

There was no significant difference between the cultivation treatments in growth at either 10 or 30 months. Neither was there any significant interaction between cultivation and weed control treatments on the growth of *A. mangium* (Table 7). Growth in the control plots and plots treated with the Savannah plough and weed control is shown in Figures 11–14.

Conclusions

The benefit to *A. mangium* of control of *Imperata* grass with Roundup™ was clear at 10 months and was maintained to 30 months. This resulted in a doubling of wood production to 51 m³/ha at 30 months. Cultivation treatments had no additional effects on tree growth.

Table 7. Total volume of *A. mangium* in response to cultivation and weed control treatments in the cultivation trial.

Weed control	Cultivation	Total volume (m ³ /ha)	
		10 months	30 months
Nil	Pit	1.06	23.25
Nil	Disc harrow	0.91	27.71
Nil	Savannah plough	1.35	27.30
Roundup™	Pit	3.71	51.66
Roundup™	Disc harrow	3.76	54.00
Roundup™	Savannah plough	3.51	48.06

Note: there are no statistically significant interactions between weed control and cultivation. Main effect due to weed control is statistically significant (see Table 6).



Figure 9. The Savannah 3-in-1 plough. Looking towards the rear of the plough can be seen in sequence the wide winged tip of the blade plough, the tip of the winged deep ripping tyne, the offset discs, and the following tritter wheel.



Figure 10. Contour ploughed mounds produced with the Savannah 3-in-1 plough.



Figure 11. *A. mangium* in a control plot in the cultivation trial at 10 months. These trees received fertilizer at planting only.



Figure 12. *A. mangium* in a control plot in the cultivation trial at 30 months. These trees received fertilizer at planting only.



Figure 13. *A. mangium* in a treatment plot of Savannah plough and weed control in the cultivation trial at 10 months. These trees received fertilizer at planting.



Figure 14. *A. mangium* in a treatment plot of Savannah plough and weed control in the cultivation trial at 30 months. These trees received fertilizer at planting.

CHAPTER 5

Savannah Plough Trial

Objective

THE objective of this trial was to demonstrate and evaluate the effects of the component parts of the Savannah 3-in-1 plough on tree growth. The component parts of the Savannah 3-in-1 plough include a blade plough cultivating to 40–50 cm depth, a winged ripper cultivating to 90–100 cm depth, and four large discs cultivating the surface 30 cm of soil over a width of 2–2.5 m.

Design

The trial was laid out in three blocks in a NE–SW direction on an almost flat piece of land. Each block contained 16 plots. The treatments were applied as a full factorial design with each of the three plough components (blade plough, ripping tyne and mounding discs) being tested alone and in combination with the other two components. Each block was planted with two species, but the shortage of seedlings allowed only one species (*A. mangium* from Wipim, PNG) to be represented across each of the three blocks. *A. mangium* from Lake Murray (PNG) was also planted in one block; this allowed for a comparison between the Wipim and Lake Murray

provenances of *A. mangium*. The other species planted are not analysed here.

Base Treatments

Imperata grass was killed with Roundup™, and NPK fertilizer was applied after planting.

Results

Block effects

The cultivation effects in this trial were analysed across only two of the three blocks due to a significant block by treatment interaction which caused the elimination of one block from the statistical analysis.

Cultivation effects

The only statistically significant main effect at 10 months was due to discing, which significantly increased tree size and total volume (from 2.7 to 3.9 m³/ha). However, by 30 months the only significant difference between the disc and no-disc treatments was an increase in height due to discing, and fewer stems above breast height (Table 8). Discing also changed tree form at 10 months, making the faster-growing *A. mangium* trees squatter than the trees growing on soil that had not been disc ploughed (Table 8).

Table 8. Growth response of *A. mangium* at 10 and 30 months to cultivation with Savannah discs in the Savannah trial.

Treatment	Height (m)	Diameter (cm)	Mean tree volume (cm ³)	Basal area (m ² /ha)	Total volume (m ³ /ha)	Stems	Height:diameter
10 months							
Without Savannah discs	3.38	5.30	2717	2.30	2.7	1.99	65.60
With Savannah discs	3.51	5.98	3693	3.19	3.93	2.08	60.79
P ^a	NS	0.031	0.029	0.006	0.011	NS	0.01
30 months							
Without Savannah discs	11.39	12.48	48059	12.34	47.24	1.15	
With Savannah discs	11.82	12.80	50645	13.36	52.75	1.06	
P	0.038	NS	NS	NS	NS	0.039	

^aP indicates the level of statistical significance of the difference between the treatments.

