GROWTH DIFFERENCES, FERTILITY STATUS AND FOLIAR DEFICIENCY LEVELS OF SIX-YEAR-OLD *ACACIA MANGIUM* ON BRIS SOILS

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AMIR HUSNI MOHD SHARIFF & WAN RASIDAH WAN ABDUL KADIR. 1994. Growth differences, fertility status and foliar deficiency levels of six-year-old *Acacia mangium* on BRIS soils. A study was made on the foliar elemental levels and growth differences in terms of height, diameter and basal area compositions between two soil types, and the foliar deficiency levels for elemental N, P, K, Ca, Mg, Mn and Zn. Based on ANOVA and Correlation Coefficient Analysis, it was shown that N uptake was somewhat independent of N in the soil. Significant relationships were also established for foliar K and Ca and their corresponding soil nutrients. Influence of site was significant for accumulated height but not for diameter and basal area. Nitrogen and K levels of 2.35% and 0.65% respectively in the foliage of *A. mangium* growing in Rhudua soils were considered non-limiting, while the K level of 0.4% in the foliage of acacia growing on Jambu soils was considered as a limiting level for growth.

Key words: *A. mangium* - accumulated growth - roots - foliar elemental levels - deficiency symptoms - Rhudua and Jambu soils

AMIR HUSNI MOHD SHARIFF & WAN RASIDAH WAN ABDUL KADIR. 1994. Perbezaan pertumbuhan, status kesuburan dan beberapa nutrien pada daun *A. mangium* berumur 6 tahun di tanah BRIS. Satu kajian dibuat pada tahap unsur daun dan perbezaan tumbesaran dari segi ketinggian, diameter dan luas pangkal antara 2 jenis tanih. Kajian ini juga meliputi tahap kekurangan nutrien daun untuk unsur-unsur N, P, K, Ca, Mg, Mn dan Zn. Kadar penyerapan N tidak bergantung sepenuhnya pada kandungan N dalam tarikh berdasarkan pada naalisis ANOVA dan Analisis Koefisien Korelasi. Hubungan bererti juga wujud untuk K dan Ca pada daun dan nutrien tarikh yang sepadan. Pengaruh kawasan tapak adalah ketara untuk ketinggian terkumpul tetapi tidak ketara untuk diameter dan luas pangkal. Paras Nitrogen dan K sebanyak 2.35% dan 0.65% masing-masing pada dedaun *A. mangium* yang tumbuh di tarikh Rhudua dianggap mencukupi untuk tumbesaran. Paras K sebanyak 0.4% pada dedaun acacia yang tumbuh ditarikh Jambu dianggap sebagai tahap yang tidak mencukupi untuk tumbesaran.

Introduction

One of the factors governing the rate of nutrient accumulation in the foliage is the soil pool (Miller 1984). Amir and Mona (1991) and Amir *et al.* (1993) further elucidated that trees growing on fertile soils had higher nutrient concentration compared to those on impoverished site. Likewise, Amir and Miller (1991) and Amir *et al.* (1992) distinctively showed that fertile site is capable of sustaining higher site carrying capacity than poor soils. Based on an exhaustive review comparing the role of foliage and soil analyses as diagnostic tools for nutritional assessment, Amir (1991) concluded that the former is highly favoured. This is due to the fact that foliage itself is the best integrator of all factors affecting its nutritional status and often correlates well with tree growth.

This study, another component of the study reported by Amir *et al.* (1993), was designed to examine any differences amongst nutrient elemental levels in foliage, and fine roots, and also accumulated height, diameter and basal area of *Acacia mangium* growing on Jambu and Rhudua soil types. In addition, elemental nutrients deficiency symptoms and their critical concentration levels in the foliage were investigated. The fertility status between two soil types (covered by *A. mangium* crop) was also studied since these two soil types differ in the occurrence of spodic horizon depth and distance from the shoreline.

Materials and methods

The study site (Tanjung Batu)and its two dominant soil types (Rhudua and Jambu) have been described by Amir *et al.* (1993). The methods and materials used in the present study were generally similiar to those used in the earlier study, except where indicated here.

Sampling procedure

A total of ten composite samples each of foliar and soil samples were obtained from each plot. Sampling time for foliar samples was standardised, *i.e.*, performed only in the morning and commencing only 24 *h* after heavy rainfall. From each composite soil sample, fine roots (< 2 *mm* diameter) were isolated. A total of ten fine root samples were collected from each plot. Samples were oven dried at 60°*C* to constant weight, milled and passed through a 2 *mm* sieve. Root analysis was conducted as for foliar analysis.

Statistical analyses

A single factor analysis of variance was used to test for significant differences in foliar and root elemental concentrations between sites (soil types). A similar test was repeated for soil nutrient concentrations between the two soil types. Comparison of treatment means was carried out using F-test at $p < 0.1$, $p < 0.05$, $p < 0.01$ and $p<0.001$.

