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WHICH LEAF POSITION IN THE CROWN OF *TECTONA GRANDIS* (TEAK) SHOULD BE SAMPLED FOR FERTILITY (NUTRITIONAL) EVALUATION?

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AMIR, H.M. S., MOHD. GHAZALI, H., SUHAIMI, W.C. & ADZMI, Y. 1996. Which leaf position in the crown of *Tectona grandis* (teak) should be sampled for fertility (nutritional) evaluation? The fertility status of leaf tissues of *Tectona grandis* of various age groups and at various positions of the canopy was assessed via foliar sampling and chemical analysis. A single factor analysis was used to test for differences in elemental concentrations between the top, middle and lower canopy tiers. In addition, an *F*-test was carried out between the elemental concentrations of the foliage and leaf veins. Elemental levels of N, P, K, Mg, Cu and Zn in the foliage were generally higher in the apex zone, while those of Ca and Mn were higher in the lower tier of the canopy. In general, leaf tissues from either the top or middle tier of the sun-exposed canopy of *Tectona grandis* appeared suitable for the evaluation of nutritional status.

Key words: Canopy tier - *Tectona grandis* - foliage - leaf veins - fertility evaluation - Penambang Series soils

AMIR, H.M.S., MOHD. GHAZALI, H., SUHAIMI, W. C. & ADZMI, Y. 1996. Kedudukan daun manakah dalam silara *Tectona grandis* perlu disampel bagi jati untuk penilaian penentuan kesuburan (nutrien)? Tahap kesuburan tisu-tisu daun *Tectona grandis* dari pada berbagai kumpulan umur pada berbagai kedudukan silara telah dinilai melalui penyampelan daun dan analisis kimia. Analisis satu faktor telah digunakan untuk menguji perbezaan dalam kepekatan unsur pada bahagian atas, tengah dan bawah kanopi. Ujian-*F* juga telah dijalankan antara kepekatan unsur pada daun dan urat daun. Paras untuk unsur N, P, K, Mg, Cu dan Zn dalam daun adalah lebih tinggi di bahagian apeks, manakala kandungan Ca dan Mn adalah lebih tinggi pada tingkat bawah kanopi. Secara amnya, sampel tisu daun boleh diambil dari bahagian atas atau tengah kanopi yang terdedah kepada cahaya matahari untuk menentukan tahap kesuburan *Tectona grandis.*

Introduction

Teak (*Tectona grandis*) is an exotic species of Burmese origin. Its timber is highly durable and highly priced. Currently, teak log fetches between US$1800 and US$4500 per metric tonne for grades A and B respectively (Hashim, unpublished). A 60-y cycle is known to produce grade A quality timber. However, scientists are looking into the possibility of shortening the rotation period through tree selection, breeding and fertilising programmes. Teak has been reported by Amir (1984) to strive well in the northern states of Peninsular Malaysia, where the climate is favourable and similar to that of its native habitat.

Recently, the Malaysian government has agreed in principle to review the tax relief incentives to private entrepreneur and individuals to encourage the establishment of a private forest industry. In fact, a number of private companies have agreed to plant teak in the northern states of Peninsular Malaysia on a commercial basis with the technical support of the Forest Research Institute Malaysia (FRIM).

Besides its timber products, teak is also being planted in Malaysia for its aesthetic value. The road shoulders of the northern highway have been planted with this species and more planting has been planned by the highway authority.

It is therefore imperative to know and be able to diagnose the nutritional status of this species to maintain its healthy growth. A rapid and accurate approach is by means of foliar analysis. This technique has been widely accepted and acknowledged by agronomists (Chapman 1941, Shorrocks 1962, Pushparajah & Tan 1972) and foresters (Leaf 1968, Everard 1973, Driessche 1984, Amir *et al.* 1993, Amir & Wan Rashidah 1994), since it provides the best indicator of plant nutritional status.

The objective of this study was to determine which tier of the canopy formation, namely, top, middle or lower, provides the most reliable index for teak nutritional status.