A. mangium provenances

At 10 months there was no significant difference in growth between Wipim and Lake Murray provenances. However, by 30 months, the Wipim provenance of *A. mangium* had produced significantly more wood volume (57 m³/ha) than the Lake Murray provenance (50 m³/ha) (Table 9).

Conclusions

Discs were the only component of the Savannah 3-in-1 plough which improved the growth of

A. mangium on this soil type in South Kalimantan. There was no apparent benefit to *A. mangium* from deep ripping in this clay-loam soil type with a soft parent rock and deep C horizon. Discing had a marked effect on early tree growth, and the more rapid growth due to discing also resulted in trees which were relatively more squat and had more stems than those which were growing on soil that had not been disced.

Table 9. Growth response at 10 and 30 months of *A. mangium* provenances from Wipim (PNG) and Lake Murray (PNG) in the Savannah trial.

Provenance	Height (m)	Diameter (cm)	Mean tree volume (cm ³)	Basal area (m ² /ha)	Total volume (m ³ /ha)
10 months					
Wipim	3.80	6.12	4006	3.31	4.30
Lake Murray	3.69	6.08	4645	3.76	4.89
P ^a	NS	NS	NS	NS	NS
30 months					
Wipim	12.00	12.91	52983	14.25	57.00
Lake Murray	11.84	12.21	47737	12.44	49.68
P	NS	0.043	0.049	0.005	0.012

^aP indicates the level of statistical significance of the difference between the treatments.

Herbicide Trial

Objective

To demonstrate and measure the effects of chemical control of *Imperata* grass and other weeds on the growth of selected acacias and eucalypts.

Design

The trial was a factorial design with chemical weed control at two levels (Roundup™ and nil), and species at four levels (*A. mangium* from Wipim, PNG, *A. mangium* from Subanjeriji, Indonesia, *E. urophylla* from Wetar, Indonesia, and *E. camaldulensis* from Fergusson River, N.T.). The species were selected to test provenance variation in *A. mangium* to weed control, and to test two contrasting forms of eucalypts.

The trial was laid out in four blocks on a relatively flat site. Each block comprised eight plots each containing 49 trees. The internal measured plot contained 25 trees. Trees were planted in a square 3 × 3 m spacing.

Base Treatments

The area of the herbicide trial was cultivated with the Savannah 3-in-1 plough, and NPK fertilizer was applied after planting.

Results

Weed control

The main effect of chemical weed control with Roundup™ across all species was to significantly improve tree growth, with a marked increase in wood volume production across all four tree species (Table 10). The difference in tree growth due to control of *Imperata* grass was very marked at 10 months, and the effect was maintained at 30 months. Weed control also reduced the incidence of fungal and insect damage at 10 months.

Species × weed control interaction

In general, growth of eucalypts was more affected by grass competition than was the growth of *A. mangium*. Weed control increased wood volume production at 10 months in eucalypts by 7 to 11 times, whereas the increase in *A. mangium* was 2 to 3 times (Table 10). At 30 months the difference in wood production for the eucalypts had increased to approximately 12-fold, while that in *A. mangium* had fallen to 1.3 to 1.5-fold (Table 10).

By 30 months there was clearly much better growth of *A. mangium* from Wipim (64 m³/ha) than of *A. mangium* from Subanjeriji (37 m³/ha). With weed control, *A. mangium* from Wipim produced 72% more wood than from Subanjeriji. The number of stems produced by both provenances of *A. mangium* was increased significantly by weed control.

In the absence of weed control, both species of eucalypts grew very poorly and there was no significant difference between them. With weed control *E. urophylla* grew significantly better than *E. camaldulensis* in height, diameter, and total volume to 10 months. A similar difference in productivity at 30 months was not statistically significant.

Without weed control *E. urophylla* from Wetar produced only 1 m³/ha at 30 months, and had carried quite high levels of fungal damage at 10 months (Figs 15 and 16). By comparison, with weed control *E. urophylla* from Wetar produced 21 m³/ha at 30 months (Table 10) (Figs 17 and 18).

