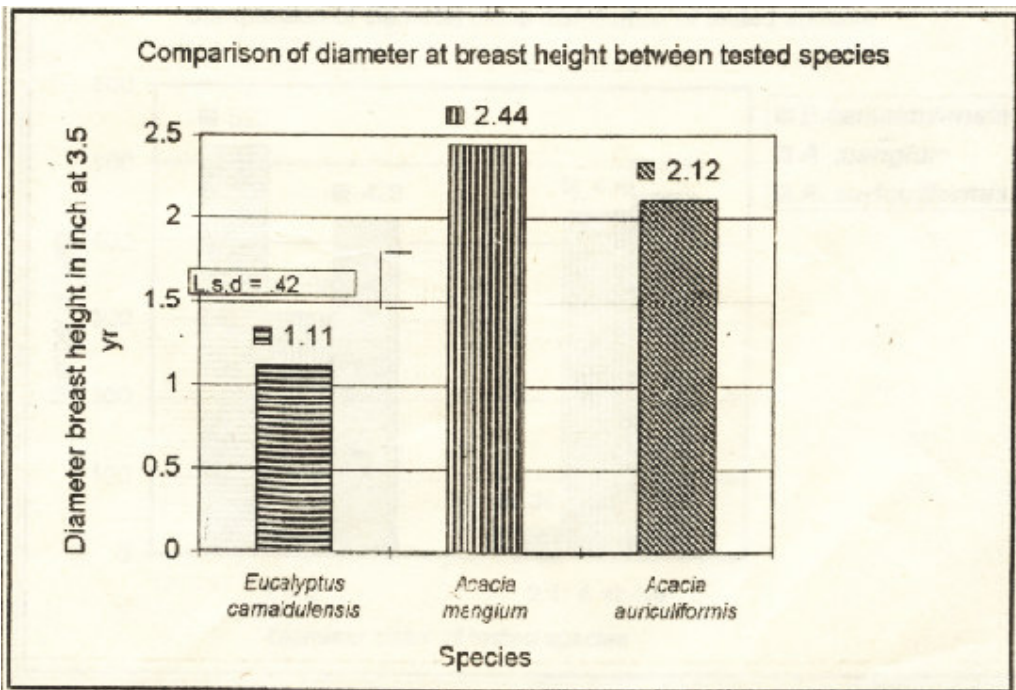
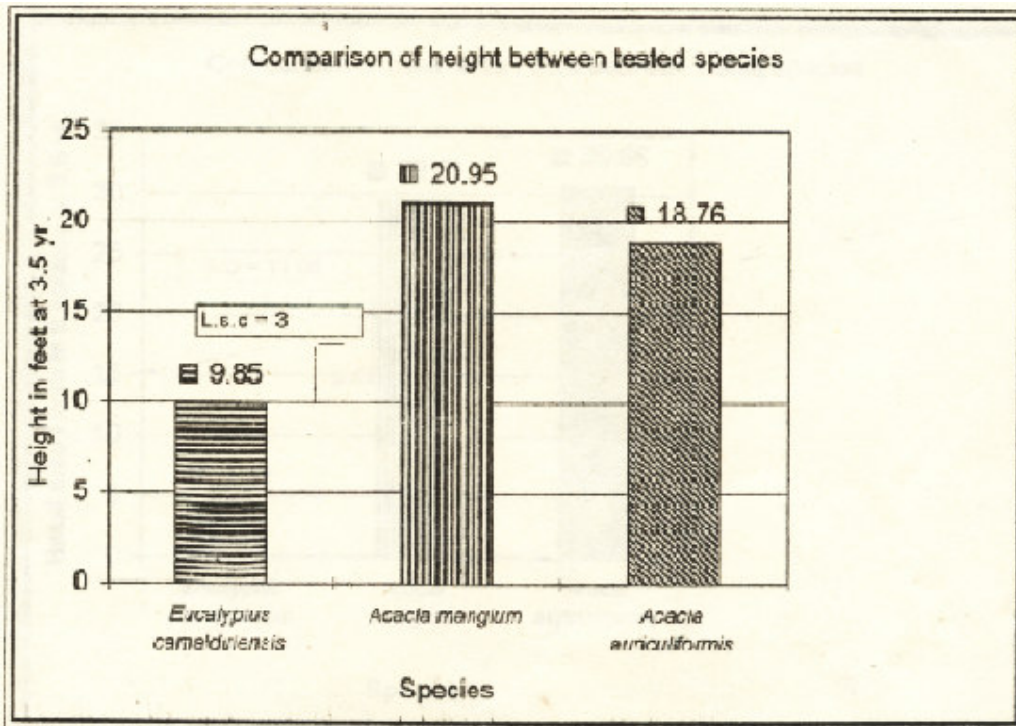
Species trial with hybrid *Acacia*, other fast growing *Acacia* species and *Eucalyptus* species on laterite and lateritic clayey soil at heavy rainfall area is required for pulpwood plantations.

