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Effect of Mycorrhizal Treatment on Growth of *Acacia* spp. on Sandy BRIS Soils in Peninsular Malaysia

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Abstract : Marginal soils such as BRIS (Beach Ridges Interspersed with Swales) soils and ex-tin mining land make up approximately 0.5 million ha or about 2% of Malaysia's land area. In the coastal areas of the east coast of Peninsular Malaysia impoverished sandy BRIS dominates the landscape with most lying idle as there is no national management plan for their utilization. A field study was carried out to see whether mycorrhizal application had any effect on the growth of three exotic *Acacia* spp., i.e. *Acacia auriculiformis, A. mangium* and *Acacia* hybrid (*A. auriculiformis* × *A. mangium*) on BRIS soils. Two types of mycorrhizal inoculum, namely, a commercially available arbuscular mycorrhizal inoculum marketed as MycoGold™ and an indigenous ectomycorrhizal *Tomentella* sp. inoculum were tested. In the initial six months, height growth of all three tree species inoculated with the arbuscular mycorrhizal inoculum was significantly improved compared to the ectomycorrhizal inoculated and uninoculated control plants. The mycorrhizal effect was not evident thereafter and repeated application of the arbuscular mycorrhizal inoculum may be necessary for continued growth enhancement. Of the three species, *A. mangium* had the highest relative height growth rate over the 24 months on BRIS soils.

***Key words* :** Acacia spp., *degraded sites, growth, mycorrhizas, sandy soils, Malaysia*

Introduction

Malaysia has a land area of about 33 million ha of which 40% is in the peninsula and 60% in the East Malaysian states of Sabah and Sarawak. Land for agricultural use is classified into five classes with land in Classes 1 to 3 recommended for agricultural development. Class 4 consists of marginal soils which are only recommended for agricultural development after a high level of land management and improvement has been applied. Class 5 land consists of land unsuitable for agriculture. Land in Class 5 and some land in Class 4 consist of predominantly fragile ecosystems such as steep land, peat, acid sulphate and BRIS (Beach Ridges Interspersed with Swales) soils (Lim, 2002).

Marginal soils such as BRIS soils and ex-tin mining land make up approximately 0.5 million ha or about 2% of Malaysia's land area (Lim, 2002). In Peninsular Malaysia, BRIS forms the dominant landscape in the coastal areas of the east coast where the alternating sandy beach ridges and swales can be found as far as 10 km inland from the present-day coastline. BRIS soils are also found on the island of Langkawi and along coastal areas in Sabah and Sarawak. These infertile soils are sandy and unstructured, with poor nutrient and water holding capacities, suffer from excessive drainage, and are subjected to high surface temperatures, high rates of evapotranspiration, and very high moisture stress. The low lying swales are prone to flooding during the northeast monsoon which brings heavy rain to the east coast between the months of November and December.

Degradation of BRIS soils occurs when the sparse natural vegetation is removed. Farming systems which do not pay special attention to the already impoverished sandy soils will cause further deterioration to the soil fertility rendering the soils even more difficult for crop cultivation (Lim, 2002). With proper management and irrigation BRIS areas can be cultivated with crops such as vegetables, watermelon, tobacco, cashewnut, coconut, rozelle (*Hibiscus sabdariffa*) and other annual crops. Management of crops on BRIS soils include the incorporation of organic matter or compost, staggered application of fertilizers, prudent water management and the use of mulches on planting beds. Presently, these soils still constitute some of the most under-utilized land in

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Malaysia. It has been estimated that only 5-10% of the BRIS soils in the country have been used for agricultural development (Abdullah, 1997), with most lying idle with no national management plan for their utilization.

The natural vegetation of BRIS areas generally consists of *Melaleuca cajuputi* trees with sparsely mixed shrubs of low economic value. Studies elsewhere have demonstrated that introduction of trees to degraded sites such as grasslands can stabilize microclimate and accelerate natural regeneration and growth of seedlings (Lee *et al.*, 2006). Research on the planting of forest and timber trees on BRIS soils was carried out by FRIM researchers in the 1990s using different forest tree species, fertilizer levels and cover crops (Amir, 2001). These efforts, however, met with limited success. The exotic nitrogen-fixing legumes, *Acacia auriculiformis* and *A. mangium* had the best survival rates, but even these rates were poor at about 50% two years after planting, declining further thereafter (Amir, 2001).

