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Survival and Early Growth of *Acacia mangium, Ceiba pentandra* and *Casuarina equisetifolia* on Sandy Tin Tailings

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ABSTRAK

Satu kajian di ladang bekas lombong telah dijalankan untuk menilai tumbesaran tiga spesis pokok (Acacia mangium, Ceiba pentandra *dan* Casuarina equisetifolia) *dengan menabur dan tidak menabur baja dan penanaman tiga spesis penutup bumi* (Centrosema pubescens, Calopogonium muconoides *dan* Puereria phaseoloides). *Kajian ini telah dijalankan di Kampung Pasir, Semenyih, Ulu Langat, Selangor. Baja (NPK) sebanyak 300 g telah ditaburkan pada anak pokok tiga bulan sekali dalam masa setahun. Ketinggian dan perepang pokok telah dikira selepas 23 bulan dari hari pokok ditanam. Sampal tanah juga telah diambil untuk analisa makmal. Keputusan menunjukkan bahawa tiga spesis pokok boleh tumbuh dengan baik walaupun tanpa baja dan tumbesaran terdapat perbezaan yang ketara diantara pokok-pokok itu. Acacia mangium menunjukkan kadar pertumbuhan yang tertinggi diikuti oleh* Ceiba pentandra *dan* Casuarina equisetifolia. *Tanaman penutup bumi telah meningkatkan nutrien-nutrien dalam tanah. Kesan daripada kajian ini adalah spesis pokok Acacia mangium boleh digunakan untuk memulihkan tanah bekas lombong manakala* Ceiba pentandra *dan* Casuarina equisetifolia *juga boleh digunakan tetapi tumbesaran tidak setanding dengan* Acacia mangium.

ABSTRACT

A field study was carried out on tin tailings to evaluate the growth performance of three timber species (Acacia mangium, Ceiba pentandra *and* Casuarina equisetifolia) *with and without fertilization and with three species of cover crops* (Centrosema pubescens, Calopogonium muconoides *and* Puereria phaseoloides). *The experiment was carried out at Kampung Pasir, Semenyih, Ulu Langat, Selangor. NPK compound fertilizer was applied at the rate of 300 g per seedling every three months during the first year of the study. Height and diameter were measured 23 months after planting. Soil samples were also collected for laboratory analysis. The results showed that the three timber species can grow well even without fertilizer and the growth rates of the three species differ significantly. The fastest growth rate was recorded by* Acacia mangium *followed by* Ceiba pentandra *and* Casuarina equisetifolia. *The planting of cover crops slightly increased the nutrient status of the soil. Thus this experiment shows that timber species, particularly* Acacia mangium, *could be successfully used to rehabilitate abandoned ex-mining land, while* Ceiba pentandra *and* Casuarina equisetifolia *could also be used, but have slower growth rates than* Acacia mangium.

INTRODUCTION

Active tin mining in Malaysia began in the late nineteenth century and has been a major contributor to the nation's economy (Lim *et al.* 1981). Most tin production is obtained from dredging, gravel pumps and open mines (Anon 1991). The mining operations have resulted in environmental destruction such as siltation of river beds and drainage systems and the destruction of agricultural land. Tin tailing areas in Peninsular Malaysia are estimated to be cover about 113,500 ha (Chan 1990).

The tin mining activities have left three types of tailings: sand tailings, slime tailings and sandy slime tailings. Slime tailings with a proper drainage system have been successfully used for producing fruits and vegetables. However, there are problems with sand tailings. Many studies have been conducted to rehabilitate the ex-tin mining land and to better utilize these tin tailings for agriculture, including the use of natural rubber skim latex, palm oil mill effluent, sewage sludge, bitumen and emulsion to improve the physical and chemical properties of the tin tailings (Lim *et al.* 1981). Afforestation and agroforestry practices have been recognized as suitable for rehabilitation of ex-tin mining areas (Mitchell 1957; Ang 1986, 1994; Nik Muhamad *et al.* 1994).

The main objective of this study was to evaluate the growth performance of three timber species with two levels of fertilization and three species of cover crops on the ex-tin mining land.

