Leaf protein contents and nitrogen-to-protein conversion factors for 90 plant species

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The leaf protein contents of 90 plants covering taxonomically diverse groups ranged from 0.2 to 7.5 g% fr. wt. The nitrogen-to-protein conversion factors (k_A) based on nitrogen recovered from amino acid analyses ranged from 5.15 to 5.93, reaffirming that the traditional factor of 6.25 is not valid for plant proteins. A more practical conversion factor (k_P) based on the ratio of protein from amino acid data to Kjeldahl nitrogen varied from 3.28 to 5.16. Variations in both leaf protein contents and the conversion factors to some extent correlated with the taxonomic groupings of the plants. For a good estimate of the leaf protein content from Kjeldahl nitrogen, factor k_P , established using plants sampled from the same taxonomic group, should be used. However, for plants in general, a k_P of 4.43 should provide a reasonably good estimate of the protein content.

INTRODUCTION

Leaves are a potential source of proteins. They have both actual and potential values as animal feed and in the production of unconventional protein food (Pirie, 1986). Many tropical plant species are potentially useful in this respect and may not have been analysed for their protein content. It is therefore useful to have a quick and reasonably accurate method of estimating the protein content. The total nitrogen analysis using the Kjeldahl method is still widely favoured for crude protein estimation but its accuracy is dependent on the nitrogen-to-protein conversion factors used. There have been a few reports showing that the traditional protein conversion factor of 6.25 is not valid for plant materials (Milton & Dintzis, 1981; Handley et al., 1989; Mosse, 1990). So far, the conversion factor reported for only a small number of plant species ranged from 3.7 to 6.0 (Milton & Dintzis, 1981; Handley et al., 1989).

Thus we have set out to determine the leaf protein content and establish the nitrogen-to-protein conversion factors for a wide ranging and taxonomically diverse group of plants. Bearing in mind that taxonomic schemes have predictive capabilities in various contexts and in our previous studies on plant proteins (Yeoh & Watson, 1981, 1982; Yeoh *et al.*, 1986, 1992), the plants used in this study have been selected to represent the major taxonomic groups of the plant kingdom. Moreover, results from such a study can help us

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assess how far a knowledge of taxonomy is helpful in identifying variations in leaf protein contents and the nitrogen-to-protein conversion factors.

MATERIALS AND METHODS

Freshly harvested mature leaves were used for all analyses. Leaf samples were collected from plants grown in the Botany Department garden, the Singapore Botanic Gardens and elsewhere in Singapore. Total nitrogen was determined using the micro-Kjeldahl technique (Bailey, 1967) with 1 g fr. wt leaf. For amino acid analysis, finely cut leaf blades (100-200 mg) were hydrolysed in 0.5 ml 3N mercaptoethane sulphonic acid in a sealed tube at 110°C for 22 h according to Yeoh et al. (1986), then analysed using the Beckman amino acid analyser 119CL. For total nitrogen determination, four samples were analysed whereas for amino acid determination duplicate analyses were carried out. Leaf protein contents were calculated from the amino acid analyses and expressed as g% fr. wt. Moisture was determined as described in Bradbury and Holloway (1988). Significant differences reported are at the 5% probability level.

RESULTS AND DISCUSSION

The plants used in this study covered the three major plant phyla, namely the Pteridophyta, Gymnospermae and Angiospermae. We have also analysed the angiosperm data against the super-orders of Dahlgren's