Soil and foliar data of Jambu and Rhudua soils were respectively combined for Correlation Analysis. The decision was based on the fact that the stand was of pure *A. mangium* plants. Furthermore, the overlapping of points between the two sites suggests that they can be regarded as a single group.

Results

Foliar and root analyses

Significant differences of $p < 0.001$ and $p < 0.05$ occurred in foliar P, K and Mn, and N and Ca concentrations of *A. mangium* between Jambu and Rhudua soil types respectively (Table 1). A weak relationship was established for Zn ($p < 0.1$), but no relationship was observed for Mg.

Generally, the mean root elemental concentrations of *A. mangium* growing on Jambu soils were higher than those on Rhudua soils (Table 2) with the exception of K. Significant differences of $p < 0.001$ and $p < 0.01$ were noted for P, Ca and Mg, and K and Mn respectively. No relationship was established for N and Zn.

Table 1. Foliar elemental concentrations, (% dry mass) in top plant canopy tier of *A. mangium* growing on two different soil types

Soil types	Foliar elemental concentrations						
	N	P	K	Ca	Mg	Zn	Mn
	% dry soil mass					*ppm*	
Jambu soils	2.14	0.11	0.40	0.47	0.19	23	324
Rhudua soils	2.35	0.08	0.65	0.33	0.18	29	194
F-value	*	***	***	*	ns	+	**

+, *, ** and *** are significant at $p < 0.1$, $p<0.05$, $p <0.01$ and $p < 0.001$, respectively; ns - not significant; values are means of 10 replicates; notations same for all tables following.

Table 2. Root elemental concentrations (% dry mass) of *A. mangium* growing on two different soil types

Sites / Soil types	Root elemental concentrations						
	N	P	K	Ca	Mg	Zn	Mn
	% dry mass					*ppm*	
Jambu soils	1.18	0.053	0.041	0.225	0.051	18	70
Rhudua soils	1.07	0.023	0.051	0.138	0.037	17	28
F values	ns	***	**	***	***	ns	**

Soil analyses

Significant differences were recorded in all the measured soil physical and chemical properties between the two soils, except for total P, exchangeable Mg and CEC values (Table 3). Differences ($p < 0.001$) were recorded for C, N, organic matter, soil pH, exchangeable K, Ca, Na, total K, Ca, Mg, Zn and Mn between Jambu and Rhudua soils. Significant differences ($p< 0.05$) were observed for carbon to nitrogen ratio (C/N) and available P.

Table 3. Mean soil physical and chemical properties of Jambu and Rhudua soil types in Tanjung Batu, Pahang

Soil types	Mean soil physical and chemical properties																
								Exchangeable Cations				Total Cations					
	C	N	O.M	C/N	Av.P	T.P	pH	K	Ca	Mg	Na	K	Ca	Mg	CEC	Zn	Mn
	% dry mass				*ppm*			*mmol+kg^{-1}*							*cmol+kg^{1}*	*ppm*	
Jambu	8.24	0.43	14	18	2.49	148	3.7	0.32	3.14	1.82	0.42	0.73	46.32	27.13	3.05	3.8	70
Rhudua	3.16	0.20	5	15	0.80	163	4.1	0.53	1.35	1.76	0.71	5.26	9.28	12.24	3.27	5.0	111
F-values	***	***	***	*	*	ns	***	***	***	ns	***	***	***	***	ns	***	***

Comparative relationships between foliar and soil nutrients

Significant relationships of $p < 0.01$ were established between foliar elemental levels of N, K and Ca with their corresponding nutrients in the soils, but that for N was negative (Table 4). No relationship was observed for elemental levels of P, Mg, Zn and Mn. It is interesting to note significant relationships of $p < 0.01$ between foliar N and soil K concentrations (both total and exchangeable cations).

Significant relationships of $p < 0.001$ and $p < 0.01$ between nutrient levels in the foliar were recorded between N and K, and P and Ca respectively, whilst relationships of $p < 0.05$ were established between Ca and Mg and also between Ca and Zn (Table 5).

