WHICH CANOPY TIER SHOULD BE SAMPLED TO DETERMINE THE FERTILITY (NUTRITIONAL) STATUS OF *ACACIA MANGIUM* ON BRIS SOILS?

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Received March 1992

AMIR HUSNI MOHD. SHARIFF, SUHAIMI WAN CHIK, ADZMI YACCOB & MOHD. GHAZALI HASAN . 1993. Which canopy tier should be sampled to determine the fertility (nutritional) status of *Acacia mangium* on BRIS soils? Foliar elemental levels, determined in different canopy tiers of *Acacia mangium* growing on two different soil types, were compared with soil textural and chemical data. Foliage of trees growing on relatively fertile Jambu soils had higher elemental concentrations than those growing on nutrient impoverished Rhudua soils. On both soil types, foliar elemental levels differed in the different canopy tiers, but their distributions among tiers did not conform with observed patterns in other taxa. It is recommended that for an evaluation of the fertility status of *A. mangium*, the lower tier of sun-exposed foliage should be sampled for N and P levels and the top tier for other elemental levels.

Key words: BRIS soils - canopy tier of *Acacia mangium* - fertility evaluation

AMIR HUSNI MOHD. SHARIFF, SUHAIMI WAN CHIK, ADZMI YACCOB & MOHD. GHAZALI HASAN. 1993. Silara susun tegak yang manakah harus di sampel untuk menentukkan tahap kesuburan (nutrien) *Acacia mangium* di tanah BRIS? Kepekatan nutrien daun pada bahagian atas, tengah dan bawah silara *A. mangium* yang hidup pada dua jenis tanah pantai dibandingkan dengan tektur dan data kimia tanah. Kepekatan nutrien pada daun pokok yang hidup di atas tanah jenis Jambu yang subur (secara relatif) adalah lebih tinggi jika di bandingkan dengan daun pokok yang tumbuh di atas tanah jenis Rhudua (yang ketandusan zat nutrien). Pada kedua-dua jenis tanah yang dikaji, kadar zat nutrein pada daun berbeza pada ketiga-tiga bahagian silara, di mana kepekatan zat nutriennya tidak seperti yang lazim terjadi pada spesies yang lain. Kajian ini menunjukkan bahawa bagi penentuan kepekatan zat nitrogen dan fosporan, daun *A. mangium* dari bahagian bawah silara yang terdedah pada cahaya matahari bolehlah di sampel bagi kedua-dua jenis tanah yang di kaji. Bagi zat nutrien yang lain pula, daun dari bahagian atas silara adalah di syorkan.

Introduction

In 1982 the Forestry Department of Peninsular Malaysia launched the *Acacia mangium* plantation project. Since 1988, 40,000 *ha* have been planted in four selected states. The objective is to avert the shortage of local hardwood timber supply, which is expected to occur between 1996 and 2010 (Mohamed Darus & Lockman 1991). The rotation is set for 15 *y* with an expected yield of 180 m^3 ha^{-1}. However, a shorter rotation period is necessary for quick investment returns. Therefore, swift and accurate assessment of the plant nutritional status is inevitable. The best approach should be through foliar analysis, since it has been widely acknowledged by agricultural agronomists (Chapman 1941, Pushparajah & Tan 1972) and foresters (Leaf 1968, Van den Driessche 1984, Miller 1991) that this provides the best indicator of plant nutritional status.

The importance of adhering to a specific tree position for foliar sampling of perennial crops (Lundegrath 1951) at a fixed sampling time and the need to randomise sampling are recognised (Everard 1973). In pines, sampling has been confined to the current year foliage from the upper two to three branch whorls (Leyton & Armson 1955). However, the frond position in *A. mangium* which will best indicate its nutrient status for fertility evaluation is unknown.

The purpose of this study was to determine which tier of the canopy formation, namely top, middle or lower, provides the most reliable nutritionl status index for *A. mangium*.

Materials and methods

Study site

The study site at Tanjung Batu situated in the southeastern part of Pahang in Peninsular Malaysia was a 6-*ha* *Acacia mangium* plantation, adjoined by a 3-*ha* coconut plantation located 2 *km* from the beach front at latitude 3° 12' N and longitude 103° 27' E. Mean annual precipitation ranges between 3125 *mm* and 3165 *mm* and mean air temperature between 26.0°*C* and 28.4°*C* (unpublished meteorological data).