Species	Moisture (g% fr. wt)	Protein (g% fr. wt)	Nitrogen recovery			Nitrogen-to-protein		
			Amino acids	Amino acids and NH ₃ (g% fr. wt)	Kjeldahl nitrogen	k_A	k' _A	k _p
Pteridophyta							<u></u>	
Angiopteris evecta	84 ·7	0.94	0.15	0.16	0.19	6.15	5.71	4 ·91
Asplenium nidus	80.5	0.99	0.16	0.17	0.20	6.19	5.82	4.95
Bolbitis heteroclita	73·9	2.83	0.46	0.52	0.55	6.11	5·69	5.14
Cibotium barometz	64.8	3.61	0.59	0.62	0.80	6.11	5.81	4.52
Cyathea latebrosa	71-1	2.21	0.36	0.38	0.50	6.15	5.82	4.42
Davallia denticulata	74-2	2.23	0.36	0.38	0.47	6.25	5.83	4·72
Dicranopteris linearis	55.9	2.44	0.39	0.42	0.59	6·19	5.85	4.16
Lygodium microphyllum	70 ·8	1.83	0.30	0.32	0.43	6.11	5.78	4.24
Nephrolepis biserrata	85.6	1.15	0.19	0.20	0.26	6.14	5.77	4.47
Trichomanes javanicum	77.6	2.02	0.33	0.36	0.40	6.14	5.67	5.04
Taxonomic mean	73.9	2.03	0.33	0.35	0.44	6.15	5.78	4.66
Gymnospermae								
Araucaria columnaris	52.5	2.65	0.43	0.47	0.81	6.16	5.62	3.28
Cycas rumphii	67·0	3.88	0:63	0.69	0.90	6·17	5.62	4·33
Gingko biloba	78.7	3.10	0.50	0.54	0.64	6.18	5.77	4.81
Gnetum gnemon	65.1	4.65	0.74	0.81	1.10	6.25	5.76	4.24
Pinus merkusii	61.1	1.91	0.31	0.34	0.42	6.12	5.64	4.50
Podocarpus polystachyus	47.4	3.44	0.56	0.60	0.84	6.19	5.75	4.11
Taxonomic mean	62.0	3.27	0.53	0.58	0·79	6.18	5.69	4.21

Table 1. Moisture, protein and nitrogen analyses of leaves of Pteridophyta and Gymnospermae

 $k_{\rm A}$, ratio of protein to amino acid nitrogen; $k_{\rm A}$, ratio of protein to nitrogen from amino acids and ammonia; $k_{\rm p}$, ratio of protein to Kjeldahl nitrogen.

scheme (Dahlgren, 1980) and have superimposed on Dahlgren's dicotyledon super-orders the main division into Crassinucelli and Tenuinucelli advocated by Young and Watson (1970).

Tables 1-3 give the moisture, leaf protein and nitrogen contents, and nitrogen-to-protein conversion factors for the 90 plants covering the pteridophytes, gymnosperms and angiosperms. The total leaf protein amino acid content of these plants represent not only amino acids derived from proteins but also those in the free form. Thus in the calculation of protein content from total leaf amino acid data, contribution by the free protein amino acids must be acknowledged. The extent to which the free amino acids will influence the overall estimation of leaf protein content is likely to vary from plant to plant. It was shown for 36 grass species that the free amino acids constituted 0.9-12 % of the total leaf protein amino acids (Yeoh & Watson, 1982). However, the quantity of free protein amino acids is generally less than 5% of total leaf amino acids (Yeoh & Chew 1976; Yeoh & Watson, 1982). In interpreting the results one must be cautioned that many factors, such as plantleaf age, stage of growth and environmental conditions could contribute to changes in the quantity and quality of leaf proteins, amino acid compositions and other nitrogenous compounds (Smith, 1976; Yeoh & Watson, 1982; Yeoh & Paul, 1989).

A large variation in protein content was observed, ranging from 0.2 g% fr. wt in *Dischidia nummularia* to 7.45 g% fr.wt in *Adenanthera pavonia*. Group by group comparisons showed that the Gymnospermae and Angiospermae had protein contents $(3.3\pm1.0 \text{ g}\% \text{ fr. wt})$ and $3.3\pm1.7 \text{ g}\%$ fr. wt, respectively) significantly higher than that of the Pteridophyta $(2.0\pm0.8 \text{ g}\% \text{ fr. wt})$. Within the Angiospermae, the dicotyledonous plants exhibited significantly higher protein content $(3.8\pm1.7 \text{ g}\% \text{ fr. wt})$ than the monocotyledonous plants $(1.7\pm0.8 \text{ g}\% \text{ fr. wt})$ (Tables 2 and 3). Leaves of grasses were reported to be poor in protein, averaging $2.2\pm1.0 \text{ g}\%$ fr. wt (Yeoh & Watson, 1982), similar in range to those reported here for the monocotyledonous plants.