Materials and methods

Study site

This study was conducted at the Mata Air Forest Reserve, Perlis, located in the northern parts of Peninsular Malaysia. The reserve contains 200 ha of *Tectona grandis* plantation, established in 1959 by the Forestry Department, at latitude 6° 4' N and longitude 100° 15' E. Mean annual precipitation ranges between 1800 mm and 1850; a period of three months is distinctly dry and mean air temperature ranges from 28 °C to 29.5 °C (unpublished meteorological data).

Soils consist mainly of alluvial, lateritic and shale derivatives with some degree of limestone influence. For this particular study, trees were only selected from the alluvial soils of Penambang Series belonging to the T_2 terrace formation (Paramananthan 1986). The soil is deep, yellowish brown in colour with sandy clay loam texture. The general characteristics of this soil type at the study site are presented in Table 1.

Table 1. Characteristics of Penambang Series soils at Mata Air study site

Soil series	Parent material	Pedological features
Penambang	Alluvial deposits	Deep, sandy clay loam soils; friable to slightly firm; weak to slightly strong, fine to medium to coarse subangular blocky, yellowish brown.

Sampling procedure

One plot, each 50 5 100 m, was established on four selected stands of *Tectona grandis*, i.e. of ages 10, 13, 20 and 34 years. The choice of the plot was based on uniform planting distance (3.2 × 3.2 m) and soil type. Silviculture treatments such as thinning and pruning were standard as applied by the Forestry Department but without fertilisation. Each plot was subdivided into ten paired but adjacent rows. In each pair of adjacent rows, twenty trees were sampled alternately 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 (each tree crown was divided into three equal portions, and each one-third portion was defined as top, middle and lower canopy tiers) and combined into a composite sample for each tier irrespective of age classes. A total of ten composite samples were taken from each tier position.

Sampling time was standardised, i.e. performed only in the morning and commencing 24 hours after heavy rainfall. Due to the nature of the foliage, the petioles in combination with the midribs, referred to as leaf veins, were separated from the leafy material for analysis. Each plot had therefore twenty composite samples.

A representative soil profile, 1.5 m deep, was dug and 1 kg of soil sample was taken at different depths from each described soil horizon. In addition, ten composite soil samples were collected to represent depths of 0 to 15 cm (topsoil) from each plot, where each composite sample was derived from twelve augering points, with each augering line equally spaced. Samples were oven-dried at 60 °C to a constant dry mass, milled and passed through a 2 mm sieve.

Foliar and soils analyses

Foliar samples were prepared according to methods given by Yeoh (1975). Nitrogen [by Kjeldahl digestion method (Anonymous 1977)] and phosphorus concentrations were measured colometrically using an auto-analyzer (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. Nitrogen was measured colometrically and P by formation of yellow vanado-molybdophosphate and measured with Shimadzu UV/VIS Spectrophotometer. Organic carbon was determined by the Walkley & Black (1934) method and exchangeable cations by leaching with 1N NH_4OAc at pH 7 (Chapman 1965).

Statistical analyses

A single factor analysis of variance was used to test for significant differences in elemental concentrations of the combined foliage (Table 2) and combined leaf veins (Table 3) between the top, middle and lower canopy tiers. In addition, for every tier location (top, middle and lower), an *F*-test was carried out between elemental concentrations of foliage and leaf veins to separate their significant differences (Table 4) at $p<0.05$, $p<0.01$ and $p<0.001$ levels. Further significant difference testing was also carried out between elemental concentrations of foliage and leaf veins of the combined age classes (Table 5).

For soil data, a similar test for significant differences was carried out between the soil elemental concentrations and physical properties in the four selected crop age classes. Significant different means were separated using a Duncan's multiple range test at $p<0.05$, whilst for the *F*-test the means were separated at $p<0.05$, $p<0.01$ and $p<0.001$ levels.

Results

All elemental concentrations for foliage and leaf veins of *T. grandis* for combined age classes revealed no significant differences ($p<0.05$) among top, middle and lower tiers except for Ca and Mn, being significant at $p<0.05$ level (Tables 2 & 3). All elemental concentrations in foliage exhibited a parallel increment going from lower to top canopy tiers (Table 2). A reverse but significant trend ($p < 0.05$) was observed for Ca and Mn. In the leaf vein elemental concentrations, N, P and K were almost similar in all the tiers, and except for Mg, the rest of the elements showed a decreasing trend (Table 3).