Acacias, in particular *A. mangium* and *Acacia* hybrid (*A. mangium* × *A. auriculiformis*) are popular species for large-scale forest plantations in Malaysia and South East Asia (Lee, 2003; 2004). Mycorrhizal fungi clearly benefit tree growth and are known to be able to enhance the uptake of certain soil nutrients, in particular inorganic phosphorus (Smith and Read, 1997), as well as improve drought resistance in plants (Brownlee *et al.*, 1983; Read and Boyd, 1986; Kyllo *et al.*, 2003). *Acacia* species are predominantly arbuscular mycorrhizal (Redell and Warren, 1986) but recent experiments have clearly demonstrated that *A. mangium* can also form ectomycorrhizas with at least two indigenous Malaysian ectomycorrhizal fungal strains, namely, a *Tomentella* sp. isolated from ectomycorrhizal roots of *Shorea parvifolia* (Dipterocarpaceae) and *Pisolithus aurantioscabrosus* isolated from a basidiome collected under *Shorea* spp. in Pasoh Forest Reserve, Negeri Sembilan, Malaysia (Lee and Patahayah, 2003). Therefore, the application of mycorrhizas may potentially benefit the establishment and growth of acacias on degraded sites such as BRIS.

Oil palm mesocarp fiber is the waste material remaining after extraction of oil from the mesocarp of the oil palm (*Elaies guineensis*) fruits. Large amounts of this material are readily available at no cost and it is either burned to fuel the boilers in the oil palm mills or discarded as waste. Earlier studies (unpublished data) have shown that the composted oil palm mesocarp fibre is an excellent potting medium as well as an organic soil amendment. Therefore, its potential as a low cost, readily available organic amendment for use in degraded areas such as BRIS soils is high.

A field study was thus carried out to see whether mycorrhizal application had any effect on the growth of three exotic *Acacia* spp., i.e. *Acacia auriculiformis, A. mangium* and *Acacia* hybrid (*A. auriculiformis* × *A. mangium*) on BRIS soils using composted oil palm mesocarp fibre as a soil conditioner. The results after 24 months field planting are reported here.

Materials and Methods

Seedlings of *A. auriculiformis* and *A. mangium* were produced from seeds collected from trees in the Kepong area near the Forest Research Institute Malaysia (FRIM) and from seeds obtained from the FRIM Seed Laboratory, respectively. Seeds were scarified by soaking in boiling water for 5 minutes before being sown onto washed river sand in the nursery at the FRIM sub-station at Setiu, Terengganu. Two week-old seedlings were potted into 15 × 23 cm black polyethylene bags containing well-composted oil palm mesocarp fiber. *Acacia* hybrid (clone M5 from *A. auriculiformis* × *A. mangium*) plantlets originating from tissue cultured material obtained from the FRIM Tissue Culture Unit were potted into black polyethylene bags containing composted oil palm mesocarp fiber and acclimatized in the main FRIM nursery at Kepong. They were transferred to the nursery at Setiu sub-station three months before field planting.

The FRIM Setiu sub-station is located at Kampung Bari Besar, Penarik, Terengganu, approximately 55 km northwest of the state capital of Kuala Terengganu on the east coast of Peninsular Malaysia. The 50 ha station is located about 3 km inland from the beach and was originally covered with degraded Melaleuca-heath forest. The area experiences the full force of the northeast monsoon and receives a mean annual precipitation of more than 4500 mm where about 40% is received between November and December (Amir, 2001). The very heavy rain during these two months often causes flooding of the low-lying areas as is characteristic of BRIS soils. Strong winds blow between November and February while the hot dry period occurs between February and May when monthly average rainfall is only about 100 mm (Amir, 2001). The mean daily temperature at the Setiu sub-station ranges between 25°C and 32°C.