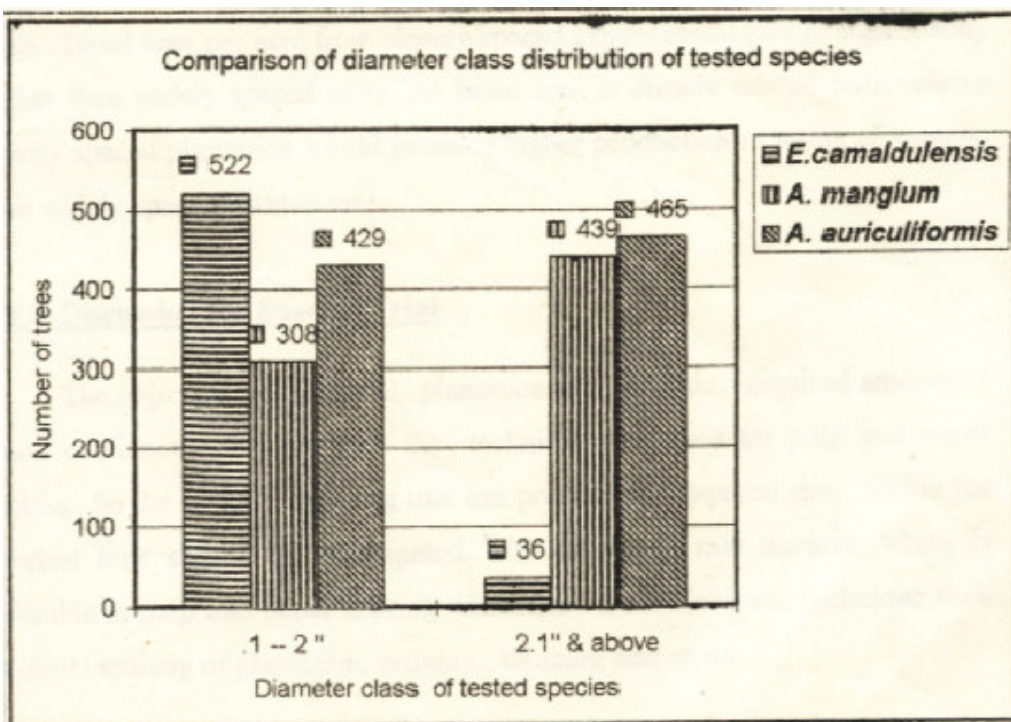
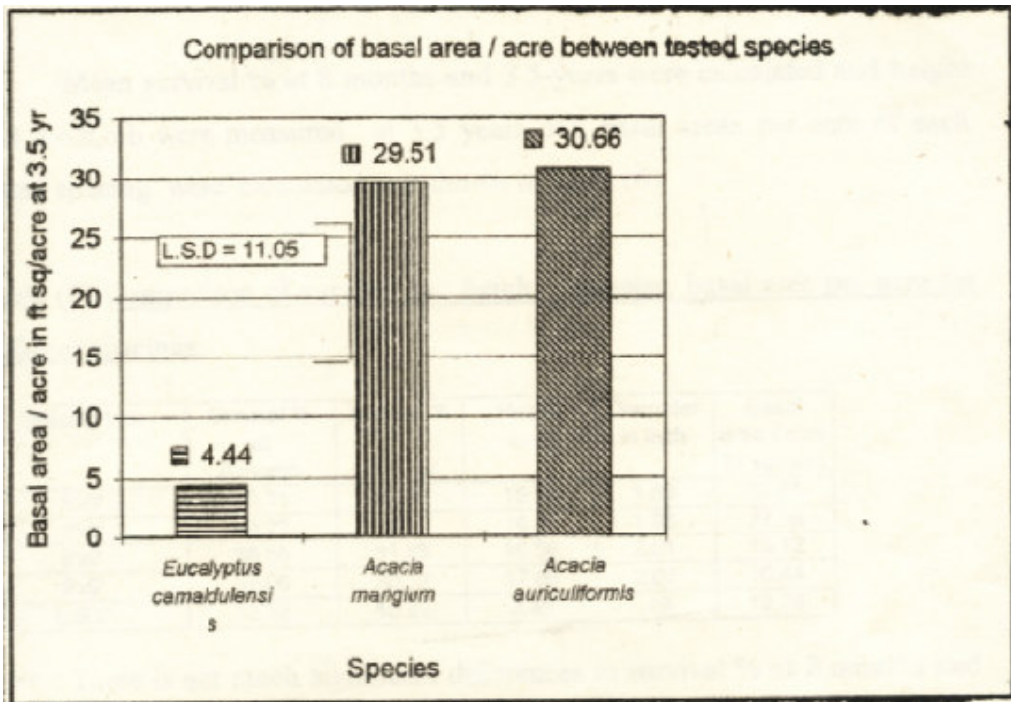
All tested species at lateritic soil should be observed when they will terminate their rate of growth and life-span. Minimum utilizable size for pulpwood of these species should be found out with the cooperation of paper mill.

### **3.2.3 Conclusion on Species Trial**

*A. mangium* & *A. auriculiformis* can be introduced at clayey laterite and lateritic soils in heavy rainfall areas for pulpwood and fuelwood, provided if appropriate measures are being taken for fire protection, heart rot disease control and pruning.







### 3.3.1 Spacing

Mean survival % at 8 months and 3.5 years were calculated and height and d.b.h.o.b were measured at 3.5 years old; basal areas per acre of each tested spacing were calculated and shown in table (6)

**Table (6) Comparison of survival %, height, diameter, basal area per acre for different spacings.**

Spacing trial	Survival % at 8 months	Survival % at 3.5 yr	Height in ft	Diameter in inch	Basal area/ acre (ft.sq)
3' x 6'	40.11	32.78	15.19	1.63	32.96
3' x 9'	40.22	33	16.67	1.86	27.58
6' x 9'	38.56	31.83	16.56	2.01	15.12
9' x 9'	37.06	30.12	17.65	2.07	10.44
L.S.D	13.62	10.82	3.46	0.49	12.76

There is not much significant differences in survival % at 8 months and 3.5 years as well as height and diameter growth between the different spacing trials. Basal area per acre from closely spaced experimental plot is significantly higher than widely spaced plots. As basal area is closely related with volume closely spaced plantation would produce higher production in terms of volume, than widely spaced plantations.