Table 4. Correlation coefficient (rs) of soil elemental levels versus foliar elemental levels of *A. mangium* of combined sites (Rhudua and Jambu soil types)

Foliar / Soil	N	P	K	Ca	Mg	Zn	Mn
N	- 0.578**	- 0.687***	- 0.713***	0.524*	0.071	- 0.309	0.124
P	- 0.014	- 0.087	0.036	0.139	0.071	0.307	- 0.298
K	0.612**	- 0.832***	0.715***	- 0.584**	- 0.205	0.398	- 0.283
Ca	- 0.630**	0.735***	- 0.759***	0.566**	0.185	- 0.313	0.251
Mg	- 0.637**	0.672***	- 0.763***	0.505*	0.108	- 0.295	0.170
Zn	- 0.463**	- 0.768***	0.573**	- 0.612**	- 0.330	0.340	- 0.280
Mn	0.337	- 0.647**	0.466*	- 0.528*	- 0.475*	0.407	- 0.376
Av.P	- 0.555**	0.365	- 0.514	0.547*	0.185	- 0.016	0.209
Ex.K	0.562**	- 0.554**	0.597**	- 0.385	- 0.090	0.079	- 0.395
Ex.Ca	- 0.517*	0.763***	- 0.676***	0.504	0.110	0.383	0.150
Ex.Mg	- 0.417	0.025	- 0.514*	- 0.318	0.235	- 0.399	- 0.251

Table 5. Correlation coefficient (rs) of foliar elemental levels of *A. mangium* of combined sites (Jambu and Rhudua soil types)

Foliar	N	P	K	Ca	Mg	Zn
P	- 0.245					
K	0.842***	- 0.413				
Ca	- 0.229	0.535**	- 0.382			
Mg	- 0.138	0.206	- 0.304	0.566*		
Zn	0.236	- 0.280	0.424	0.505*	- 0.249	
Mn	0.094	0.230	0.166	- 0.612	- 0.153	0.050

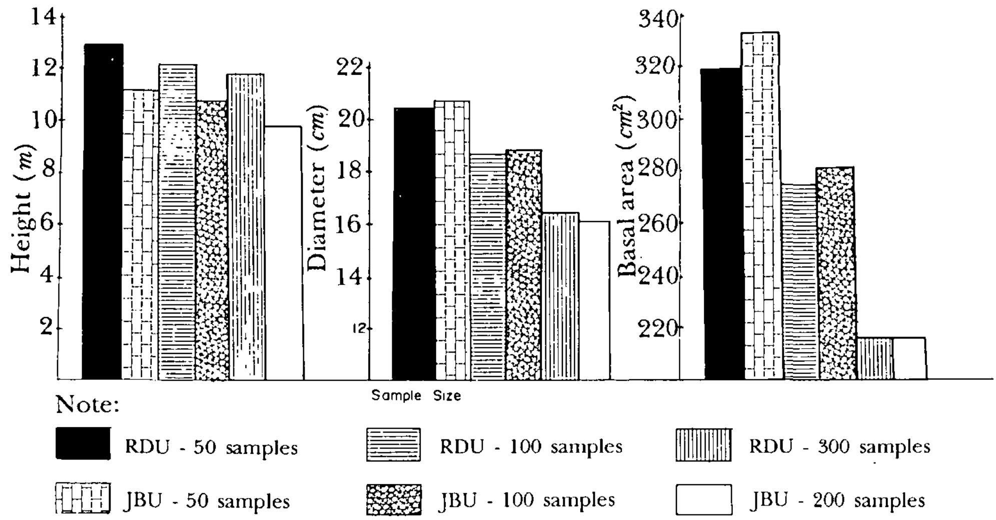
Comparative relationship between accumulated diameter, height and basal area of A. mangium

Mean accumulated height of *A. mangium* was significantly different ($p<0.05$, Figure 1) between soil types for all the three sample sizes tested. For accumulated diameter and basal area data no difference was observed for all sample sizes tested.

Discussion

Comparative elemental levels in foliage, soil and root between soil types

Relatively minimal elemental concentrations of P (0.08%), K (0.40%) and Ca (0.33%) have been noted in the foliage of *A. mangium* growing on Jambu and Rhudua soils (Table 1). These concentration levels were suspected as deficiency levels in forestry crops (Leaf 1968, Baule & Fricker 1970, Amir 1991). The foliage of *A. mangium* growing on Jambu soils were generally of lighter green colour whilst some were yellowing, especially the older foliage. By contrast, foliage on Rhudua soils were dark green in colour. For Mg, Zn and Mn, their foliar concentrations were well above the reported minimum levels (Leaf 1968), and no deficiency symptoms were observed in the field. Foliar elemental Ca concentration of 0.33% appeared to be low on Rhudua soils as against standards set for forestry crops (Leaf 1968), whilst on Jambu soils, Ca foliar concentration was just over the minimal set range (0.40%). However, no sign of deficiency was noted at this point for this element, but further checking is necessary. Therefore, our discussion then will centre on these nutrients, their availability and relationships to growth.



RDU = Rhudua soil type
JBU = Jambu soil type

(All results are not significant except for height, $p < 0.5$)

Figure 1. Accumulated height, diameter and basal area of *A. mangium* (means of 50, 100 and 200 replicates) on different soil types

It is interesting to note significantly higher N elemental levels in the foliage of *A. mangium* growing on Rhudua soils compared to Jambu soils (Table 1), despite the lower amount recorded in the former compared to the latter topsoils (Table 3).