Table 10. (a) The main effect at 10 months of weed control and interactions between species and weed control on the growth of *A. mangium*.

	Weed control	Height (m)	Diameter (cm)	Mean tree volume (cm ³)	Basal area (m ² /ha)	Total volume (m ³ /ha)	Height: diameter (m:m)	Number of stems	Fungal damage	Insect damage
Weed control main effect	Nil	2.94	3.27	1059	0.98	1.08	97.8	1.07	1.68	4.17
	Roundup™	4.14	5.82	4144	3.02	4.13	72.5	1.48	1.34	4.05
	pa	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0022
Species × weed control interaction		Rank	Rank	Rank	Rank	Rank	Rank	Rank	Rank	Rank
<i>A. mangium</i> , Wipim	Nil	3.22 ab	3.87 b	1457 a	1.29 ab	1.5 a	87.6 a	1.01 a	1.49 a	4 a
<i>A. mangium</i> , Subanjeriji	Nil	3.34 abc	3.94 b	1547 a	1.46 b	1.7 ab	90.5 a	1.24 a	1.49 a	4.02 a
<i>E. urophylla</i> , Wetar	Nil	2.63 a	2.76 a	737 a	0.58 a	0.6 a	104.5 a	1.01 a	2.22 b	4.23 b
<i>E. camaldulensis</i> , N. T.	Nil	2.57 a	2.52 a	498 a	0.59 a	0.5 a	108.7 a	1.02 a	1.51 a	4.42 c
<i>A. mangium</i> , Wipim	Roundup™	3.83 bc	6.16 cd	4184 c	3.48 d	4.6 d	64.9 a	1.81 b	1.33 a	4.01 a
<i>A. mangium</i> , Subanjeriji	Roundup™	3.61 bc	5.25 c	2822 b	2.48 c	3.1 bc	70.7 a	1.95 b	1.29 a	4.02 a
<i>E. urophylla</i> , Wetar	Roundup™	5 d	6.51 d	6269 d	3.53 d	6.4 e	77.7 a	1.10 a	1.41 a	4.12 ab
<i>E. camaldulensis</i> , N. T.	Roundup™	4.11 c	5.37 c	3300 bc	2.61 c	3.7 c	76.4 a	1.06 a	1.31 a	4.03 a

^aP indicates the level of statistical significance of the difference between the treatments.

Rank: common letters indicate means which are not significantly different from one another at 5% significance level.

Table 10. (b) The main effect at 30 months of weed control and interactions between species and weed control on the growth of *A. mangium*.

	Weed control	Height (m)	Diameter (cm)	Mean tree volume (m ³)	Basal area (m ² /ha)	Total volume (m ³ /ha)					
Weed control main effect	Nil	7.96	6.93	17837	5.22	18.51					
	Roundup™	10.18	9.84	31301	8.88	33.80					
	P ^a	0.0001	0.0001	0.0001	0.0001	0.0001					
Species × weed control interaction		Rank	Rank	Rank	Rank	Rank					
<i>A. mangium</i> , Wipim	Nil	11.14	de	11.20	e	41208	e	10.39	c	41.48	e
<i>A. mangium</i> , Subanjeriji	Nil	10.30	cd	9.78	cd	27057	cd	8.58	c	29.73	cd
<i>E. urophylla</i> , Wetar	Nil	5.39	a	3.68	a	2077	a	1.07	a	1.79	a
<i>E. camaldulensis</i> , N.T.	Nil	5.01	a	3.08	a	1008	a	0.83	a	1.05	a
<i>A. mangium</i> , Wipim	Roundup™	12.19	e	12.70	f	58276	f	14.40	d	64.09	f
<i>A. mangium</i> , Subanjeriji	Roundup™	10.46	cd	10.70	de	34126	de	10.05	c	37.25	de
<i>E. urophylla</i> , Wetar	Roundup™	9.70	c	8.70	c	21391	c	6.30	b	21.28	bc
<i>E. camaldulensis</i> , N.T.	Roundup™	8.35	b	7.25	b	11410	b	4.77	b	12.59	b

^a P indicates the level of statistical significance of the difference between the treatments.