The soil at the site is of the Jambu Series and is classified as spodosols where the top soil is grayish black (10YR 5/1), with a whitish albic horizon (10YR 7/2). The soil is deep, sandy and siliceous, structureless and single grained (Amir, 1999). Four planting blocks of 0.5 ha each were set up for this study. Blocks 1 and 2 are sited over an area with a deep water table of between 85 cm and 1 m depth while Blocks 3 and 4 are sited over an area with a moderately deep water table of 45-60 cm depth.

Oil palm mesocarp fiber was obtained from a nearby palm oil processing mill and naturally composted by exposure to the sun and rain for six months with regular turning. Samples of the composted fiber and bulked BRIS soil samples collected from each of the four blocks at the study site of Setiu sub-station prior to planting were sent to a commercial analytical laboratory for chemical analysis and the results are shown in Table 1.

For the ectomycorrhizal inoculum, a peat-vermiculite inoculum with a yet to be identified *Tomentella* sp. (Thelephoraceae) (Lee and Patahayah, 2003) was produced using the method described by Yazid *et al.* (1996). Five week-old plants growing in the polyethylene bags were inoculated by placing one heaped teaspoonful or 20% v/v of the well-colonized inoculum in contact with the roots. For control plants a heaped teaspoonful of peat-vermiculite only, i.e. without the fungus, was placed in contact with the roots. All plants were placed in the nursery under plastic sheeting which was replaced with 70% shade netting after three months. One month before field planting, the netting was removed to harden the seedlings by exposing them to full sun.

For inoculation of plants with arbuscular mycorrhizal (AM) fungi, 250g of Mycogold™, a locally produced commercially available AM inoculum, was added to the planting hole at the time of field planting. According to the manufacturer, Malaysia Agri Hi-tech Sdn. Bhd., Mycogold™ is a mixture of nine species of arbuscular mycorrhizal fungi from the four important genera *Glomus, Gigaspora, Acaulospora* and *Scutellospora* isolated from Malaysian native soils in sterilized sand as growth and carrier media. The identity of the nine fungi species was not revealed but the inoculum has a spore count of 200-250 spores per 10g. Infected roots of 60-80% are added as a bonus and the inoculum has a shelf-life of one and a half years.

Seven month-old plants were planted out during the rainy season in December 2003, in the four blocks at the FRIM Setiu sub-station, at a spacing of 3.0m×4.0m. Some sparse vegetation on the site was cleared prior to planting. During planting, 500g of well composted mesocarp fibre was added to each planting hole. The trial consisted of four treatments, i.e. T1: arbuscular mycorrhizal (AM) inoculum application only, T2: ectomycorrhizal inoculum (ECM) application only, T3: AM + ECM application, and T4: uninoculated control, with three host species, namely, *A. auriculiformis, A. mangium* and *Acacia* hybrid clone M5, with 35 plants per species per treatment in a split plot design. Survival rate and total height of the plants were monitored at monthly intervals for the first three months and at three monthly intervals thereafter. Mean stem diameter was measured from the second year onwards as the stem diameter of the plants was still very small due to their slow growth on BRIS soil.

Soil samples were randomly collected from around 5 plants in each treatment at six and 24 months after planting. The roots and soil were examined for the presence of arbuscular mycorrhizal spores according to the wet sieving methods of Daniels and Skipper (1982) and Tommerup (1992). Roots were also examined macroscopically and microscopically for the presence of *Tomentella* sp. ectomycorrhizas.

The initial size of the plants varied considerably between species with *A. mangium* seedlings being much smaller. Thus height data were converted to relative growth rates of cm cm^{-1} $month^{-1}$ for assessment of plant growth. The effects of species, infection and treatment on growth were tested using two-way analysis of variance (ANOVA) and the means tested using Duncan's Multiple Range Test. Statistical analyses were conducted using SAS release 6.12 (SAS Institute, 1989-1996).