However, Amir *et al.* (1993) pointed that Rhudua soils contained high amounts of N in the subsoils. In addition, the C:N ratio of Jambu soils was higher compared to Rhudua soils in the Ap layer (Amir *et al.* 1993), an indication of low N mineralisation rate, possibly due to low soil pH (Table 3) affecting the growth of microorganisms. Furthermore, Danso *et al.* (1992) postulated that soil N build up (as the case of Jambu topsoils) may be responsible for reduction in rhizobial fixation of N by roots. The suppressive effect on biological nitrogen fixation by inorganic N has also been reported elsewhere (Stewart & Bond 1961, Hansen & Pate 1987, Sanginga *et al.* 1987).

Potassium elemental concentration was comparatively higher in the foliage of *A. mangium* growing on Rhudua soils than on Jambu soils (Table 1). This was due to higher levels of K in the former compared to the latter soils (both exchangeable and total K) (Table 3). Furthermore, significant relationships were established between foliar K to exchangeable K and total K in soils (Table 4). In addition, compared to the Jambu plot the Rhudua plot was closer to the sea, the natural source of K (O'Carroll & McCarthy 1973). Foliar K concentration levels of 0.40% on Jambu soils was considered deficient to plant growth. Some of the sampled foliage displayed visual symptoms of deficiency, where foliage margins and tips were scotched. Healthy growing *A. mangium* on inland soils have been observed to contain a mean value of 1.28% of K (Amir *et al.* 1992). However, a mean K value of above 0.6% in the foliage of *A. mangium* growing on Rhudua soils showed no deficiency symptoms.

Higher elemental P level was noted in the foliage of *A. mangium* growing on Jambu soils than Rhudua soils (Table 1). This is less surprising since significantly high amounts of organic P and inorganic P were recorded in organic matter and mineral soils respectively, and the former is well-known for its higher organic P source (Lau *et al.* 1992). It is interesting to note significant relationships between foliar P to reserve Mg, Ca, Mn, Zn and exchangeable Ca in the soils (Table 4). These elements may form complexes with P (Allen *et al.* 1974), thus reducing P availability for plant uptake. Furthermore, these complexes may have contributed to the negative relationship between foliar P and soil P through masking effects. In addition, the significant covarying relationship between foliar Ca and foliar P (Table 5) may further support the above phenomenon. The acidic nature of the soils (pH 3.7 and 4.1) could affect P uptake. The roles of soil Al (since the soils are acidic) will further reduce P availability, but no data were available for this element in this study.

Fine roots of *A. mangium* on Jambu soil type contained more of the nutrients investigated except K (Table 2). The relatively rich organic matter may give rise to larger exploitation capacity for the roots on the Jambu soils (Table 3). It is anticipated that upon death and decay the contribution to site fertility will be more significant on Jambu than on Rhudua sites.

Accumulated diameter, height and basal area

A. mangium, growing on Rhudua soils (an impoverished site), supported significantly higher accumulated height growth compared to relatively fertile Jambu soils when using 50, 100 and 200 test trees (Figure 1). However, no significant growth differences in *A. mangium* were observed for accumulated diameter and basal area compositions between sites, (Figure 1), but numerically Jambu soils had higher site carrying capacity. Based on the above results, it was adequate to choose 83 dominant test trees of *A. mangium* per hectare for growth comparison.

Due to limited data set no correlation analysis was carried out between accumulated growth data and soil chemical data. However, foliage of *A. mangium* growing on Rhudua soils contained high elemental concentrations of N and K compared to Jambu soils (Table 1). Nitrogen and K levels of 2.35% and 0.65% respectively, in the foliage of *A. mangium* growing on Rhudua soils were considered as non limiting level for growth, whilst K level of 0.4% in the foliage on Jambu soils can be considered as a growth limiting level (Leaf 1968), thus affecting growth.

Nitrogen and K were reported to have a synergistic effect on yield and growth of rubber tree (Pushparajah 1969) and oil palm (Chan 1982). Even in this study, a significant synergistic relationship was observed between these two nutrients (Table 5). For forestry crops, Heinsdorf (1964) reported large growth increase by applying N and K fertilisers. Leyton and Armson (1955) observed a depression in height growth due to N application but coupled with K growth improved. Even site carrying capacity of natural forest has been shown by Amir and Miller (1991) to be somewhat controlled by nutrients, in particular K and to some extent N and P. Based on the above results and available literature, it is highly likely for N and K nutrients to play some role in the growth of *A. mangium.* However, field trails are necessary to resolve the issue.

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