Rank: common letters indicate means which are not significantly different from one another at 5% significance level.



Figure 15. *E. urophylla* in a control plot in the herbicide trial at 10 months. These trees received only fertilizer at planting.



Figure 16. *E. urophylla* in a control plot in the herbicide trial at 30 months. These trees received only fertilizer at planting.



Figure 17. *E. urophylla* in a herbicide plot in the herbicide trial at 10 months. These trees received fertilizer at planting.



Figure 18. *E. urophylla* in a herbicide plot in the herbicide trial 30 months. These trees received fertilizer at planting.

Conclusions

Weed control is important to the success of *A. mangium* plantation establishment and can treble early volume production up to 64 m³/ha at 30 months. Provenance differences were maintained across weed control treatments, indicating that growth differences due to provenances did not primarily arise from a capacity to cope with weed competition.

Effective weed control is essential for the establishment of eucalypt plantations in *Imperata* grass areas where, without effective weed control, the plantation cannot be considered commercially viable.

Effective weed control in eucalypt plantations can result in an eleven-fold increase in early volume production and reduced fungal damage to foliage. The Wetar provenance of *E. urophylla* grew well, producing 21 m³/ha at 30 months on this monsoonal and coastal site, indicating potential for further selection and improvement in this provenance.

CHAPTER 7

Fertilizer Trial

Objective

TO examine the requirements of *A. mangium*, growing on moderately leached and degraded clay loam soils, for NPK and trace elements, and to compare the response to fertilizer applied to the surface after planting with the response to slow-release fertilizer applied in the soil at planting.

Design

The trial used a 9 × 4 randomised block design of eight fertilizer treatments and a control (nil) treatment. Phosphorus was tested at three rates, and NPK at three rates with the P rate the same as in the P alone treatments (Table 11). By comparing the effect of P alone with the effect of NPK treatments, the additional effect of NK fertilizer can be estimated. The effect of N alone or K alone cannot be estimated from this trial. Trace elements were also applied in combination with a parallel high NPK treatment. Growth response to the slow-release fertilizer Osmocote™ was also tested. Table 12 gives the elemental contents used in the trial.

The F1 treatment is the fertilizer rate which was applied over all trees in the other trials.

Table 12. Elemental contents of fertilizers used in the fertilizer trial.

Product	Elemental content (%)		
	N	P	K
TSP	0	20	0
15:15:15	15	6.6	12.5
Osmocote™	10	26	10

The trial was laid out in four blocks with each block containing one each of the nine treatments, randomly located. The plots contained 49 trees with an internal measurement plot of 25 trees. The trial was planted with *A. mangium* from Wipim (PNG) in a square 3 × 3 m spacing.

Base Treatments

The area of the fertilizer trial was cultivated with the Savannah 3-in-1 plough, and the *Imperata* grass was killed with Roundup™.

Table 11. Treatments in the fertilizer trial.

Treatment	Treatment level ^a	Product	Product (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Control	1	None	Nil	Nil	Nil	Nil
P1	2	TSP ^b	130	0	26	0
P2	3	TSP	261	0	52	0
P3	4	TSP	391	0	78	0
Osmocote™	–	Osmocote™	31	3.1	8	3
F1	2	15:15:15	400	60	26	50
F2	3	15:15:15	800	120	52	100
F3	4	15:15:15	1200	180	78	150
F3 + Trace elements	–	15:15:15 + Librel ^c	1200 + 5	180	78	150

^aRefers to levels 1–4 in Figure 19

^bTSP = triple superphosphate 46% P₂O₅

^cLibrel = proprietary trace element fertilizer mix

Results

At 10 months there were two main response groups; the nil fertilizer and P fertilizers, and the Osmocote™ and NPK fertilizers. There was some overlap between these groups. Within these groups at 10 months there was no statistically significant difference between means from different rates of fertilizer. At 30 months, there was an indication of a response to the higher levels of NPK fertilizer which was not evident at 10 months (Fig. 19).

At 10 months, maximum tree growth in the P treatments occurred at 52 kg P/ha, and in the NPK treatments at 52 kg P/ha, 120 kg N/ha, and 100 kg K/ha (Table 13, Fig. 19). Further application of P and NPK did not improve growth at this age. There was no additional growth response to the application of trace elements; this indicates that lack of trace elements is not limiting growth of *A. mangium* in this soil.