### 3.3.2 Discussion for Spacing Trial

The objective of industrial plantation is to provide required amount of wood continuously in line with the technical girth limit for pulp and paper making. So the optimum spacing that can produce the required size within the shortest time should be investigated. The quality of raw material which is desirable in pulp and paper making influences the silvicultural technique such as initial spacing of plantation, pruning, thinning and so on.

It is recommended to adopt closer spacing on adverse soil so as to ensure the artificial regeneration. Weed problem can be abrogated by adopting closer spacing. Weeds can be suppressed with closed canopy of closely spaced trees. In accessible area, where fuelwood is in great demand, by adopting closer spacing, the pole size trees from the first thinning can be marketed to alleviate fuelwood shortage problem.

*A. mangium* & *A. auriculiformis* are very branchy especially if they were planted at wider spacing. According to preliminary observation at spacing trial, these species produce very large lateral branches, which often start from the lower part of the trunk. If planted with wider spacing, pruning have to be done for the production of clean boles.

### 3.3.3 Conclusion for Spacing Trial

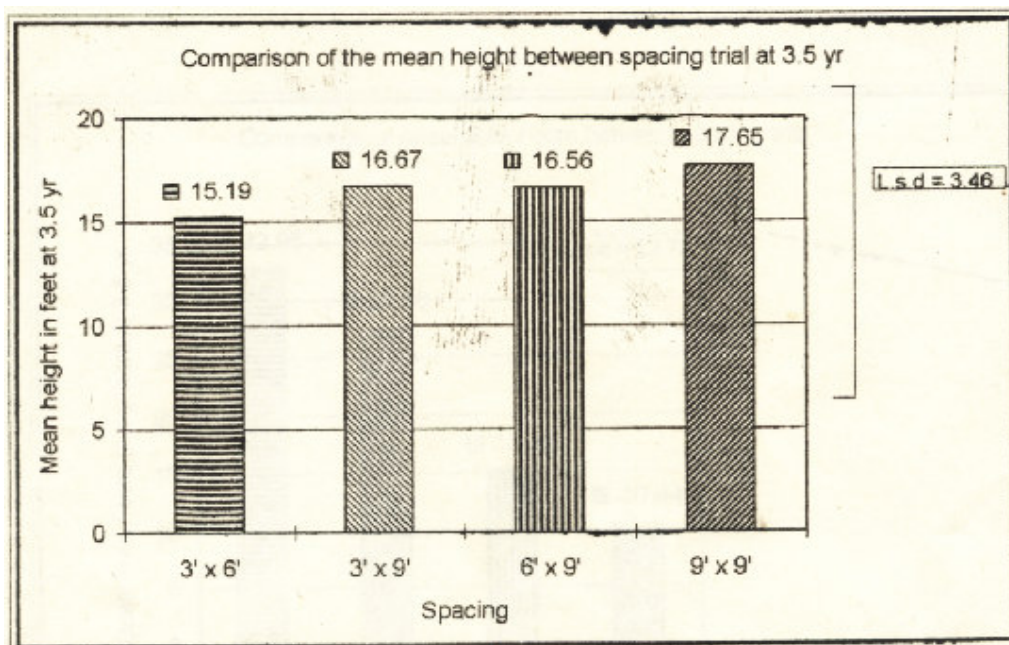
1. Close spacing [ 3' x 6', 3' x 9'] can be adopted for the following conditions:
  - (a) if branchy species are to be used;
  - (b) on adverse soil type;
  - (c) for reducing weeds;
  - (d) in easily accessible area;