Soils consist of coastal sand known as BRIS (Beach Ridges Interspersed with Swales). They are classified as Spodosols and characterised by the presence of an albic horizon found in the Ae layer and underlain by a spodic horizon. The albic horizon is whitish while the spodic horizon is dusky red in colour. The latter horizon can occur at any level between 0.3 *m* and about 1.3 *m*, with sand being dominant throughout the profile development. The general characteristics of the two dominant soil types at the study site are presented in Table 1.

Table 1. Characteristics of two dominant soil types at Tanjung Batu study site

Soil type	Parent material	Pedological features
Rhudua	Estuarine deposits	Moderately deep & sandy soils; structureless & single grained; Yellowish brown (10YR 5/2); spodic horizon at 80 *cm* depth.
Jambu	Estuarine deposits	Deep & sandy soils; structureless & single grained; light grey (10YR 7/2).

Sampling procedure

One plot (110 × 55 *m*) was established on each of the two dominant soil types. Each plot was subdivided into ten paired but adjacent rows. In each pair of adjacent rows, twenty trees were sampled alternatively from each row, *i.e.* in a zig-zag pattern. Five foliar samples per tier were taken 15 *cm* below the apex of sun-exposed shoots from the upper, middle and lower canopy tiers of each tree and combined into a composite sample for each tier. In addition, two fronds sampled from each canopy tier were combined into a composite sample for the whole tree. A total of forty composite foliar samples were obtained from each plot. Sampling time was standardised, *i.e*. performed only in the morning and commencing only 24 *h* after heavy rainfall.

Soil pits (one per plot), 1.5 *m* deep, were excavated in each plot and 1 *kg* of soil sample was taken at different depths from each described soil horizon. Samples were oven dried at 60°*C* to a constant dry mass, milled and passed through a 2 *mm* sieve.

Foliar and soil analysis

Foliar samples were prepared according to methods given in Yeoh (1975). Nitrogen (Anonymous 1977) and phosphorus concentrations were measured colorimetrically using an auto-analyser (Kitson & Mellon 1944, Barton 1948). Potassium concentration was determined by flame photometry, and Ca, Mg, Zn and Mn concentrations on an atomic absorption spectrophotometer (Allen *et al.* 1974).

Soil pH was determined using 1:2.5 soil-water ratio. N was measured colorimetrically, P using Shimadzu UV/VIS Spectrophotometer after conversion to yellow vanadomolybdophosphate, and organic carbon by Walkley and Black's method(1934). Exchangeable cations were determined by leaching with 1N NH_4OAc at pH 7 (Chapman 1965); reserved P, K, Ca, Mg, Cu, Zn and Mn were determined by digestion with perchloric: sulfuric acid (1:1) for 2 *h* at 230°C (Lim 1975). Subsequent determination procedures were as outlined by Jackson (1958).

Statistical analysis

A single factor analysis of variance was used to test for significant differences in foliar elemental concentrations between plant canopy tiers on each soil type and between plants, irrespective of canopy tier level, on different soil types. Significant different means were separated using a Duncan's multiple range test at $p<0.05$.

Results

Foliar analyses

Significant ($p<0.05$) differences in foliar concentrations occurred between top, middle and lower canopy tiers of *A. mangium.* These differences were generally not consistent in plants growing on the two different soil types. Only foliar Ca and Mg concentrations declined from lower to top canopy tiers on both soil types (Table 1). Other elemental concentrations exhibited an irregular pattern. For example, K concentrations declined and Zn concentrations increased from top to lower canopy tiers of plants growing on Jambu soils, but this was not clearly evident in plants growing on Rhudua soils (Table 1). Foliar P concentrations exhibited no significant differences between plant canopy tiers on both soil types. The highest foliar N concentrations occurred in the top canopy tier on both soil types (Table 1).

There were significant differences ($p<0.001$) and ($p<0.01$) in P, K, Ca, Mg, Mn and N foliar elemental concentrations respectively between the combined canopy tiers on both soil types. However, no relationship was observed for elemental concentration Zn (Table 2).