Within the Dicotyledonae, differences in leaf protein contents were observed for some of Dahlgren's superorders; the Malviflorae, Violiflorae and Fabiflorae exhibited higher leaf protein contents (4.4 g% fr. wt) than those of Magnoliflorae, Theiflorae and Gentianiflorae (3.5 g% fr. wt; Table 2). With respect to Young and Watson's scheme (Young & Watson, 1970), the crassinucellate group exhibited a protein content (4.0±1.7 g% fr. wt) significantly higher than that of the tenuinucellate group $(2.9\pm1.3 \text{ g}\% \text{ fr. wt})$. Even among the closely related crassinucellate members, the legumes yielded protein content (5.2±1.6 g% fr.wt) significantly higher than those of the caryophylloids $(4.0\pm1.7 \text{ g}\% \text{ fr.})$ wt) and magnolioids (3.5±1.1 g% fr. wt). Although many factors such as the physiology of the plants and environmental conditions, could affect the levels of proteins in the leaves, it is noteworthy that differences are detected at different levels of taxonomic hierarchy.

Three types of nitrogen contents relevant to the calculation of nitrogen-to-protein conversion factors were considered. The first type was nitrogen derived

$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Species I (g	Moisture	Protein (g% fr. wt)	Nitrogen recovery			Nitrogen-to-protein		
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		g% Ir. w()		Amino acids	Amino acids and NH ₃ (g% fr. wt)	Kjeldahl nitrogen		k' _A	k _p
	Magnoliflorae ¹			- <u></u>					
$\begin{array}{c} \mbod Michelia champaca^h_{1} 547 & 3.66 & 0.59 & 0.63 & 0.90 & 6.19 & 5.78 & 4 \\ \mbod Taxonomic mean & 56.2 & 3.23 & 0.52 & 0.56 & 0.79 & 6.16 & 5.72 & 4 \\ \mbod Taxonomic mean & 56.2 & 3.23 & 0.52 & 0.56 & 0.79 & 6.16 & 5.72 & 4 \\ \mbod Taxonomic mean & 56.9 & 1.74 & 0.28 & 0.30 & 0.44 & 6.19 & 5.73 & 1 \\ \mbod Taxonomic mean & 56.9 & 1.74 & 0.28 & 0.30 & 0.44 & 6.19 & 5.73 & 1 \\ \mbod Taxonomic mean & 56.9 & 1.74 & 0.28 & 0.30 & 0.44 & 6.19 & 5.76 & 4 \\ \mbod Taxonomic mean & 89.3 & 1.58 & 0.25 & 0.27 & 0.35 & 6.26 & 5.76 & 4 \\ \mbod Taxilly Jalapat & 89.3 & 1.58 & 0.25 & 0.27 & 0.35 & 6.26 & 5.80 & 4 \\ \mbod Taxilly Jalapat & 89.3 & 1.58 & 0.58 & 0.63 & 0.92 & 6.13 & 5.72 & 3 \\ \mbod Taxonomic metal & 58.3 & 4.47 & 0.72 & 0.71 & 10.2 & 6.24 & 5.84 & 4 \\ \mbod Taxao Taxonomic mean & 56.9 & 0.40 & 0.65 & 0.70 & 0.90 & 6.22 & 5.80 & 4 \\ \mbod Taxonomic mean & 