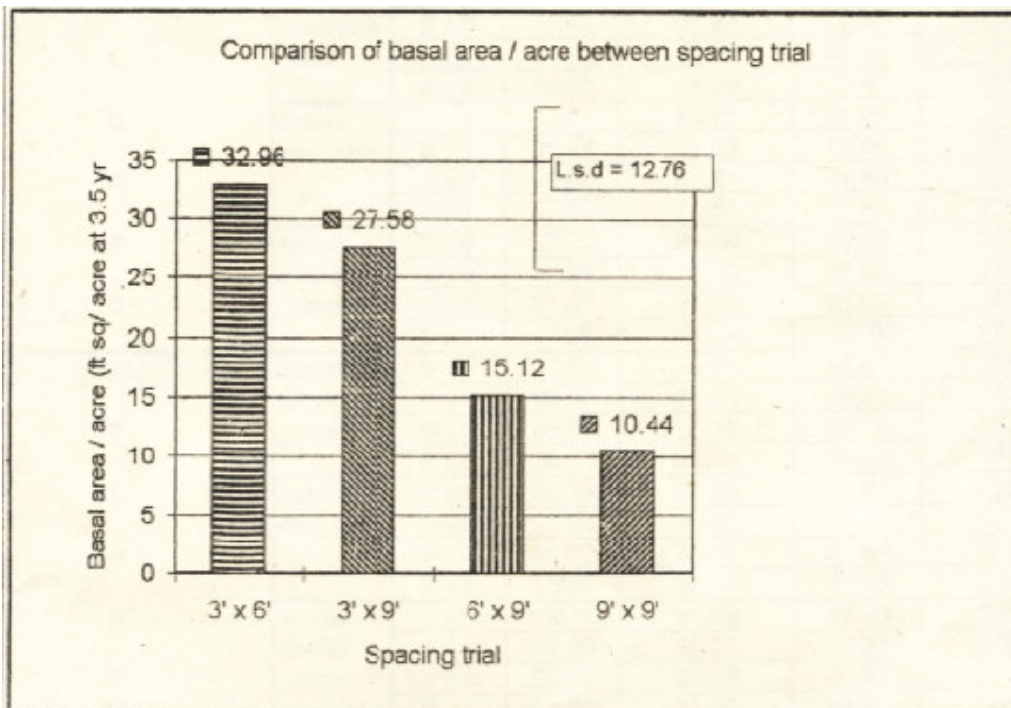
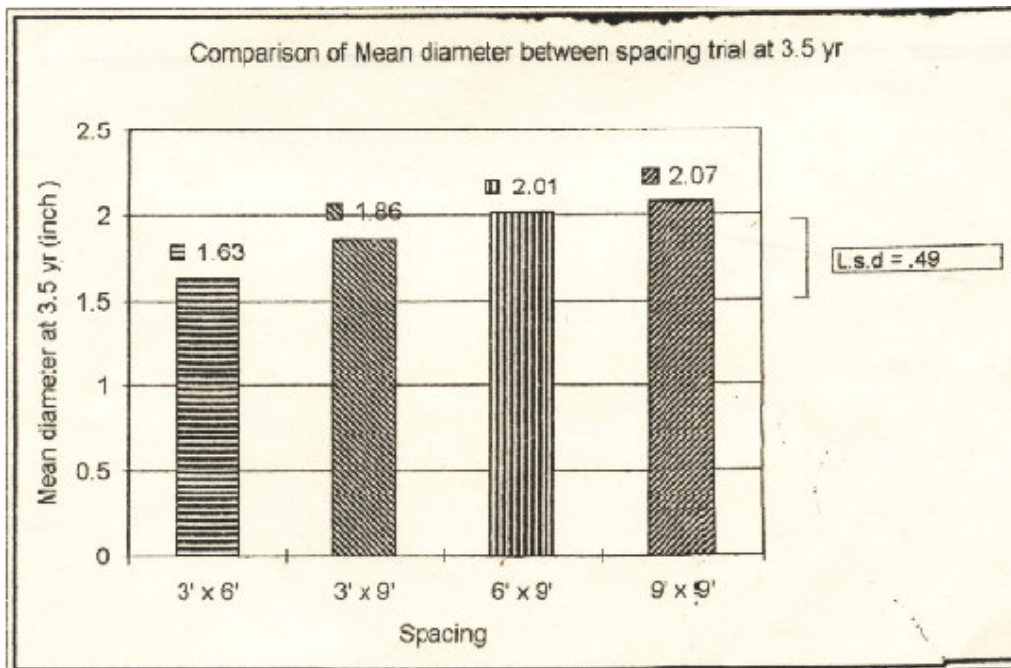
- (e) if small material produced from first thinning can be marketed as fuelwood and the remaining stems used as pulpwood.
2. Wider spacing [6' x 9', 9' x 9'] can be adopted under the following conditions;
- (a) in inaccessible area
  - (b) if pruning can be done for branchy species.
  - (c) if small fuelwood is not required for villagers and the object of plantation is not only for pulpwood but also for sawn timber.

### 3.3.4 Suggestion for Spacing Trial

The effect of the various diameter classes on the pulping quality should be studied for fast growing species. This will result in selecting the right rotation of each species and consequently the initial spacing to be adopted for pulpwood plantations.

Height and diameter growth in each spacing trial plots should be measured annually so as to detect the decrease in rate of growth. Thinning should be carried out when the diameter growth begins to decrease.





## Appendix I

**Table (1.A) Raw data, study on the effective of side preparation, species and spacing trial on survival% at 8 months**

Treatment combination			Survival % by block			Treatment Total
			B I	B II	B III	
P  L  O  W  E  D	<i>Eucalyptus camaldulensis</i>	3' x 6'	65.31	79.59	75.51	220.41
		3' x 9'	71.43	81.63	75.51	228.57
		6' x 9'	61.22	42.86	69.39	173.47
		9' x 9'	44.90	44.90	73.47	163.27
	<i>Acacia mangium</i>	3' x 6'	73.47	85.71	91.84	251.02
		3' x 9'	91.84	81.63	89.80	263.27
		6' x 9'	95.92	65.31	91.84	253.06
		9' x 9'	87.76	75.51	95.92	259.18
	<i>Acacia auriculiformis</i>	3' x 6'	97.96	91.84	95.92	285.71
		3' x 9'	97.96	77.55	97.96	273.47
		6' x 9'	91.84	97.96	95.92	285.71
		9' x 9'	77.55	100.00	100.00	277.55
UN  P  L  O  W  E  D	<i>Eucalyptus camaldulensis</i>	3' x 6'	57.14	53.06	81.63	191.84
		3' x 9'	63.27	69.39	75.51	208.16
		6' x 9'	46.94	55.10	55.10	157.14
		9' x 9'	36.73	65.31	55.10	157.14
	<i>Acacia mangium</i>	3' x 6'	69.39	67.35	91.84	228.57
		3' x 9'	91.84	93.88	71.43	257.14
		6' x 9'	95.92	71.43	91.84	259.18
		9' x 9'	75.51	69.39	93.88	238.78
	<i>Acacia auriculiformis</i>	3' x 6'	100.00	97.96	97.96	295.92
		3' x 9'	97.96	85.71	63.27	246.94
		6' x 9'	95.92	93.88	97.96	287.76
		9' x 9'	97.96	77.55	89.80	265.31
Block Total			1885.71	1824.49	2018.37	5728.57