Table 1. Foliar elemental concentrations, % oven dry mass (means of 10 replicates) in different plant canopy tiers of *A. mangium* growing on two different soil types

Crown position	Foliar elemental			Concentrations		
	N	P	K	Ca	Mg	Zn	Mn
	% oven dry mass					$\mu g\, g^{-1}$	
Jambu soils							
Top	2.14a	0.11a	0.40a	0.47c	0.19c	23b	324b
Middle	2.02b	0.10a	0.32b	0.83b	0.26b	28ab	462a
Lower	2.04ab	0.11a	0.31b	1.03a	0.31a	32a	465a
Whole	2.06ab	0.11a	0.34b	0.83b	0.25b	26ab	420a
F-value	*	ns	*	*	*	*	*
Rhudua soils							
Top	2.35a	0.08a	0.65a	0.33c	0.18c	29a	194a
Middle	2.19b	0.07a	0.49b	0.52ab	0.21a	31a	222a
Lower	2.25ab	0.08a	0.55ab	0.62a	0.22a	27a	238a
Whole	2.26ab	0.08a	0.59ab	0.47bc	0.20ab	26a	220a
F-value	*	*	*	*	ns	ns	ns

Values not sharing the same letter(s) are significant at $p<0.05$, ns is not significant.

Table 2. Foliar elemental concentrations % oven dry mass (means of 20 replicates) of combined top, middle and lower plant canopy tiers of *A. mangium* growing on two different soil types

Foliar location on	Foliar elemental concentrations						
	N	P	K	Ca	Mg	Zn	Mn
	% oven dry mass					$\mu g\ g^{-1}$	
Jambu soils	2.06	0.11	0.34	0.83	0.25	26	420
Rhudua soils	2.26	0.08	0.59	0.47	0.20	26	220
F values	**	***	***	***	***	ns	***

, * and ns are significant at p<0.01, p<0.001 and not significant, respectively.

Soil analyses

Both soil types were characterised by a dominant sand fraction. Exchangeable cations were low with CEC values not exceeding 5% in the top 30 *cm* of the soil profile, except for the Ap layer (0-8 *cm*) of Jambu soils. N concentration declined sharply in the subsoil and similarly for available and total P, except in spodic layers of both soils (Table 3).

The Jambu soil type was slightly more acidic and more rich in organic matter and carbon content than the Rhudua soil type, especially in the top layer (Ap horizon). The C/N ratios exceeded 20 in Jambu soils while those at Rhudua site were below 15, except in the zone approaching their respective spodic layers where the values were exceptionally low (Table 3).

Discussion

Foliar elemental levels in different canopy tiers did not generally conform with the observed patterns in other taxa, *i.e.* a decline in N, P, K, Mg and Zn levels with increasing distance from the canopy apex (Ovington 1957, Everard 1973).

High N and K concentration levels recorded in the top canopy tiers on both soil types (Tables 1 & 2) correspond with observations on rubber trees (Pushparajah & Tan 1972) and may be attributed to active meristematic tissues in this region. However, no similar pattern was observed for P, Mg and Zn despite the fact that these nutrients are highly mobile (Van den Driessche 1974, 1984, Kadeba & Aduayi 1985). The reverse trend observed could have been due to the poor soil fertility status (Table 3). On such soils, nutrients in the tree biomass tend to be allocated to more urgently needing tissues and organs.

Interestingly, a decreasing pattern was observed for Ca and Mn which complies with observations by Baule and Fricker (1970) and Das and Ramakrishnan (1987). The poor mobility of these elements within the tree leads to accumulation in foliar tissues of lower plant canopy tiers.

The absence of significant differences in foliar N and P levels between top and lower canopy tiers, despite significant differences between top and middle