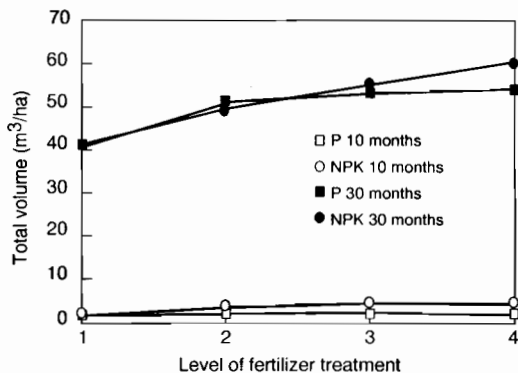


Figure 19. Total wood volume production of *A. mangium* across fertilizer treatments and time. Details of fertilizer treatment levels are given in Table 11.

At 30 months the effect of P was very evident, as was the additional effect on tree growth of N and K applied with P fertilizer. At 30 months the maximum application of NPK produced the greatest total volume of wood, but this was significantly different only from total volume production in the nil fertilizer treatment and low applications of P and NPK. The

additional effect of N and K over that of P fertilizer is shown in Table 14. NK increased total volume of *A. mangium* by about 2 m³/ha at 10 months, but the highest rate of NPK increased growth by 6 m³/ha over P alone at 30 months.

Figures 20 and 21 show growth at 10 months in an untreated control plot and a plot receiving high NPK fertilizer treatment.

The soils appear to be deficient in phosphorus; this is consistent with the presence of leaching in the soil profile (a pale A2 horizon and some ironstone gravel concretions in the B horizon). Intermittent burning of the *Imperata* grassland has left the soil with a very thin A1 horizon, and it is likely that the response to N and K is due to low organic matter in the surface soil.

The slow-release fertilizer, Osmocote™, was applied at rates of 3.1, 8, and 3 kg /ha NPK respec-

Table 14. Difference in total volume production between fertilizer treatments with the same rates of P, to demonstrate the additional effect of N with K fertilizer at 10 and 30 months. Treatment details are given in Table 11.

Treatments	Difference at 10 months (m³/ha)	Difference at 30 months (m³/ha)
F1-P1	1.02	-0.75
F2-P2	2.06	1.69
F3-P3	2.35	6.20

tively. This was applied in the planting zone at the time of planting. The response in tree growth at 10 months was similar to that of the surface applied 60, 26, and 50 kg /ha NPK treatment (F1).

The number of stems at breast height was related directly to the total volume production in each treatment and is shown in Figure 22. There was also a strongly negative correlation between total volume production and stem form, expressed as height:diameter, at 10 months, as shown in Figure 23. These two relationships between total volume production and the form of the tree indicate that the increased branching and squat stem form in *A. mangium* are due primarily to early rapid growth rates.

Table 13. Growth response of *A. mangium* at 10 and 30 months to P and NPK fertilizers in the fertilizer trial.

Treatment	Mean height		Mean diameter		Basal area		Mean tree volume		Total volume		Stems		Height:Diameter	
	(m)	Rank ^a	(cm)	Rank	(m ² /ha)	Rank	(cm ³)	Rank	(m ³ /ha)	Rank	(Number)	Rank	(m:m)	Rank
Control	2.60	a	3.83	a	1.44	a	1353	a	1.46	a	1.42	a	71.94	d
10 months														
P1	2.73	ab	4.21	ab	1.79	a	1722	a	1.90	a	1.55	ab	69.54	cd
P2	3.07	abcd	4.73	ab	2.14	a	2377	a	2.52	a	1.60	ab	69.21	cd
P3	2.81	abc	4.37	ab	1.89	a	1989	a	2.10	a	1.40	a	72.11	d
Osmocote	3.19	abcd	5.22	abc	2.51	ab	2739	ab	2.91	ab	1.74	ab	64.20	bc
F1	3.11	abcd	5.28	bc	2.58	abc	2757	ab	2.92	ab	1.87	ab	63.20	bc
F2	3.69	d	6.48	c	3.52	bc	4602	c	4.58	b	2.04	b	60.00	ab
F3	3.37	bcd	6.55	c	3.72	c	4407	bc	4.45	b	2.00	b	54.40	a
F3 + Te ^b	3.53	cd	6.50	c	3.51	bc	4595	c	4.37	b	1.99	b	57.20	ab
30 months														
Control	11.25	a	10.95	a	10.63	a	38485	a	41.22	a				
P1	11.30	a	12.02	ab	13.23	bc	46174	ab	50.80	ab				
P2	11.75	a	12.67	bcde	13.61	bc	50574	bcd	53.38	bc				
P3	11.53	a	12.72	bcde	13.98	bc	52231	bcd	54.60	bc				
Osmocote	11.50	a	12.42	bcd	13.06	bc	47687	abc	50.35	abc				
F1	11.81	a	12.25	bc	12.67	b	47934	abc	50.05	ab				
F2	12.02	a	13.63	de	13.79	bc	57959	cd	55.07	bc				
F3	11.95	a	13.80	e	15.15	c	60823	d	60.80	c				
F3+Te	11.87	a	13.48	cde	14.03	bc	58145	cd	56.19	bc				