MATERIALS AND METHODS

Site Description

The study was conducted at Kampung Pasir Semenyih, Selangor, about 20 km from Universiti Putra Malaysia campus, on soil belonging to the order Ultisol (Nik Muhamad *et al.* 1994) which is sandy in texture. The study area is relatively flat and has an average rainfall of about 2506.9 mm per year. The monthly rainfall figues for April 1994 - February 1996 are presented in Table 1. Average annual temperature ranges from 20 - 33°C. The water table is 2 m from the soil surface, determined by the digging of a 2-m deep soil pit. The soil was moist above this level due to capillary rise of water, but the water was available only at a depth of 2 m. The physical and chemical properties of the soil before planting are given in Table 2.

TABLE 1
Monthly rainfall (mm) at Semenyih during the study period

Month	1994	1995	1996
	Rainfall (mm)		
January		75	80
February		120	128
March		165	
April	205	218	
May	245	240	
June	182	170	
July	195	200	
August	230	245	
September	348	370	
October	300	280	
November	290	270	
December	185	160	

TABLE 2
Soil properties (before planting)

A. Physical	
Coarse sand (%)	49.10
Fine sand (%)	37.65
Silt (%)	4.29
Clay (%)	8.06
Moisture content (%) (0-40 cm depth)	0.55
B. Chemical	
pH (H_2O)	4.47
N (%)	0.02
P (ppm)	6.75
K (meq/100 g soil)	0.09
Ca (meq/100 g soil)	1.35
Mg (meq/100 g soil)	0.50
CEC (meq/100 g soil)	1.54

Experimental Layout

Seedlings of *A. mangium*, *C. equisetifolia* and *C. pentandra* were planted in early April 1994 at a spacing of 3 x 3 m. The experimental area was divided into 4 blocks (replicates) of 45 x 45 m, each block consisting of nine subplots (Table 3), each with 25 seedlings. Three cover crops (*Centrosema pubescens, Calopogonium muconoides* and *Puereria phaseoloides*) were planted in rows between the tree species. The cover crops were planted only once, at the beginning of the experiment, and gave 100% coverage for each of the tree species. A 9-m buffer zone was established between the blocks.

Fertilizer was applied to two blocks at 3-monthly intervals during the first year of the

TABLE 3
Plot layout

	R1			R2	
T2A3	T1A1	T2A1	T3A1	T2A3	T1A3
T3A1	T2A2	T3A2	T1A2	T1A1	T2A1
T1A2	T3A3	T1A3	T3A3	T3A2	T2A2
	R3			**R4**	
T3A2	T2A2	T1A2	T1A1	T1A2	T1A3
T1A3	T3A3	T2A3	T2A1	T2A2	T2A3
T2A1	T1A1	T3A1	T3A1	T3A2	T3A3

Note: T1- *Acacia mangium*
A1- *Centrosema pubescens*
T2- *Ceiba pentandra*
A2- *Calopogonium muconoides*
T3- *Casuarina equisetifolia*
A3- *Puereria phaseoloides*

study period at the rate of 300 g NPK blue (15:15:15) per seedling. The remaining two blocks were not fertilized. The fertilizer was applied 24 hours after rainfall 0.3 m away from the base of the seedlings in a 10-cm deep circular trench and lightly covered with soil.

Data Collection

Growth in terms of total height and diameter was monitored for 23 months during the study period (April 1994-February 1996). The initial average height and diameter of the seedlings were as follows: Height - *A. mangium* (68.3 cm), *C. pentandra* (73.6 cm) and *C. equisetifolia* (44.7 cm); Diameter - *A. mangium* (8.2 mm), *C. pentandra* (10.3 mm) and *C. equisetifolia* (8.5 mm). Survival rate one year after planting was 93% for *A. mangium*, 87% for *C. equisetifolia* and 89% for *C. pentandra*.

Soil samples were collected randomly from each subplot prior to and 23 months after planting. Soil sampling was done at depths of 0-20 and 20-40 cm, randomly from five sampling points within each of the subplots and composited to form a sample. A soil auger was used to collect the samples, which were kept in plastic bags before being oven dried. The results are presented as average values of two soil depths.