**Table (1-B) Two way table of survival % at 8 month for species and site preparation trial**

Species Trial	Site Preparation Trial		Species Total	Mean sur % of species
	Plowed	Unplowed		
<i>Eucalyptus camaldulensis</i>	785.72	714.28	1500	62.5
<i>Acacia mangium</i>	1026.53	983.67	2010.2	83.8
<i>Acacia auriculiformis</i>	1122.44	1095.93	2218.37	92.4
Site preparation total	2934.69	2793.88	5728.57	
Mean survival % of site pre	81.5	77.6		

**Table (1-C) Two way table of survival % at 8 month for spacing and species trial**

Species Trial	Spacing Trial				Species Total	Mean sur % of species
	3' x 6'	3' x 9'	6' x 9'	9' x 9'		
<i>Eucalyptus camaldulensis</i>	412.25	436.73	330.61	320.41	1500	62.5
<i>Acacia mangium</i>	479.59	520.41	512.24	497.96	2010.2	83.8
<i>Acacia auriculiformis</i>	581.63	520.41	573.47	542.86	2218.37	92.4
Spacing total	1473.47	1477.55	1416.32	1361.23	5728.57	
Mean survival % of spacing	81.9	82.1	78.7	75.6		

**Table (1-D) Two way table of survival % at 8 month for spacing and site preparation trial**

Species Preparation	Spacing Trial				Site preparation total	Mean sur % of spp.
	3'x 6'	3'x 9'	6' x 9'	9' x 9'		
Plowed	757.14	765.31	712.24	700	2934.69	81.5
Unplowed	716.33	712.24	704.08	661.23	2793.88	77.6
spacing Total	1473.47	1477.55	1416.32	1361.23	5728.57	
Mean sur% of spacing	81.9	82.1	78.7	75.6		

continue to (ANOVA table 1)

**Appendix II**

**Table (2.A) Raw data, study on the effect of side preparation, species and spacing trial on survival% at 3.5 yr**

Treatment combination			Survival % by block			Treatment Total
			B I	B II	B III	
P  L  O  W  E  D	<i>Eucalyptus camaldulensis</i>	3' x 6'	55.10	65.30	65.30	185.70
		3' x 9'	57.10	71.40	59.20	187.80
		6' x 9'	42.90	63.30	75.50	181.60
		9' x 9'	20.40	26.50	42.90	89.80
	<i>Acacia mangium</i>	3' x 6'	61.20	79.60	51.00	191.80
		3' x 9'	67.30	63.30	71.40	202.00
		6' x 9'	77.60	59.20	79.60	216.30
		9' x 9'	85.70	40.80	87.80	214.30
	<i>Acacia auriculiformis</i>	3' x 6'	98.00	85.70	79.60	263.30
		3' x 9'	98.00	83.70	91.80	273.50
		6' x 9'	81.60	69.40	85.70	236.70
		9' x 9'	75.50	95.90	79.60	251.00
UN  P  L  O  W  E  D	<i>Eucalyptus camaldulensis</i>	3' x 6'	42.90	59.20	55.10	157.10
		3' x 9'	53.10	55.10	61.20	169.40
		6' x 9'	32.70	44.90	49.00	126.50
		9' x 9'	34.70	55.10	42.90	132.70
	<i>Acacia mangium</i>	3' x 6'	55.10	55.10	63.30	173.50
		3' x 9'	79.60	63.30	20.40	163.30
		6' x 9'	83.70	28.60	55.10	167.30
		9' x 9'	79.60	30.60	79.60	189.80
	<i>Acacia auriculiformis</i>	3' x 6'	100.00	81.60	51.00	232.70
		3' x 9'	98.00	63.30	55.10	216.30
		6' x 9'	93.90	81.60	65.30	240.80
		9' x 9'	93.90	59.20	79.60	232.70
Block Total			1667.30	1481.60	1546.90	4695.90

**Table (2-B) Two-way table of survival % at 3.5 yr for species and site preparation trial**

Species Trial	Site Preparation Trial		Species Total	Mean sur % of species
	Plowed	Unplowed		
<i>Eucalyptus camaldulensis</i>	644.9	585.7	1230.6	51.3
<i>Acacia mangium</i>	824.5	693.9	1518.4	63.3
<i>Acacia auriculiformis</i>	1024.5	922.5	1946.9	81.1
Site preparation total	2493.9	2202.1	4695.9	
Mean survival % of site pre	69.3	61.2		

**Table (2-C) Two-way table of survival % at 3.5 yr for spacing and species trial**

Species Trial	Spacing Trial				Species Total	Mean sur% of species
	3' x 6'	3' x 9'	6' x 9'	9' x 9'		
<i>Eucalyptus camaldulensis</i>	342.9	357.2	308.2	222.5	1230.6	51.3
<i>Acacia mangium</i>	365.3	365.3	383.7	404.1	1518.4	63.3
<i>Acacia auriculiformis</i>	495.9	489.8	477.6	483.7	1946.9	81.1
Spacing total	1204.1	1212.3	1169.5	1110.3	4695.9	
Mean survival % of spacing	66.9	67.3	65.0	61.7		