Table 1. Some chemical properties of the BRIS soils from the four blocks at Setiu, Terengganu, and of the fully composted mesocarp fiber used in the experiment.

Block	Soil depth	Total N %	Org. C %	Available P (ppm)	Exch. Ca	Exch. Mg	Exch. K	pH (wet)
					cmol/kg			
1	0 - 15 cm	0.03	1.71	0.36	0.08	n.d.	0.01	4.3
	15 - 30 cm	0.03	0.87	0.20	0.06	n.d.	0.01	5.08
2	0 - 15 cm	0.09	2.51	0.59	0.14	0.13	0.02	4.25
	15 - 30 cm	0.01	1.08	0.21	0.06	n.d.	0.01	5.32
3	0 - 15 cm	0.06	2.74	0.14	0.17	0.09	0.01	4.59
	15 - 30 cm	0.07	1.37	0.33	0.10	n.d.	0.01	5.11
4	0 - 15 cm	0.52	18.54	0.63	0.23	0.17	0.02	4.22
	15 - 30 cm	0.18	7.08	0.39	0.10	n.d.	0.01	5.21
Fully composted mesocarp fibre		0.56	17.1	144	n.a.	n.a.	0.07	5.01

n.a.: data not available
n.d.: not detected

Results and Discussion

Results of the soil analysis show that soil nutrient levels in Blocks 1, 2 and 3 (Table 1) were comparable with those obtained by Wan Asma *et al.* (2000) for untreated BRIS soils in Terengganu. They reported that BRIS soil sampled from four depths (0-5 cm, 5-15 cm, 15-30 cm and 30-45 cm) had 0.01-0.07% N, 0.20-0.87 mg/kg P, 0.02-0.05 cmol/kg exchangeable K, and pH ranging from 4.30-4.98. Organic C values were not reported by Wan Asma *et al.* (2000) but another study by Amir (2001) reported organic C levels of 0.64-0.69% for BRIS soils at Setiu. The higher levels of organic C reported here were probably due to the presence of some small weeds at the site. Block 4 had much higher levels of total N and organic C than the other three blocks (Table 1). These were most probably contributed by the clearing and burning of some undergrowth and shrubs during preparation of Block 4 for planting whereas no clearing or burning was carried out during preparation of the other three blocks. The soil in Blocks 1, 2 and 3 could thus be considered highly leached with very low nutrient content or soil of very poor fertility while Block 4 was relatively more fertile because of the higher total N and organic C content.

During the first three months, mortality of all seedlings in every block was very low; two *A. mangium* died in Blocks 1, 2 and 4 while two *A. auriculiformis* and one *Acacia* hybrid died in Block 3 (Figure 1). However, numerous *A. mangium* seedlings died after six months, 9 in Block 3 and 21 in Block 4 (Figure 1). Blocks 3 and 4 were located next to each other with Block 4 located close to a patch of secondary forest. It was observed that death of seedlings at 6 months in Blocks 3 and 4 was associated with wild boar damage where plants had been excavated by the animals. Damage was much less severe in the other plots which were located further away from the secondary forest. As *A. mangium* plants were much smaller than plants of the other two species they probably suffered more severe damage and could not recover so well, thereby resulting in higher mortality. In Blocks 3 and 4, *A. mangium* seedlings given treatments T1 (AM only) and T3 (AM + ECM) suffered lower mortality compared to seedlings given treatments T2 (ECM only) and T4 (uninoculated control) (Figure 1). These results appear to indicate that plants given the AM inoculum had better survival or were better able to recover after animal damage compared to plants without AM inoculum. However, survival of all the three species after 24 months, i.e. 91% for *A. mangium*, 97% for *A. auriculiformis*, and 98% for *Acacia* hybrid, is still considered good compared to the 50% survival reported by Amir (2001) on similar BRIS soils at Setiu. The overall higher