In general, differences in elemental concentrations among the different canopy tiers were more pronounced in the foliage than in the leaf veins.

Table 2. Elemental concentrations in the foliage of various canopy tiers of *Tectona grandis* (oven dry mass, means of 10 replicates)

Canopy tier	Elemental concentrations of foliage							
	N	P	K	Ca	Mg	Cu	Zn	Mn
			%				ppm	
Top	1.80a	0.13a	1.24a	2.93a	0.70a	7.3a	30a	65a
Middle	1.77a	0.11a	1.17a	3.57a	0.67a	6.4a	25a	89b
Lower	1.63a	0.11a	1.14a	4.81b	0.55a	3.8a	22a	105c

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

Table 3. Elemental concentrations in the leaf veins of top, middle and lower tiers of *Tectona grandis* (oven dry mass, means of 10 replicates)

Canopy tier	Elemental concentrations of leaf veins							
	N	P	K	Ca	Mg	Cu	Zn	Mn
			%				ppm	
Top	0.80a	0.06a	3.23a	3.25a	0.81a	11a	53a	39a
Middle	0.81a	0.06a	3.23a	3.61a	0.78a	14a	73a	39a
Lower	0.79a	0.07a	3.21a	4.05b	0.61a	15a	77a	54b

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

Table 4. Elemental concentrations between foliage and leaf veins of various canopy tiers of *Tectona grandis* (oven dry mass, means of ten replicates)

Canopy tier	Elemental concentrations of foliage and veins							
	N	P	K	Ca	Mg	Cu	Zn	Mn
			%				ppm	
Top tier								
Foliage	1.80	0.13	1.24	2.93	0.70	7	30	65
Veins	0.80	0.06	3.23	3.25	0.61	11	53	39
F-value	**	*	***	ns	ns	ns	**	**
Middle tier								
Foliage	1.77	0.11	1.17	3.57	0.67	6	25	89
Veins	0.81	0.06	3.23	3.61	0.78	14	73	39
F-value	**	*	***	ns	ns	*	**	**
Lower tier								
Foliage	1.63	0.12	1.14	4.81	0.65	4	22	104
Veins	0.77	0.07	3.21	4.05	0.81	15	77	45
F-value	**	*	***	ns	ns	*	**	***

ns = not significant; *, ** and *** = significant at $p < 0.1$, $p < 0.05$ and $p < 0.001$ respectively.

In terms of macro-elemental concentrations, significant differences were observed for N ($p<0.01$), P ($p<0.05$) and K ($p<0.001$), whilst for Ca and Mg no differences were recorded in the top tier (Table 4). A similar trend was observed for the middle and lower canopy tiers. An exceptionally high concentration of elemental K was detected in the leaf veins for all the three tiers in comparison to the foliage ($p<0.001$) (Table 4).

For micro-element concentrations, significant differences were recorded for Cu ($p<0.05$), Zn ($p<0.01$) and Mn ($p <0.01$) in all the three canopy tiers between foliage and leaf veins with the exception of Cu in the top canopy tier (Table 4). A highly significant difference was recorded between foliage and leaf veins in the lower tier for Mn ($p<0.001$).

Table 5. Elemental concentrations between foliage and leaf veins of *Tectona grandis* for combined age classes (oven dry mass, means of 10 replicates)

Vegetative matter	Elemental concentrations of foliage and veins							
	N	P	K	Ca	Mg	Cu	Zn	Mn
			%				ppm	
Foliage	1.86	0.11	1.18	3.32	0.63	4	26	81
Veins	0.85	0.07	3.47	3.36	0.76	13	68	43
F-value	**	*	***	ns	ns	**	**	**

ns - not significant; *, ** and *** are significant at $p<0.1$, $p<0.1$ and $p<0.001$ respectively.

On combining the elemental concentrations of foliage and of veins of the top, middle and lower tiers, significant differences were recorded between these two components for N, P, K, Cu, Zn and Mn elements with the exception of Ca and Mg (Table 5). Significantly high concentrations of N and Mn elements were recorded in the foliage tissues compared to the vein tissues whilst the reverse was very significant for K, significant for Cu and Zn but somewhat less significant in the case of Ca and Mg (Table 5).