0.14 & 4.57 & 0.77 & 10.2 & 6.24 & 5.84 & 4 \\ \mbod State Taxonomic mean & 0.14 & 4.57 & 0.77 & 0.01 & 0.80 & 6.21 & 5.77 & 4 \\ \mbod Taxonomic mean & 0.14 & 4.57 & 0.74 & 0.79 & 0.10 & 6.80 & 6.21 & 5.77 & 4 \\ \mbod State Taxonomic mean & 0.14 & 4.57 & 0.51 & 0.54 & 0.70 & 6.17 & 5.77 & 4 \\ \mbod State Taxonomic mean & 0.14 & 4.57 & 0.71 & 0.93 & 1.08 & 6.23 & 5.73 & 4 \\ \mbod State Taxonomic mean & 0.14 & 4.57 & 0.71 & 0.71 & 0.96 & 6.22 & 5.79 & 4 \\ \mbod Taxonomic mean & 0.14 & 4.57 & 0.71 & 0.71 & 0.96 & 6.22 & 5.79 & 4 \\ \mbod Taxonomic mean & 0.14 & 4.57 & 0.71 & 0.71 & 0.61 & 6.23 & 5.73 & 4 \\ \mbod State Taxonomic mean & 73.1 & 4.46 & 0.71 & 0.77 & 0.61 & 6.23 & 5.73 & 4 \\ \mbod Taxonomic mean & 61.5 & 2.00 & 0.32 & 0.35 & 0.43 & 6.17 & 5.71 & 4 \\ \mbod Taxonomic mean & 61.5 & 2.00 & 0.32 & 0.35 & 0.43 & 6.17 & 5.71 & 4 \\ \mbod Taxonomic mean & 61.5 & 2.00 & 0.32 & 0.35 & 0.43 & 6.17 & 5.71 & 4 \\ \mbod Taxonomic mean & 61.5 & 2.00 & 0.32 & 0.35 & 0.43 & 6.17 & 5.71 & 4 \\ \mbod Taxonomic mean & 61.5 & 2.00 & 0.32 & 0.35 & 0.43 & 6.17 & 5.71 & 4 \\ \mbod Taxonomic mean & 61.5 & 2.00 & 0.32 & 0.87 & 6.82 & 5.83 & 3 \\ \mbod Taxonomic mean & 61$	Annona squamosa ^b	51-3	3.53	0.57	0.62	0.93	6.16	5.65	3.80
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Michelia champaca ^b	54.7	3.66	0.59	0.63	0.90	6.19	5.78	4.06
Taxonomic mean 56.2 3.23 0.52 0.56 0.79 6.16 5.72 4 Nymphaeilforael 5.73 5 5 5 7 5 7 5 7 5 7 5 7 5 7 5 7 5 7 5 7 5 7 5 6 5 6 5 7 6 4 Mirabilis jalapat 8 9 2 0.35 6 20 5 80 4 7 0.35 6 20 5 80 4 7 0.72 0.73 0.85 6 20 5 80 4 4 4 4 6 6 6 8 4	Myristica fragrans ^b	62.6	2.50	0.41	0.44	0.55	6.13	5.73	4-53
Nymphaeiflorae ¹ Piper nigram 65.9 1.74 0.28 0.30 0.44 6-19 5.73 2 Caryophyillorae ¹ Amaramhus bilum ⁴ 89.3 1.58 0.25 0.27 0.35 6.26 5.76 4 Mirabilis jalapa ⁴ 89.3 1.58 0.25 0.27 0.35 6.25 5.80 4 Polygonilorae ¹ Antigonon leptopus ⁴ 74.2 3.58 0.58 0.63 0.92 6.13 5.72 3 Malviflorae ¹ Antigonon leptopus ⁴ 74.2 3.58 0.59 0.63 0.92 6.13 5.72 3 Malviflorae ¹ Artocorpus heterophyllta ⁴ 68.8 3.63 0.59 0.63 0.92 6.13 5.72 3 Bixa orelland ⁴ 56.1 58.1 4.72 0.77 1.02 6.20 5.84 4 Goldona ⁴ 0.51 0.54 0.70 6.17 5.77 4 Taxonomic mean 61.4 4.57 0.74 0.79 1.02 6.22	Taxonomic mean	56.2	3.23	0.52	0.56	0.79	6.16	5.72	4.13
	Nymphaeiflorae ¹								