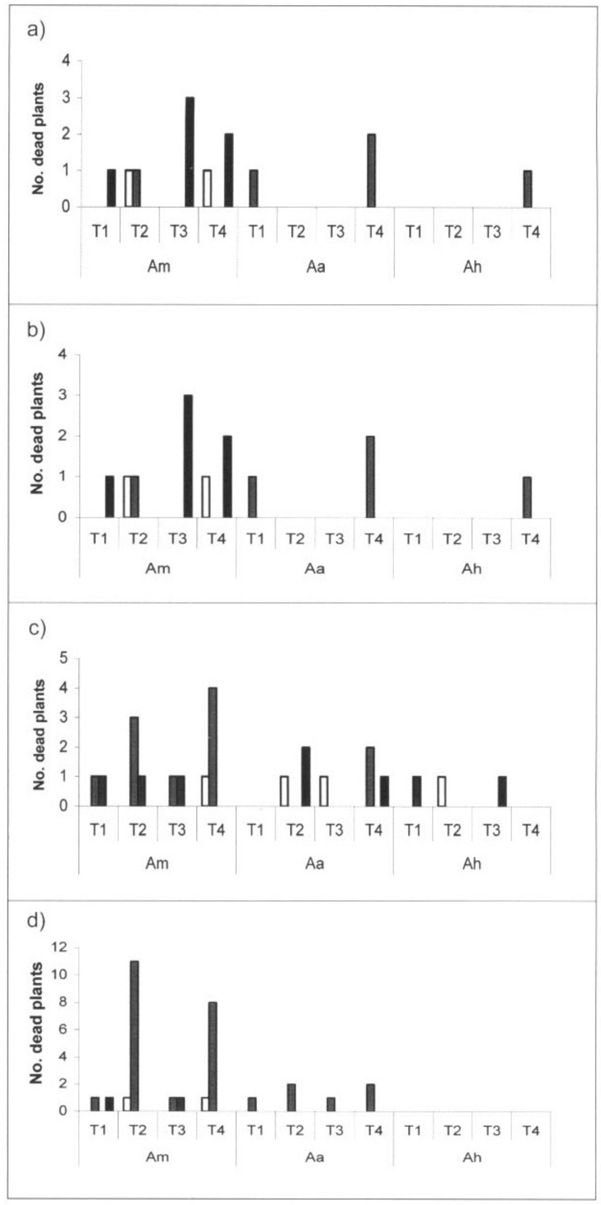

Figure 1. Actual number of dead *Acacia mangium* (Am), *A. auriculiformis* (Aa) and *Acacia* hybrid (Ah) seedlings in the four blocks at 3 (□), 6 (□), 12 (□) and 24 (■) months after planting. a) Block 1, b) Block 2, c) Block 3 and d) Block 4. Treatments-T1: arbuscular mycorrhizal (AM) inoculum application only, T2: ectomycorrhizal inoculum (ECM) application only, T3: AM + ECM application, and T4: uninoculated control.

survival rate of plants in this study was most probably due to the addition of the composted mesocarp fibre which appeared to assist plant growth and establishment. Data for plants which subsequently died or were missing in subsequent visits were excluded from the data analysis.

Growth of all plants due to the block effect was consistently significantly different (Table 2). Plants gener-

Table 2. F-ratios for main effects and interactions from an analysis of variance due to mycorrhizal treatment and block effect on the relative growth rates of *Acacia auriculiformis*, *A. mangium* and *Acacia* hybrid up to 24 months (*$p \leq 0.05$, **$p<0.01$, ***$p<0.0001$, ns = not significant).

	F-ratio							
Main effect	Mth 2	Mth 3	Mth 6	Mth 9	Mth 12	Mth 18	Mth 21	Mth 24
Block(Blk)	15.04***	57.99***	8.66***	12.85***	13.17***	10.75***	12.42***	12.11***
Species(Sp)	30.75***	320.53***	62.61***	92.14***	83.70***	76.83***	103.13***	89.78***
Treatment(Trt)	3.32*	4.60*	3.01*	2.75 ns	2.61 ns	1.96 ns	1.76 ns	1.31 ns
Interaction								
Blk × Sp	3.08*	22.57***	2.95*	3.38*	3.17*	3.82**	3.88**	4.03**
Sp × Trt	1.55 ns	1.65 ns	1.10 ns	1.24 ns	1.06 ns	0.54 ns	0.56 ns	0.87 ns