Table 5. Elemental concentrations of Penambang series soils under *Tectona grandis* stands of selected age classes (oven dry-mass, means of 10 replicates)

Crop age (years)	Mean soil physical and chemical properties							
	N	Av. P	K	Ca	Mg	Na	CEC	pH
			Exchangeable cations					
	%	ppm		$\text{mmol}^{+}\ \text{kg}^{-1}$			$\text{cmol}^{+}\ \text{kg}^{-1}$	
36	0.09a	1.85a	0.29a	0.61c	0.57b	0.14a	4.8a	4.8c
32	0.09a	1.63ab	0.19b	0.92c	0.60b	0.11ab	1.9b	4.8c
15	0.09a	1.17b	3.19b	2.01b	1.05a	0.11ab	1.7b	5.2b
12	0.09a	1.75a	0.10c	8.12a	0.95ab	0.09b	3.7a	6.9a

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

No particular trend or distinct differences were observed between the elemental concentrations of soils under *Tectona grandis* stand of the selected age classes except for soil pH and Ca concentration (Table 6). A high amount of Ca was observed in the 12-y-old stand (8.12 $\text{mmol}^{+}\ \text{kg}^{-1}$) and this was reflected by the correspondingly high pH value (6.9).

Discussion

The elemental levels of N, P, K, Mg, Cu and Zn in the foliage conformed to the general observed patterns recorded in other taxa, where higher elemental concentrations were observed in the apex zone of the tree crown (Ovington 1957, Shorrocks 1962, Amir *et al.* 1993, Amir & Wan Rashidah 1994). The higher elemental concentration levels recorded in the top canopy tiers of *Tectona grandis* foliage (Tables 2) correspond to observations on rubber tree (Pushparajah & Tan 1972). This phenomenon may be attributed to the active meristematic tissues in this region and the mobility of these elements (Driessche 1974, 1984, Miller 1984, Kadeba & Aduayi 1985).

Ca and Mn concentrations in the foliage and leaf veins of *Tectona grandis* were significantly greater in the lower canopy tier which complies with observations by Baule and Fricker (1970), Das and Ramakrishnan (1987), Killsgaard *et al.* (1987), Amir *et al.* 1993, and Amir and Wan Rashidah (1994). The poor mobility of these elements within the tree leads to accumulation in the foliar tissues of the lower canopy tier.

The elemental concentrations in the foliage and leaf veins, especially between the top and middle tiers, were not statistically different, thus suggesting that either of these tiers of the crown of *Tectona grandis* can be sampled for fertility evaluation. Besides fixing the canopy position it is also important to fix the sampling time (Pusparajah & Tan 1972) and the need to randomise (Everard 1973).

Irrespective of any crown position (top, middle or lower tier), higher macro-elemental concentrations with the exception of K were observed in the foliage than in the leaf veins (Tables 4 & 5). Elemental K is known to strengthen the cell wall (Perrenoud 1977, Beringer & Nothdurft 1985) and this corresponds to the findings of Amir and Mona (1990) who observed that trees of emergent layers, in particular *Koompassia malaccensis*, contain higher levels of K in their crown foliage than dipterocarp trees of lower layers.

Generally, the soils of Penambang series can be considered nutritionally poor. It is well documented that Malaysian soils are inherently poor in available P (Owen 1953, Paramananthan 1977, Amir *et al.* 1989) and exchangeable cations (Law & Tan 1975). The almost neutral pH value recorded in the 12-y-old stand is attributed greatly to the high amounts of exchangeable Ca present at the site. It is well known mented that Ca is taken into the plant through mass-flow action (Beringer & Nothdurft 1985), and the high amount of Ca recorded in this plot reflects the high uptake of this element by the plant.

Conclusion

This study suggests that for an evaluation of fertility status of *Tectona grandis*, either the top or the middle tier of the tree crown of sun-exposed foliage can be sampled for fertility evaluation.

Elemental K accumulated significantly in the leaf veins in all the three tiers, indicating its role in strengthening the cell wall of the leaf veins, while Ca and Mg accumulated in other older plant tissues. In addition, high concentrations of elemental N, P, K, Mg, Cu and Zn were observed in the apex zone of the tree crown suggesting the presence of active meristematic tissues in this region and high mobility of these elements.

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