Data Analysis

The soil samples collected were air dried and sieved through a 2-mm sieve to ensure that soils with very coarse sand (1-2 mm particle size) could also be incorporated for analysis. The samples were analysed to determine the physical and chemical properties. The physical properties determined were soil texture (determined by the pipette method) and moisture content (determined by the gravemetric method).

The soil chemical properties determined were total N, available P, exchangeable Ca, Mg, K, pH and cation exchange capacity (CEC). Total N was determined by the Kjeldahl digestion procedure (Bremner 1962). Available P was determined using a spectronic-20 spectrophotometer. Exchangeable Ca, Mg, K were determined by the leaching method (1N NH_4OAc at pH 7.0) and analysed by using an atomic absorption spectrophotometer. Soil pH was determined at 1:2.5 soil/water solution by a glass electrode pH-meter. Total organic carbon was determined by the Walkley and Black method (1934).

The data were subjected to analysis of variance (ANOVA) to test the effects of the fertilizers and cover crops on the growth parameters of three tree species and soil properties.

RESULTS AND DISCUSSION

Soil Physical Properties

The results of the analysis of soil physical properties are shown in Table 4. These show that the plots planted with *A. mangium* had significantly higher moisture content (0.57%) than the *C. pentandra* (0.43%) and *C. equisetifolia* (0.41%) plots. This is probably due to the higher organic matter accumulated through litterfall under the *A. mangium* plot compared to the plots of the other two species. The moisture content of the *P. phaseoloides* (0.54%) and *C. muconoides* (0.49%) plots was significantly ($P<0.05$) higher than that of *C. pubescens* (0.39%) plot. There was a significant ($P<0.05$) difference in moisture content between the fertilized and unfertilized plots.

Generally, soil moisture content was very low compared to other types of soil. For instance, the moisture content of a normal agricultural soil is about 25%. According to Letey (1985), low soil moisture content will affect plant growth because of the direct relationship between water potential and soil water content.

The sand content was significantly ($P<0.05$) higher in the *C. pentandra* (86.79%) plot than in the plots of the other two tree species. The silt and clay contents were, however, significantly ($P<0.05$) higher in the *A. mangium* plot than in the other two plots. For plots on the cover crops, the sand content was higher in the *C. muconoides* plot whereas silt and clay contents were higher in the *C. pubescens* plot as than in the other two cover crop plots. Similarly, silt and clay contents were significantly ($P<0.05$) higher in the unfertilized plots than the fertilized ones whereas there was no significant ($P<0.05$) difference for sand content between these two plots. However, in quantitative terms, the differences in soil physical properties apparently caused by planting tree species and cover crops are too small to have any real impact on site quality.

The high percentage of sand (85.07-86.72%) causes high soil temperature during the day time. This is a limiting factor for tree growth (Ang 1994). High sand content in the soil also

TABLE 4
Soil physical properties

(a) between three timber species

Soil physical properties	Acacia mangium	Ceiba pentandra	Casuarina equisetifolia
Sand (%)	85.48b	86.79a	85.75b
Silt (%)	5.16a	4.35b	4.10b
Clay (%)	10.16a	8.02b	7.64b
M. C. (%)	0.57a	0.43b	0.41b

(b) between the cover crop species

Soil physical properties	Centrosema pubescens	Calopogonium muconoides	Puereria phaseoloides
Sand (%)	86.02ab	86.51a	85.48b
Silt (%)	4.75a	4.50a	4.36a
Clay (%)	9.04a	8.14b	8.64ab
M.C. (%)	0.39a	0.49b	0.54b

(c) between two levels of fertilizer

Soil physical properties	with fertilizer	without fertilizer
Sand (%)	86.14b	85.26b
Silt (%)	4.29b	4.78a
Clay (%)	8.06b	9.15a
M.C. (%)	0.55a	0.39b

Note: Means with the same letter are not significantly different ($P<0.05$) as determined by Duncan's new multiple range test
M.C.- moisture content

increases the porosity and reduces the water retention capacity (Ang 1994) and will cause excessive drainage and leaching of nutrients. According to Shamsuddin *et al.* (1986), a high sand levelwill slow down the process of soil structure development.