^aCommon letters denote differences between means not significant at the 5% level.^bTe = trace elements



Figure 20. *A. mangium* in an untreated control plot (foreground) in the fertilizer trial at 10 months. The plot had been cultivated with the Savannah plough and received herbicide treatment.



Figure 21. *A. mangium* in a high NPK fertilizer treatment (180 kg N/ha, 78 kg P/ha and 150 kg K/ha) in the fertilizer trial at 10 months. The plot had been cultivated with the Savannah plough and received herbicide treatment.

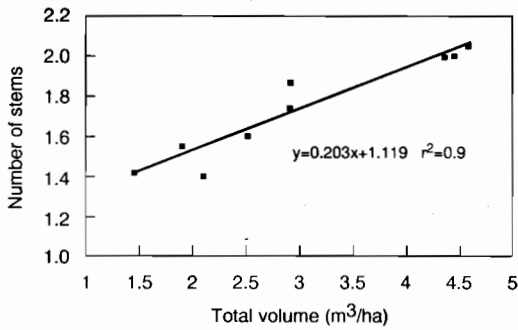


Figure 22. Relationship between growth of *A. mangium* and stems produced in the fertilizer trial at 10 months.

Conclusions

At 10 months there was a clear limit to the response of *A. mangium* to surface applied fertilizer; this limit was at the 52 kg P/ha treatment, and 120 kg N/ha, 52 kg P/ha and 100 kg K/ha treatment. There was no response to additional applications of trace element fertilizer to this soil. At 30 months the main response to the fertilizer treatments was increased volume growth at the higher rate of 180 kg N/ha, 78 kg P/ha and 150 kgK/ha. This suggests that there may be responses to higher rates of NPK fertilizer if applied incrementally over time to the trees.

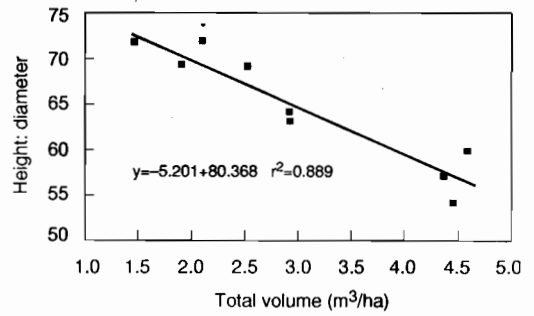


Figure 23. Relationship between height:diameter ratio and total volume of *A. mangium* in the fertilizer trial at 10 months.

At 10 months, the slow-release fertilizer, Osmocote™, gave growth responses similar to fertilizer applied to the surface at rates of up to 20 times greater i.e. lower rate of NPK application, and this relativity was maintained at 30 months.

Across all fertilizer treatments it was clear that increased total volume production at 10 months was concomitant with changes in stem form (becoming more squat), and increased numbers of stems at breast height. Thus, although additional fertilizer created increased volume production, it was directly responsible for a change in the stem form of the tree.

General Trends in *A. mangium*

TWO trends in the early growth of *A. mangium* (10 months) became clear when data from all the trials were put together; these trends are in the number of stems produced by the tree, and the shape of the stem. The means at 10 months for *A. mangium* (Wipim provenance) from the species trial, together with all treatment means for *A. mangium* (Wipim provenance) from the other trials, were combined to investigate these general trends.