**Table (2-D) Two-way table of survival % at 3.5 yr for spacing and site preparation trial**

Species Preparation	Spacing Trial				Site preparation total	Mean sur% of spp.
	3'x6'	3' x 9'	6' x 9'	9' x 9'		
Plowed	640.8	663.3	634.7	555.1	2493.9	69.3
Unplowed	563.3	549	534.7	555.1	2202.1	61.2
Spacing Total	1204.1	1212.3	1169.4	1110.2	4695.9	
Mean sur% of spacing	66.9	67.3	65	61.7		

continue to (ANOVA table 2)

Appendix III

**Table (3.A) Raw data, study on the effect of site preparation, species and spacing trial on height growth of tested trees**

Treatments combination			Mean height in feet by block			Treatment Total
			B I	B II	B III	
P  L  O  W  E  D	<i>Eucalyptus camaldulensis</i>	3' x 6'	7.07	10.94	7.97	25.98
		3' x 9'	7.74	12.71	9.41	29.86
		6' x 9'	7.42	13.62	9.85	30.89
		9' x 9'	14.40	18.62	8.05	41.07
	<i>Acacia mangium</i>	3' x 6'	20.17	25.52	9.26	54.95
		3' x 9'	24.92	26.06	16.94	67.92
		6' x 9'	25.35	28.01	15.50	68.86
		9' x 9'	24.61	30.38	18.11	73.10
	<i>Acacia auriculiformis</i>	3' x 6'	23.45	30.48	17.11	71.04
		3' x 9'	19.42	29.43	17.44	66.29
		6' x 9'	21.80	26.38	12.82	61.00
		9' x 9'	17.37	26.25	14.05	57.67
UN  P  L  O  W  E  D	<i>Eucalyptus camaldulensis</i>	3' x 6'	7.00	5.93	7.20	20.13
		3' x 9'	9.70	7.67	9.43	26.80
		6' x 9'	13.43	5.10	10.25	28.78
		9' x 9'	14.90	6.59	11.28	32.77
	<i>Acacia mangium</i>	3' x 6'	25.80	12.35	18.47	56.62
		3' x 9'	26.12	12.13	16.34	54.59
		6' x 9'	32.80	17.03	15.10	64.93
		9' x 9'	29.68	13.01	19.09	61.78
	<i>Acacia auriculiformis</i>	3' x 6'	21.28	10.08	13.33	44.69
		3' x 9'	26.04	12.46	16.16	54.66
		6' x 9'	18.95	11.90	12.74	43.59
		9' x 9'	23.70	13.94	13.65	51.29
Block Total			463.1	406.6	315.50	1189.20

**Table (3-B) Two-way table of Height growth at 3.5 yr for species and site preparation trial**

Species Trial	Site Preparation Trial		Species Total	Mean height % of species
	Plowed	Unplowed		
<i>Eucalyptus camaldulensis</i>	127.8	108.48	236.28	9.85
<i>Acacia mangium</i>	264.83	237.92	502.75	20.95
<i>Acacia auriculiformis</i>	256	194.21	450.21	18.76
Site preparation total	648.63	540.61	1189.24	
Mean height % of site pre	18.02	15.02		

**Table (3-C) Two-way table of height growth at spacing and species trial**

Species Trial	Spacing Trial				Species Total	Mean height % of species
	3'x6'	3' x 9'	6' x 9'	9' x 9'		
<i>Eucalyptus camaldulensis</i>	46.11	56.66	59.67	73.84	236.28	9.85
<i>Acacia mangium</i>	111.57	122.51	133.79	134.88	502.75	20.95
<i>Acacia auriculiformis</i>	115.73	120.95	104.57	108.96	450.21	18.76
Spacing total	273.41	300.12	298.03	317.68	1189.24	
Mean height % of spacing	15.19	16.67	16.56	17.65		

**Table (3-D) Two way table of height growth at 3.5 yr for spacing and site preparation trial**

Species Preparation	Spacing Trial				Site preparation total	Mean sur % of spp.
	3'x6'	3' x 9'	6' x 9'	9' x 9'		
Plowed	151.97	164.07	160.75	171.84	648.63	18.02
Unplowed	121.44	136.05	137.28	145.84	540.61	15.02
spacing Total	273.41	300.12	298.03	317.68	1189.24	
Mean height of spacing	15.19	16.67	16.56	17.65		

continue to (ANOVA table 3)

Appendix IV

**Table (4.A) Raw data, study on the effect of site preparation, species and spacing trial on diameter growth at 3.5 yr.**

Treatments combination			Mean diameter in inch by blocks			Treatment total
			B I	B II	B III	
P  L  O  W  E  D	Eucalyptus camaldulensis	3' x 6'	0.61	1.12	0.97	2.70
		3' x 9'	0.60	1.34	0.76	2.70
		6' x 9'	1.40	2.26	1.25	4.91
		9' x 9'	1.43	2.80	0.52	4.75
	Acacia mangium	3' x 6'	2.30	2.96	1.01	6.27
		3' x 9'	2.94	3.32	1.94	8.20
		6' x 9'	3.06	3.36	1.84	8.26
		9' x 9'	3.19	4.15	1.99	9.33
	Acacia auriculiformis	3' x 6'	2.07	3.22	1.78	7.07
		3' x 9'	1.98	3.22	2.13	7.33
		6' x 9'	2.56	3.75	1.51	7.82
		9' x 9'	2.26	2.85	1.46	6.57
UN  P  L  O  W  E  D	Eucalyptus camaldulensis	3' x 6'	0.69	0.54	0.73	1.96
		3' x 9'	0.86	0.70	1.22	2.78
		6' x 9'	1.75	0.47	1.30	3.52
		9' x 9'	1.63	0.60	1.06	3.29
	Acacia mangium	3' x 6'	2.96	1.43	2.20	6.59
		3' x 9'	2.87	1.03	2.06	5.96
		6' x 9'	3.69	1.53	1.61	6.83
		9' x 9'	3.75	1.52	1.76	7.03
	Acacia auriculiformis	3' x 6'	2.16	1.03	1.52	4.71
		3' x 9'	2.89	1.27	2.27	6.43
		6' x 9'	2.15	1.22	1.39	4.76
		9' x 9'	3.01	1.65	1.59	6.25
Block Total			52.81	47.34	35.88	136.02