Soil Chemical Properties

The results of the analysis of soil chemical properties are shown in Table 5. The pH value, exchangeable Ca, Mg and CEC showed significant ($P<0.05$) difference among the three tree species. A. mangium recorded the highest values, followed by *C. equisetifolia* and *C. pentandra* plots, probably due to the higher accumulation of organic matter through litterfall under *A. mangium* plots. There was no significant ($P<0.05$) difference between plots of the three tree species for total N, available P and exchangeable K. However, available P was highest in *C. equisetifolia,* followed by *A. mangium* and *C. pentandra* plots. Organic carbon was highest in the *A. mangium* plot, and this was significantly ($P<0.05$) different from the other two tree species plots.

In the plots under cover crops, exchangeable Ca, organic carbon and CEC values showed significant ($P<0.05$) difference between the plots, *C. pubescens* plot giving the highest value for exchangeable Ca whereas the *C. muconoides* plot recorded the highest value for CEC. Similarly, only exchangeable Ca and CEC values were significantly ($P<0.05$) higher in fertilized plots than the unfertilized ones.

The results show that total soil N after planting with tree crops, cover crops with and without fertilizer application was still low (0.04%) compared to the other agricultural

TABLE 5
Soil chemical properties

(a) between three timber species

Soil chemical properties	*Acacia mangium*	*Ceiba pentandra*	*Casuarina equisetifolia*
Org C	1.12a	0.92b	0.88b
pH	4.87a	4.73c	4.76b
N (%)	0.04b	0.03b	0.03b
P (ppm)	9.59a	8.60a	10.40a
K (meq/100 g soil)	0.11a	0.12a	0.11a
Ca (meq/100 g soil)	1.12a	0.84c	0.95b
Mg (meq/100 g soil)	0.57a	0.48b	0.52ab
CEC (meq/100 g soil)	1.95a	1.87c	1.88b

(b) between the cover crop species

Soil chemical properties	*Centrosema pubescens*	*Calopogonium muconoides*	*Puereria phaseoloides*
Org C	1.08a	0.82b	0.88b
pH	4.80a	4.80a	4.78b
N (%)	0.03a	0.03a	0.03a
P (ppm)	10.12a	9.32a	9.15a
K (meq/100 g soil)	0.12a	0.11a	0.12a
Ca(meq/100 g soil)	1.04a	0.97b	0.88c
Mg (meq/100 g soil)	0.54a	0.52a	0.51a
CEC (meq/100 g soil)	1.90b	1.96a	1.84c

(c) between two levels of fertilizer

soil chemical properties	with fertilizer	without fertilizer
Org C	0.96a	0.92a
pH	4.95a	4.95a
N (%)	0.03a	0.03a
P (ppm)	11.02a	10.82a
K (meq/100 g soil)	0.13a	0.12a
Ca (meq/100 g soil)	0.81a	0.74b
Mg (meq/100 g soil)	0.53a	0.54a
CEC (meq/100 g soil)	2.09a	2.06b

Note: Means with the same letter are not significantly different ($P<0.05$) as determined by Duncan's new multiple range test

soils under Malaysian conditions, which is about 0.12% (Law and Tan 1973). The results of the present study confirmed the findings of Mitchell (1957) because of the high leaching process in the soil and low organic matter content. This is also related to the high sand content and the high soil temperature (Black 1968). Similarly, CEC in the soil is very low (2.09 meq/100g soil) compared to the normal soils under Malaysian conditions (>100 meq/100g soil) (Law and Tan 1973), probably due to the low clay content (<10%) in tin tailing areas. In general, it can be concluded that soil chemical properties were little influenced, quantitatively, by the planting of tree or cover crops.