Number of Stems

The number of dominant stems at 10 months increased as mean tree volume increased, as shown in Figure 24. The relationship was best described statistically by the 'number of stems' and a natural logarithm transformation of mean tree volume, 'ln mean tree volume'.

Stem Form

As mean tree volume increased at 10 months, the ratio of height:diameter of the stem decreased, i.e., as tree volume increased the shape of the stem became more squat. Conversely, in trees of smaller size, stem form was more slender (Fig. 25). The relationship was best described statistically by 'height:diameter' and a reciprocal transformation ($1/x$) of mean tree volume.

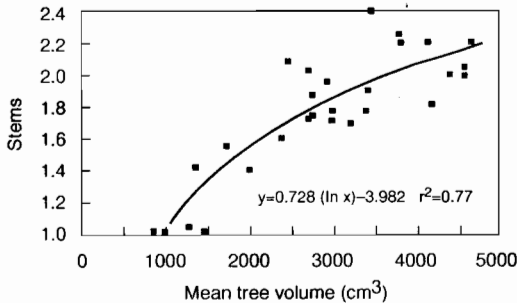


Figure 24. Relationship between stems and mean tree volume of *A. mangium* (Wipim) at 10 months.

Proportional Contribution of Treatments

The range of treatments in this series of trials allows for an estimate of the proportional contribution of each treatment to total volume production of *A. mangium*. The proportional contribution of treatments was estimated by comparing the difference in growth between treatments for cultivation (Savannah discs), P and NK fertilizer, chemical weed control, and the effect of using either Wipim or Subanjeriji provenances of *A. mangium*.

The estimated proportional contribution of treatments to total volume production of *A. mangium* are shown in Figure 26. Early growth of *A. mangium* at 10 months was affected most by chemical weed control (33%), followed by NK fertilizer (26%), cultivation (16%), P fertilizer (14%) and Wipim provenance (12%). However, at 30 months, the effects of the provenance (38%) and chemical weed control (33%) were most persistent, followed by the effects of P fertilizer (19%) and NK fertilizer (10%); the effect of cultivation did not persist to 30 months.

This analysis clearly shows the importance of chemical weed control in contributing to the successful establishment of *A. mangium* plantations in *Imperata* grassland, and the importance of fertilizer and cultivation in ensuring good early growth of the

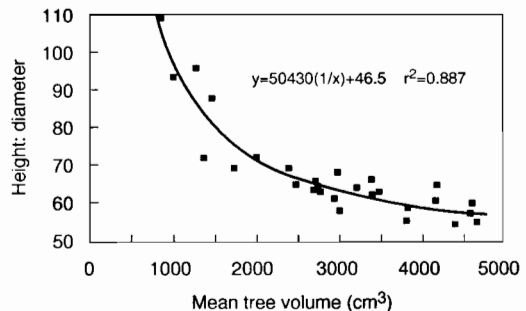


Figure 25. Relationship between height:diameter and mean tree volume of *A. mangium* (Wipim) at 10 months.

plantation. However, the enduring and most important treatments with respect to growth rate in this environment were the selection of a provenance with a high performance, and application of chemical weed control and NPK fertilizer.

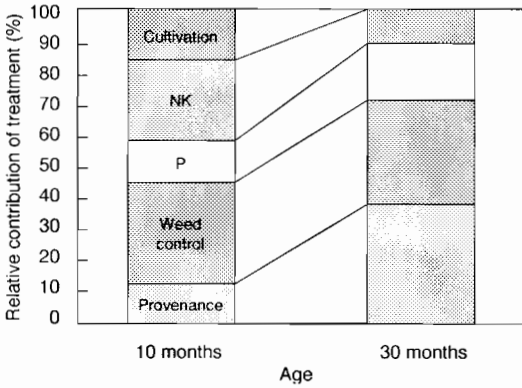


Figure 26. Proportional contribution of treatments to total volume production of *A. mangium*.