**Table (4-B) Two-way table of Height growth at 3.5 yr for species and site preparation trial**

Species Trial	Site Preparation Trial		Species Total	Mean diameter of species
	Plowed	Unplowed		
<i>Eucalyptus camaldulensis</i>	15.06	11.55	26.61	1.1
<i>Acacia mangium</i>	32.01	26.41	58.42	2.4
<i>Acacia auriculiformis</i>	28.79	22.15	50.94	2.1
Site preparation total	75.86	60.11	135.97	
Mean diameter of site pre	2.1	1.7		

**Table (4-C) Two way-table of diameter at 3.5yr for spacing and species trial**

Species Trial	Spacing Trial				Species Total	Mean diameter of species
	3'x6'	3'x9'	6'x9'	9' x 9'		
<i>Eucalyptus camaldulensis</i>	4.67	5.47	8.43	8.04	26.61	1.1
<i>Acacia mangium</i>	12.86	14.16	15.09	16.36	58.47	2.4
<i>Acacia auriculiformis</i>	11.78	13.76	12.58	12.82	50.94	2.1
Spacing total	29.31	33.39	36.1	37.22	136.02	
Mean diameter of spacing	1.63	1.86	2.01	2.07		

**Table (4-D) Two-way table of diameter at 3.5 yr for spacing and site preparation trial**

Species Preparation	Spacing Trial				Site preparation total	Mean diameter of spp.
	3'x6'	3'x 9'	6' x 9'	9' x 9'		
Plowed	16.04	18.23	20.99	20.65	75.91	2.1
Unplowed	13.26	15.17	15.11	16.57	60.11	1.7
spacing Total	29.31	33.39	36.1	37.22	136.02	
Mean diameter of spacing	1.63	1.86	2.01	2.07		

Continue to (ANOVA table 4)

Appendix V

**Table (5.A) Raw data, study on the effect of site preparation, species and spacing trial on basal area per acre (square feet/acre)**

Treatments combination			Mean area per acre by block			Treatment Total
			B I	B II	B III	
P  L  O  W  E  D	<i>Eucalyptus camaldulensis</i>	3' x 6'	2.74	10.95	8.27	22.0
		3' x 9'	1.83	11.43	3.02	16.3
		6' x 9'	3.74	14.40	5.26	23.40
		9' x 9'	1.24	6.18	0.35	7.8
	<i>Acacia Mangium</i>	3' x 6'	43.30	93.22	6.96	143.5
		3' x 9'	51.88	62.15	23.96	138.0
		6' x 9'	32.36	29.77	12.01	74.1
		9' x 9'	25.91	20.88	10.32	57.1
	<i>Acacia Auriculiformis</i>	3' x 6'	56.11	118.80	33.71	208.6
		3' x 9'	34.23	77.32	37.13	148.7
		6' x 9'	23.84	43.48	8.71	76.0
		9' x 9'	11.46	23.14	5.04	39.6
UN  P  L  O  W  E  D	<i>Eucalyptus camaldulensis</i>	3' x 6'	2.73	2.31	3.96	9.00
		3' x 9'	3.50	2.39	8.12	14.0
		6' x 9'	4.46	0.40	3.69	8.5
		9' x 9'	2.74	0.59	1.43	4.8
	<i>Acacia Mangium</i>	3' x 6'	64.54	15.06	40.93	120.5
		3' x 9'	58.43	5.98	7.72	72.1
		6' x 9'	50.77	2.98	6.36	60.1
		9' x 9'	33.25	2.10	7.32	42.7
	<i>Acacia Auriculiformis</i>	3' x 6'	62.37	11.58	15.76	89.7
		3' x 9'	72.92	9.09	25.30	107.3
		6' x 9'	18.92	5.41	5.62	30.0
		9' x 9'	25.27	4.79	5.98	36.0
Block Total			688.50	574.4	286.9	1549.8

**Table (5-B) Two-way table of basal area/acre at 3.5 yr for species and site preparation trial**

Species Trial	Site Preparation Trial		Species Total	Mean basal area/acre of spp
	Plowed	Unplowed		
<i>Eucalyptus camaldulensis</i>	69.5	36.3	105.8	4.41
<i>Acacia mangium</i>	412.7	295.4	708.1	29.5
<i>Acacia auriculiformis</i>	472.9	263	735.9	30.66
Site preparation total	955.1	594.7	1549.8	
Mean basal area/acre of site pre	26.53	16.52		