Height Growth

A. mangium showed the fastest height growth of the three tree species (Table 6). There was, however, no significant ($P<0.05$) difference in

TABLE 6
Growth performance

Growth parameters	Cover crops	*A. mangium* F	*A. mangium* WF	*C. pentandra* F	*C. pentandra* WF	*C. equisetifolia* F	*C. equisetifolia* WF
Height	*C. pubescens*	615c	620c	270bc	280b	170d	290b
(cm)	*C. muconoides*	580d	760b	290b	380a	280b	300a
	P. phaseoloides	780a	758b	270bc	220d	180d	240c
Diam	*C. pubescens*	78c	81bc	58b	68a	26c	28c
(mm)	*C. muconoides*	75c	85b	67a	72a	34b	38a
	P. phaseoloides	120a	83b	57b	55b	33b	34b

Note: F- fertilized WF- without fertilizer
Means with the same letter(s) are not significantly (P<0.05) different as determined by Duncan's new multiple range test

height growth between *C. pentandra* and *C. equisetifolia. A. mangium* interplanted with *P. phaseoloides* (fertilized) recorded the highest height growth followed by *A. mangium* with *C. muconoides* (unfertilized) and *A. mangium* with *P. phaseoloides* (unfertilized). The other two tree species (*C. pentandra* and *C. equisetifolia*) recorded the maximum height growth in combination with *C. muconoides* (unfertilized). Interestingly, the results show that generally the trees in the unfertilized plots have better height growth than trees in the fertilized plots. This is possibly due to the nutrients taken by the cover crops in fertilized plots. In simultaneous agroforestry where the tree and crop components grow at the same time and sufficiently close to each other, there is competition for light, water or nutrients (Sanchez and Palm 1996). Thus it might be possible that the competition for nutrients between trees and cover crops led to reduced height growth in fertilized plots.

Diameter Growth

A. mangium recorded the greatest diameter growth, followed by *C. pentandra* and *C. equisetifolia* (Table 6), and the growth was significantly (P<0.05) different between the three tree species. A. mangium interplanted with *P. phaseoloides* (unfertilized) showed the highest diameter growth followed by *A. mangium* with *C. muconoides* and *C. pubescens* (both unfertilized), respectively. *C. pentandra* and *C. equisetifolia* showed maximum diameter growth with *C. muconoides* (unfertilized). Similar to height growth, unfertilized plots generally had higher diameter growth than the fertilized ones, possibly for the reason explained earlier.

The results clearly demonstrated better growth performance of *A. mangium* than the other two tree species on sandy tin tailings because *A. mangium* is a pioneer species that can grow very well in rocky, disturbed and even on sandy soils. Ramli (1995) reported that *A. mangium* recorded the highest growth on ex-tin mining land. Similarly, Zakari (1990) also reported the successful planting of *A. mangium* Willd. on sandy ex-tin mining land in Semenyih.

C. pentandra has also established well on this ex-tin mining land. Earlier, Paudyal and Nik Muhamad (1992) reported that *C. pentandra* can be used to rehabilitate the ex-tin mining land. Similarly, *C. equisetifolia* has shown promising results for such rehabilitation.

Fertilizer application at the rate of 300 g NPK per seedling may not be sufficient as there was significantly poorer tree growth. Similarly, there was little quantitative effect on soil properties before and after planting tree species with cover crops. This is probably because of high leaching of nutrients and also changes in soil properties in poor soils, such as, tin tailings, take a longer time period to occur.

CONCLUSION

All the three tree species can grow well on sandy tailings. *A. mangium* showed the best growth performance followed by *C. pentandra* and *C. equisetifolia.* The planting of the cover crops and tree species improved, in smaller quantities, some soil chemical properties. This combination might be a viable option for reducing the input of chemical fertilizers as growth was enhanced even without the application of fertilizers.

RECOMMENDATIONS

As there was no significant effect on height and diameter growth of the three tree species by the application of fertilizer, more research needs to be conducted to determine the cause of this effect. Another area for further research is to determine the optimum dose of fertilizers for boosting growth of trees. Other types of slow release fertilizers should be used for longer retention in the soil. Similarly, further studies on other indigenous species need to be conducted in the rehabilitation of ex-tin mining land as information in this area is lacking.

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