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

	Rhudua soils							Jambu soils			
Depth (*cm*) Horizon	0-10 (Ap)	10-32 (E1)	32-50 (E2)	50-85 (B)	85-105 (Bhs)	105++ (BC)	0-8 (Ap)	8-30 (E1)	30-80 (E2)	80-160 (E3)	160++ (Bhs)
% Clay	2	1	-	-	4	-	6	1	-	-	6
Silt	1	-	-	-	2	-	2	-	-	-	2
F. sand	8	6	6	5	10	5	7	10	11	5	7
C. sand	89	93	94	95	84	95	85	89	89	95	85
pH	4.4	4.3	4.5	4.5	4.3	4.6	3.6	4.1	4.1	4.5	4.1
% O. matter	5.93	1.59	1.07	1.93	6.10	0.71	21.55	1.19	0.71	0.24	14.90
C	3.44	0.92	0.62	1.12	3.54	0.41	12.20	0.69	0.41	0.12	8.64
N	0.26	0.09	0.05	0.17	0.22	0.03	0.53	0.03	0.02	0.02	0.20
C/N	13	10	12	7	16	14	23	23	21	6	43
Total elements ($mmol \cdot kg^{-1}$)											
P	3.65	1.71	2.58	6.01	18.98	4.94	5.07	1.39	0.96	0.68	113.87
K	4.86	6.45	7.29	7.93	10.35	8.57	1.74	0.90	1.15	4.35	6.39
Ca	3.39	1.10	0.90	0.90	0.75	0.97	8.16	1.05	0.85	0.95	0.72
Mg	4.36	1.48	2.10	4.77	8.97	10.20	20.91	2.29	2.14	1.36	3.37
Exchangeable cations ($mmol^{+} kg^{-1}$)											
K	0.3	0.2	0.2	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.1
Ca	1.5	0.8	0.7	0.6	0.9	0.7	2.7	0.7	0.7	0.7	0.4
Mg	1.0	0.3	0.2	0.2	0.2	0.2	5.7	0.3	0.2	0.2	0.1
Na	0.5	0.2	0.3	0.2	0.4	0.1	1.1	0.2	0.2	0.2	0.3
CEC($cmol^{+} kg^{-1}$)	0.87	0.14	0.20	0.80	4.07	0.60	5.84	0.74	0.47	0.21	10.7
Av.P($mmol \cdot kg^{-1}$)	0.23	0.04	0.04	0.13	0.04	0.05	0.14	0.02	0.02	0.01	0.41

canopy tiers on both sites (Tables 1 & 2), suggests that for fertility evaluation of N and P the sampling of lower foliage tiers in *A. mangium* is adequate. By contrast, for a fertility evaluation of K, Ca, Mg, Mn and Zn the foliage of top tier should be selected.

In terms of soil fertility, both soil types can be considered as very inferior to sedentary derived soils. This is evident from their CEC values which are less than 5 $cmol^+ kg^{-1}$ (at 0-30 *cm* soil depth) (Table 3), compared to a common figure of 5 - 10 $cmol^+ kg^{-1}$ for a majority of sedentary derived soils (Law & Tan 1975). The C/N ratios of Jambu soils exceeded 20 indicating that the soils belong to the moder type whilst that of the Rhudua soils (C/N ratios less than 15) are classified as mull type (Baule & Fricker 1970). The former decomposes at a much slower rate than the latter, where nutrients are made available more slowly for plant uptake. This may be beneficial for plants since the rate of leaching on these two soils is high due to the high percentage of sand fractions (over 95%) (Table 3).

Generally, the Jambu soil series is comparatively more fertile than Rhudua series. This observation is well supported by high levels of CEC value (5 $cmol^+ kg^{-1}$) and organic matter content (21.55%) in the Ap layer of the former soils compared to a CEC value of 0.87 $cmol^+ kg^{-1}$ and an organic matter content of 5.39% in the latter soil type (Table 3).

The better fertility status of Jambu soils was reflected in higher P, Ca, Mg and Mn foliar elemental levels of *A. mangium* growing on this soil type (Table 3). However, despite high N levels and organic matter content in Jambu soils, foliage N content was significantly lower than in Rhudua soils. This could be due to poor N mineralisation rate in Jambu soils compared to Rhudua soils (as indicated by the higher C/N ratio and organic matter content). Comparatively, N concentration levels in Jambu subsoils (> 10 *cm* depth) were lower than in Rhudua subsoils. Furthermore, Jambu soils were more acidic than Rhudua soils in all the described horizons , thus affecting the growth and population density of microorganisms, one of the main agents of N mineralisation in the tropics (Swift *et al.* 1979).

Acknowledgements

We would like to thank the technical staff of the Soil Chemistry Laboratory of FRIM for carrying out the soil and foliar analyses. Our discussion with P.S. Chew (Head of Agriculture Applied Research) of Kepong and his critical comments and suggestions are acknowledged. Special thanks are due to Dato' Zaharuddin Jaafar, State Director of the Agriculture Department, Pahang Darul Makmur for his kind permission to FRIM to use the *A. mangium* stand for research.

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