Conclusions

At 10 months, a more rapid growth rate of *A. mangium* resulted in squatter stems and increased stem branching. Selection of provenances of *A. mangium* for stem form and the production of single stems must be done by taking into account early growth rate. The more the growth of *A. mangium* is increased by silvicultural treatments such as weed control, cultivation and fertilizer, the more important it is to prune stems (singling) early in the growth of the tree (probably the first month). However, singling stems of *A. mangium* may create the added problem of establishing sites for the possible introduction of wood rot fungi into the stem.

The most important and long-lasting treatments for improved growth rate in this environment were the selection of Wipim provenance, chemical weed control and NPK fertilizers, each of which contributed between 29 and 38% of the total volume production of *A. mangium*.

General Conclusions

THESE trials have shown the great potential for tropical acacias to be used on poor *Imperata* grassland for the purpose of industrial pulpwood plantations. *A. mangium* showed particular promise because of its rapid growth rate, particularly when assisted with effective weed control and fertilizers. These trials also showed the importance of provenance selection in this species. The Wipim and Lake Murray (PNG) provenances and Claudie River (Qld) provenance performed better than the Subanjeriji (Indonesia) provenance in terms of both growth rate and tree form. The Subanjeriji provenance has developed from a local land race of *A. mangium* and as a result it has a narrow genetic base. Vuokko et al. (1992) also recommended that the Subanjeriji provenance should be avoided for the reasons confirmed by these trials.

A. crassicarpa showed promise as a species which has better form and higher wood density than *A. mangium* (Clark et al. 1991). *A. crassicarpa* has also been found to grow faster than *A. mangium* on poor sites in South Kalimantan (Vuokko 1991) and in Sabah (Sim 1992). The other species of acacias used in the trials showed either poorer growth or multi-stemmed form. In trials at Riam Kiwa in South Kalimantan it was also found that *A. auriculiformis* and *A. aulacocarpa* had poor form (Vuokko 1991, Vuokko et al. 1992).

The results of the silviculture trials (weed control and fertilizer) confirm the importance of effective chemical weed control and NPK fertilizer for the rapid growth of *A. mangium* on poor sites. In trials at Bengkoka, Mead and Miller (1991) demonstrated the importance of NPK fertilizer, and stressed the importance of P and N fertilizer on poor sites. At Riam Kiwa in South Kalimantan, Simpson (cited in Srivastava 1993) demonstrated the importance of K nutrition in explaining the growth of *A. mangium*. It is important to stress the requirement of adequate nutrition for acacias in plantations; although they are nitrogen-fixing species, acacias still require adequate nutrition in order to grow and further fix nitrogen (Ryan et al. 1991).

The form of *A. mangium* was shown here to be directly related to growth rate; with faster growth rates resulting in increased branching and squat stem formation. Anecdotal evidence of this was found in Bengkoka, Sabah, by Mead and Miller (1991). Lim (1993) also reported that 57% of the biomass of open-grown *A. mangium* was in branches and phylloides, compared with 27% in plantation-grown trees. These trends indicate the importance of singling, pruning, and optimising stocking if *A. mangium* is to be used for mechanically-harvested pulpwood plantations.

The success at 30 months of the hybrid *E. grandis* × *E. urophylla* is in marked contrast to the poor success of its parent *E. grandis*. This hybrid was developed from land race parents at Aracruz in Brazil, and has been further developed by controlled crossing in Brazil, southern China and South Africa (Eldridge et al. 1994). Its success in this monsoonal wet/dry environment in South Kalimantan reflects the origins of *E. urophylla*, the Wetar (Indonesia) provenance of which also performed well in these trials to 30 months. The overriding conclusion from the success of these eucalypt species is that there is greater potential for growing industrial plantations of eucalypts on poor lowland *Imperata* grassland sites than previously considered, though the sometimes rapid decline of eucalypt plantations which have shown early promise (Eldridge et al. 1994) remains of concern.

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Company (London) provided advice on the design of the species trial and provided seedlots of hybrid eucalypts. The main seedlots were purchased from the Australian Tree Seed Centre of the CSIRO in Canberra, Australia. Seedlings were grown by Inhutani II at Semaras under the supervision of Ir. Totok and Ir. Nofi. Assistance with supervision of planting the trials was provided by ENSO Forest Development staff from Banjarbaru, Kalimantan Selatan (Mr Goran Adjers and Mr Markku Temmes).

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