$\begin{array}{c} Carcyophyliflorae^1 \\ Amaranthus blitum" & 88-9 & 2.63 & 0.42 & 0.46 & 0.55 & 6.26 & 5.76 & 4 \\ Mirabilis jalapar' & 89.3 & 1.58 & 0.25 & 0.27 & 0.35 & 6.25 & 5.80 & 4 \\ Polygoniforae^1 \\ Antigonon leptopus" & 74.2 & 3.58 & 0.58 & 0.63 & 0.92 & 6.13 & 5.72 & 5 \\ Malvitorae' \\ Artocarpus heterophylikar' & 68.8 & 3.63 & 0.59 & 0.63 & 0.85 & 6.20 & 5.80 & 4 \\ Bixa orellanar' & 58.3 & 4.47 & 0.72 & 0.77 & 1.02 & 6.24 & 5.84 & 4 \\ Ficus religost" & 68.9 & 4.04 & 0.65 & 0.70 & 0.90 & 6.22 & 5.84 & 4 \\ Hevea brasiliensis' & 56.1 & 5.81 & 0.94 & 1.03 & 1.26 & 6.16 & 5.65 & 4 \\ Muntingia calabarar' & 59.8 & 5.93 & 0.96 & 1.02 & 1.31 & 6.20 & 5.84 & 4 \\ Hevea brasiliensis' & 56.1 & 5.81 & 0.94 & 1.03 & 1.26 & 6.16 & 5.65 & 4 \\ Muntingia calabarar' & 59.8 & 5.93 & 0.96 & 1.02 & 1.31 & 6.20 & 5.84 & 4 \\ Taxonomic mean & 61.4 & 4.57 & 0.74 & 0.79 & 1.02 & 6.20 & 5.78 & 4 \\ Violiflorae^l & & & & & & & & & & & & & & & & & & &$	Piper nigrum	65.9	1.74	0.28	0.30	0.44	6.19	5.73	3.99
	Carvophyliflorae ¹								
Mirabilis jalapa ^a 89-3 1.58 0.25 0.27 0.35 6.25 5.80 4 Polygoniflorae ¹ Antignoon leptopus ^a 74-2 3.58 0.58 0.63 0.92 6-13 5-72 2 Malviflorae ¹ Artocarpus heterophyllus ^a 68-8 3.63 0.59 0.63 0.85 6.20 5-80 4 Artocarpus heterophyllus ^a 68-9 404 0.63 0.70 0.90 6.22 5-80 4 Hevea brasiliensic ^a 56-1 5-81 0.94 1.03 1.26 6-16 5-65 4 Munitingia calabura ^a 59-8 5.93 0.96 1.02 1.31 6.20 5-78 4 Sida rhombifolia ^a 56-4 3.54 0.57 0.61 0.80 6.21 5.77 4 Carica papaya ^b 79-2 3.12 0.51 0.54 0.70 6.17 5.77 4 Carica papaya ^b 79-2 3.12 0.51 0.54	Amaranthus blitum ^a	88.9	2.63	0.42	0.46	0.55	6.26	5.76	4.74
Polygoniflorae ¹ Antigonon leptopus ^a 74·2 3·58 0·58 0·63 0·92 6·13 5·72 3 Malviflorae ¹ Artocarpus heterophyllus ^a 68·8 3·63 0·59 0·63 0·85 6·20 5·80 4 Bixa orellana ^a 58·3 4·47 0·72 0·77 1·02 6·24 5·84 4 Ficus religiosa ^a 68·9 4·04 0·65 0·70 0·90 6·22 5·80 4 Munitingia calabura ^a 59·8 5·93 0·96 1·02 1·31 6·20 5·84 4 Munitingia calabura ^a 59·8 5·93 0·96 1·02 1·31 6·20 5·84 4 Sida rhombifolia ^a 5·64 3·54 0·57 0·61 0·80 6·21 5·77 4 Taxonomic mean 61·4 4·57 0·74 0·79 1·02 6·20 5·78 4 Violiflorae ¹ Carica papaya ^b 79·2 3·12 0·51 0·54 0·70 6·17 5·77 4 Passifienz foetida ^a 70·8 5·32 0·85 0·93 1·11 6·25 5·73 4 Satix hombiforia ^d 6·93 4·95 0·79 0·85 1·08 6·23 5·78 4 Satix hombiforia ^d 70·8 5·32 0·85 0·93 1·11 6·25 5·77 4 Taxonomic mean 7·3·1 4·46 0·71 0·77 0·96 6·22 5·79 4 Theiflorae ¹ Cratoxylon formosum ^b 58·1 1·93 0·31 0·34 