ally grew better in Block 4 probably due to the higher levels of total nitrogen and organic C in the soil (Table 1) as well as the presence of a higher water table compared to the other three blocks. The high water table in Block 4 was evident when preparing the sites for planting; water seepage into the 30 cm deep planting holes was frequently observed at that site but not at the other sites. Since water is limiting in BRIS soils (Lim, 2002) this implies that plants in Block 4 would suffer less water stress than plants at the other sites during the annual drought period. Small pockets of Block 4 were flooded during the rainy season but this lasted for only two to three weeks and did not pose a problem to the plants since Acacias are known to be able to tolerate brief to prolonged periods of flooding (Turnbull, 1986). Favourable soil moisture conditions enhance the development of larger and deeper root systems (Wan Rasidah *et al.*, 1998), thereby resulting in better growth of the trees. Amir (2001) noted that the growth and survival of *Hopea odorata, Melaleuca cajuputi, Casuarina equisetifolia, A. mangium* and *A. auriculiformis* on BRIS soils was closely related to the local rainfall pattern where highest growth and survival counts were observed during the wet season.

A. mangium plants were much shorter and smaller than *A. auriculiformis* and *Acacia* hybrid plants throughout the 24 months as they were much smaller to begin with. However, they consistently had significantly higher relative height growth rates (Figure 2). Comparative data on relative growth rates of the three species have not been reported previously. Results of the different mycorrhizal treatments on plant growth was evident only up to six months after planting with no significant differences thereafter (Table 2 and Figure 2). Up to that time, plants of all the three species in T1 (inoculated with AM only) and in T3 (AM + ECM), had significantly better relative growth rates than those in T2 and T4, i.e. those inoculated with the ectomycorrhizal *Tomentella* and the untreated control, respectively. There was no significant difference in relative growth rates of plants between T1 and T3. Since the common factor in the positive treatments is the AM inoculum, it would appear that the AM inoculum significantly enhanced height growth of all the