**Table (5-C) Two way-table of basal area/acre at spacing and species trial**

Species Trial	Spacing Trial				Species Total	Mean bac area/acre of spp
	3'x6'	3'x9'	6'x9'	9' x 9'		
<i>Eucalyptus camaldulensis</i>	31	30.3	31.94	12.56	105.8	4.41
<i>Acacia mangium</i>	264.04	210.13	134.21	99.77	708.15	29.51
<i>Acacia auriculiformis</i>	298.31	256.01	105.95	75.63	735.9	30.66
Spacing total	593.34	496.44	272.1	187.96	1549.85	
Mean basal area/acre of spacing	32.96	27.58	15.12	10.44		

**Table (5-D) Two-way table of basal area/acre at 3.5 yr for spacing and site preparation trial**

Species Preparation	Spacing Trial				Site preparation total	Mean basal area/acre of site pre
	3'x6'	3'x 9'	6' x 9'	9' x 9'		
Plowed	374.1	303	173.5	104.5	955.1	26.53
Unplowed	219.2	193.4	98.6	83.5	594.7	16.52
spacing Total	593.3	496.4	272.1	188	1549.8	
Mean basal area/acre of spacing	32.96	27.58	15.12	10.44		

continue to (ANOVA table 5)

## Appendix VI

**ANOVA table 1**

**ANOVA of the effect of site preparation, species and spacing trial on survival% of tested species at 8 months after planting**

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>F crit</i>
Site preparation	275.4	1	275.40	2.48	4.05
Species	11384.66	2	5692.33	51.25	3.2
Spacing	502.73	3	167.58	1.51	2.81
Site preparation,species	43.14	2	21.57	0.19	3.2
Site preparation,spacing	60.80	3	20.27	0.18	2.81
Species,	1747.82	6	291.30	2.62	2.3
Site preparation,species, Spacing	203.08	6	33.85	0.30	2.3
Treatment total	14217.63	23	618.16	5.57	1.75
Block total	818.52	2	409.26	3.68	3.20
Error	5109.56	46	111.08		
Total	20145.71	71			

**ANOVA table 2**

**ANOVA of the effect of site preparation, species and spacing trial on survival% of trees at 3.5 yr after planting**

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>F crit</i>
Site preparation	1185.76	1	1185.76	4.59	4.05
Species	10830.62	2	5415.31	20.97	3.2
Spacing	360.43	3	120.14	0.47	2.81
Site preparation,species	104.85	2	52.43	0.20	3.2
Site preparation,spacing	429.44	3	143.15	0.55	2.81
Species, Spacing	1665.20	6	277.53	1.07	2.3
Site preparation,species, Spacing	848.70	6	141.45	0.55	2.3
Over all treatment	15425	23	670.65	2.6	1.77
Block total	739.62	2	369.81	1.43	3.20
Error	11877.34	46	258.20		
Total	28041.961	71			

**ANOVA table 3**

**Analysis of variance of the effect of site preparation, species and spacing trial on the height growth of tested species at 3.5 yr after planting**

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>F crit</i>
Site preparation	162.06	1	162.06	6.14	4.05
Species	1660.18	2	830.09	31.424***	3.2
Spacing	55.25	3	18.42	0.70	2.81
Site preparation, species	42.75	2	21.37	0.81	3.2
Site preparation, spacing	1.50	3	0.50	0.02	2.81
Species, Spacing	96.26	6	16.04	0.61	2.3
Site preparation, species, Spacing	62.91	6	10.49	0.40	2.3
Overall Treatment	2080.87	23	90.47	3.43	1.77
Block	436.02	2	218.01	8.2531*	3.2
Error	1215.11	46	26.42		
Total	3731.99	71			

**ANOVA table 4**

**ANOVA table for the effect of site preparation, species and spacing trial on diameter growth of trees at 3.5 yr after planting**

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>F crit</i>
Site preparation	3.47	1	3.47	6.705*	4.05
Species	23.10	2	11.55	22.33***	3.2
Spacing	2.06	3	0.69	1.331 n.s	2.81
Site preparation, species	0.21	2	0.11	.206 n.s	3.2
Site preparation, spacing	0.33	3	0.11	.212 n.s	2.81
Species, Spacing	1.10	6	0.18	.353 n.s	2.3
Site preparation, species, Spacing	1.48	6	0.25	.478 n.s	2.3
Overall Treatment	31.75	23	1.38	2.6693	1.75
Block	6.22	2	3.11	6.01675	3.2
Error	23.79	46	0.52		
Total	61.77	71			

**ANOVA table 5**

**ANOVA of site preparation, species and spacing trial on basal area/acre at 3.5 yr**

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>F crit</i>
Site preparation	1803.47	1	1803.47	5.02	4.05
Species	10568.97	2	5284.48	14.71	3.2
Spacing	5961.79	3	1987.26	5.53	2.81
Site preparation, species	652.17	2	326.09	0.91	3.2
Site preparation, spacing	531.21	3	177.07	0.49	2.81
Species, Spacing	2836.7	6	472.78	1.32	2.3
Site preparation, species, Spacing	956.68	6	159.45	0.44	2.3
Overall treatment	23310.99	23	1013.52	2.82	1.75
Block	3568.37	2	1784.19	4.97	3.2
Error	16524.93	46	359.24		
Total	43404.29	71			



Soil Profile from plowed Plot.



*A. mangium* planted with 6' x 9' spacing (023-13)



*A. mangium* planted with 9' x 9' spacing (Fork, branchy, crooked stems and undergrowth are found) (124-8)



3.5 yr old *A. auriculiformis*, planted with 3' x 9' spacing (033-14)



3.5 yr old *A. auriculiformis*, planted with 6' x 9' spacing, undergrowth present due to open canopy. (033-14)

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