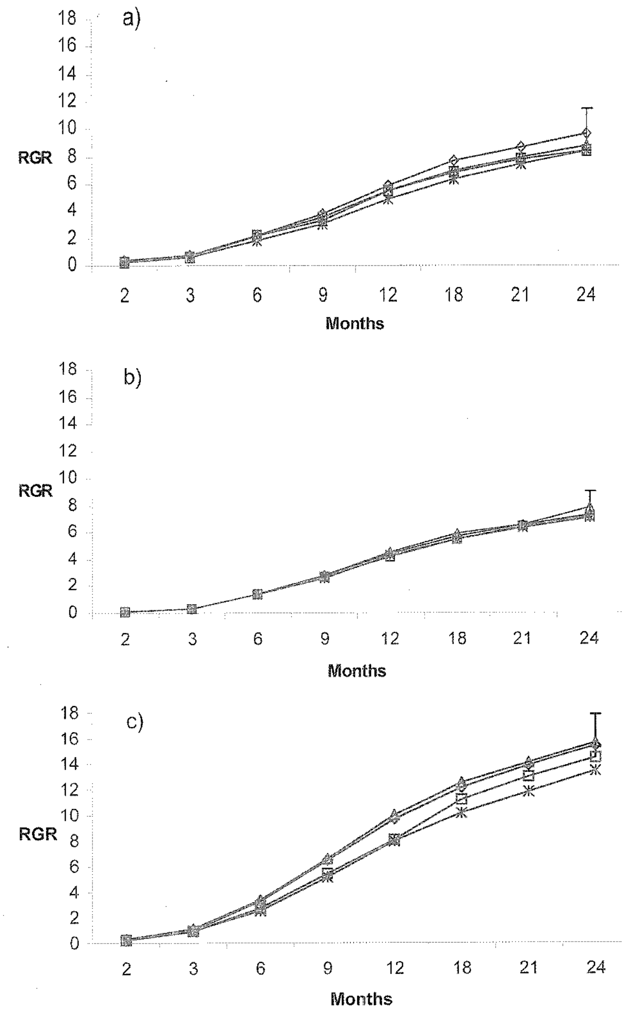

Figure 2. Relative height growth rates (RGR) for a) *Acacia auriculiformis*, b) *Acacia* hybrid and c) *Acacia mangium* over 24 months in BRIS soils at Setiu, Terengganu, Malaysia. ◇-Treatment 1 (arbuscular mycorrhizal application), □-Treatment 2 (ectomycorrhizal *Tomentella* inoculum), △ =Treatment 3 (arbuscular mycorrhizal + ectomycorrhizal *Tomentella* inoculum), X-Treatment 4 (uninoculated control). Bars are ± standard deviations. at final measurement.

Table 3. Arbuscular mycorrhizal spore abundance per 100g soil in the four blocks at 6 and 24 months, and arbuscular mycorrhizal root infection rates at 24 months* in the different acacia species given different mycorrhizal treatments after 24 months-T1: arbuscular mycorrhizal (AM) inoculum application only, T2: ectomycorrhizal inoculum (ECM) application only, T3: AM + ECM application, and T4: uninoculated control.

Block	Species	T1			T2			T3			T4		
		Spore abundance		AM inf.	Spore abundance		AM inf.	Spore abundance		AM inf.	Spore abundance		AM inf.
		6 mths	24 mths	%	6 mths	24 mths	%	6 mths	24 mths	%	6 mths	24 mths	%
1	*A. mangium*	44	36	98	15	39	38	11	46	90	8	42	28
	A. auriculiformis	10	8	55	30	5	8	22	9	26	13	6	10
	A. hybrid	2	7	62	26	33	21	7	15	38	12	10	14
2	*A. mangium*	30	22	93	6	26	32	9	30	92	5	32	31
	A. auriculiformis	2	4	57	15	6	9	10	5	24	5	2	12
	A. hybrid	2	3	60	20	15	34	4	7	31	15	5	16
3	*A. mangium*	25	18	98	2	31	27	4	32	85	3	30	22
	A. auriculiformis	7	1	61	20	3	10	5	11	42	2	2	8
	A. hybrid	5	7	75	18	17	28	7	7	23	8	1	11
4	*A. mangium*	60	53	100	25	51	52	35	52	94	24	50	43
	A. auriculiformis	12	9	77	10	8	16	12	9	35	9	8	16
	A. hybrid	5	7	65	14	9	51	16	12	52	11	6	18

*ECM infection levels were negligible or absent and are not reported here.

three species up to 6 months after application of the inoculum. Thus, even though *Acacia* species can form ectomycorrhizas (Lee and Patahayah, 2003), arbuscular mycorrhizas were predominant (Redell and Warren, 1986). These results also imply that the ectomycorrhizal *Tomentella* inoculum used in this experiment was not a particularly beneficial inoculum for improved growth of Acacias.

At the end of six months, vesicles were observed in roots of AM inoculated plants while *Tomentella* ectomycorrhizas were found on plants inoculated with *Tomentella* inoculum. Roots of the control plants (T4) had low levels of arbuscular mycorrhizal infection but no ectomycorrhizal infection. At the end of 24 months hardly any *Tomentella* ectomycorrhizas were found on roots of T2 plants while arbuscules and vesicles were still abundant in roots of the T1 and T3 plants indicating that while the *Acacia* roots in BRIS soils were well colonized by AM fungi even after 24 months, *Tomentella* mycorrhizas did not persist. As expected, arbuscular mycorrhizal root infection was highest in plants where the arbuscular mycorrhizal inoculum had been applied, i.e., T1 (Table 3). Plants given the ectomycorrhizal inoculum only (T2), had between 8 and 51 percent AM root infection and hardly any *Tomentella* ectomycorrhizas while the uninoculated control plants (T4) had low levels of AM root infection of between 8 and 43 percent and no ectomycorrhizas. Arbuscular mycorrhizal infection levels varied between a minimum of 24 percent and a maximum of 94 percent in plants given a mixture of the AM and ECM inocula (T3) (Table 3) but did not have any ectomycorrhizas. In T1 and T3, AM infection rates were highest in *A. mangium* seedlings. We are not sure why this happened; perhaps the inoculum was better suited to *A. mangium* than the other two species, or perhaps infection was more successful with the relatively younger *A. mangium* seedlings.

After 24 months, AM infection was also found in roots of plants not given the arbuscular mycorrhizal inoculum (T2 and T4). This infection could have been caused by naturally occurring AM fungi in the soil or by spread of the AM inoculum from the inoculated plants to the uninoculated plants; infection levels were, however, low (Table 3). In comparison with the original spore load of 200-250 spores per 10g in the inoculum, AM spore abundance levels in all treatments were low throughout the 24 months, never exceeding 60 live spores per 100g (Table 3). The low spore numbers were probably due to the high surface temperatures and very high moisture stress conditions of the BRIS soils which could have resulted in poor spore multiplication or spore death.

The absence of the mycorrhizal effect on growth after six months implies that the AM inoculum was no longer effective or competitive after the initial six months even though high levels of AM root infection were still observed at 24 months, especially in *A. mangium* (Table 3). In fact, the manufacturer of the AM inoculum recommends that the inoculum be reapplied every three months for plant maintenance, indicating that there is a need for reapplication for continued effect. However, at a cost of approximately USD 1.40 per kg it would be too expensive as a normal silvicultural practice. The high AM infection levels in *A. mangium* roots at 24 months could imply that although the roots were well infected, the associated AM fungi were not functionally beneficial for enhanced plant growth, or that perhaps the mycorrhizal effect took some other form, such as increased drought or disease tolerance which was not directly observable or measurable.

Information on the effect of mycorrhizal inoculation on the growth of *Acacia* species is scarce. Azizah *et al.* (1994) reported preliminary results showing that AM inoculated *A. mangium* seedlings (age not stated) had better growth compared to other treatments but no further results were available. In Thailand, 4-month-old *A. auriculiformis* plants inoculated with different types of vesicular arbuscular mycorrhizal fungi had higher fresh and dry weights than the uninoculated controls. Best growth was observed in plants inoculated with *Entrophospora* sp. no. 1 (Suwanarit *et al.,* 1997). In Indonesia, inoculation with AM fungi significantly increased the diameter and height of various fast growing 3-month-old leguminous trees, including *A. mangium* and *A. crassicarpa* (Setiadi, 2000). AM fungi are known to be not equally effective in their ability to promote plant growth (Daft, 1992; Suwanarit *et al.,* 1997) and studies have demonstrated that mixed inocula are generally more effective in improving the growth and health of plants in the nursery and for enhanced plant growth in the field (Setiadi, 2000). However, there is no information on the persistence of the mycorrhizal effect. From the results of this study it appears that the mixed inoculum in MycoGold™ was effective in enhancing growth of all the three host species in BRIS soils at least for up to six months.

Conclusion

Acacia species, particularly *A. auriculiformis, A. mangium* and *Acacia* hybrid can be grown on poor BRIS soils with the addition of some simple soil amendments such as composted oil palm mesocarp fibre. Growth of all the three species can be improved for the initial six months by the addition of 250g of the commercially available arbuscular mycorrhizal inoculum MycoGold™ but it appears that repeated application is necessary for continued effect. This may have some cost implications. Our preliminary results show that *A. mangium* has the highest relative growth rate, nearly double that of the *Acacia* hybrid after 24 months, but monitoring of plant growth needs to be continued to see how the three species perform in the long term.

Planting fast-growing trees such as *A. mangium, A. auriculiformis* and *Acacia* hybrid on degraded sites such as BRIS soils would help to improve the site quality (microclimate, soil condition, soil nutrient pool, etc.) and accelerate invasion by other tree species (Lee *et al.,* 2006) leading to improved vegetation cover in the long run.

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