0·41 6·15 5·67 4 Mesua jerrea ^a 4·78 1·55 0·25 0·27 0·33 6·20 5·73 4 Nepenthes rafficsina ^a 78·6 1·55 0·25 0·27 0·33 6·20 5·73 4 Nepenthes rafficsina ^a 78·6 1·55 0·25 0·67 6·09 5·67 4 Rosiflorae ¹ Cataca various planta 88·4 0·72 0·11 0·55 0·67 6·09 5·67 4 Advantine apusotif ^a 61·0 2·95 0·48 0·51 0·65 6·15 5·77 4 <i>Advantine apusotif</i> 61·0 2·95 0·48 0·51 0·65 6·18 5·74 4 Advantine apusotif ^a 61·0 2·95 0·48 0·51 0·65 1·5 5·77 4 Advantine apusotif ^a 61·6 3·59 0·58 0·63 0·87 6·18 5·74 4 Advantine apusotif 61·6 3·59 0·58 0·63 0·87 6·18 5·74 4 Advantine apusotif 61·6 3·59 0·58 0·63 0·87 6·18 5·74 4 Advantine apusotif 61·6 3·59 0·58 0·63 0·87 6·18 5·74 4 Advantine apusotif 61·6 3·59 0·58 0·63 0·87 6·18 5·74 4 Advantine apusotif 61·6 3·59 0·58 0·63 0·87 6·18 5·74 4 Advantine apusotif 61·6 3·59 0·58 0·63 0·87 6·18 5·74 4 Advantine apusotif 61·6 3·59 0·58 0·63 0·87 6·18 5·74 4 Advantine apusotif 61·6 3·59 0·58 0·63 0·87 6·18 5·74 4 Advantine apusotif 61·6 3·59 0·58 0·63 0·87 6·18 5·76 4 Advantine apusotif 61·6 3·59 0·58 0·63 0·87 6·18 5·76 4 Advantine apusotif 61·6 3·59 0·58 0·63 0·87 6·18 5·76 4 Advantine apusotif 61·6 3·59 0·58 0·63 0·87 6·18 5	Mirabilis jalapa ^a	89.3	1.58	0.25	0.27	0.35	6.25	5.80	4.55
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Polygoniflorae ¹								
	Antigonon leptopus ^a	74.2	3.58	0.58	0.63	0.92	6.13	5.72	3.89
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Malviflorae ¹								
Bix a orelland* S8:3 4.47 0.72 0.77 1.02 6.24 5.84 4 Ficus religiosa* 68:9 4.04 0.65 0.70 0.90 6.22 5.80 4 Heva braillensis* 56:1 5.81 0.94 1.03 1.26 6:16 5.65 4 Muningia calabura* 59:8 59:3 0.96 1.02 1:31 6:20 5:84 4 Taxonomic mean 61:4 4:57 0.74 0.79 1:02 6:20 5:78 4 Violiforae! Carica papaya* 79:2 3:12 0.51 0.54 0.70 6:17 5:77 4 Passifiora formosum* 70:8 5:32 0.85 0.93 1:11 6:25 5:73 4 Alsa konbylonica* 69:3 4.95 0.79 0.85 1.08 6:22 5:79 4 Taxonomic mean 73:2 0.44 0.55 6:18 5:77 4 <td>Artocarpus heterophyllus^a</td> <td>68·8</td> <td>3.63</td> <td>0.59</td> <td>0.63</td> <td>0.85</td> <td>6.20</td> <td>5.80</td> <td>4.28</td>	Artocarpus heterophyllus ^a	68 ·8	3.63	0.59	0.63	0.85	6.20	5.80	4.28
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Bixa orellana ^a	58.3	4.47	0.72	0.77	1.02	6.24	5.84	4.38
Heve brasiliensis ² 56.1 5.81 0.94 1.03 1.26 6.16 5.65 4 Muntingia calabura ² 59.8 593 0.96 1.02 1.31 6.20 5.84 4 Sida rhombifolia ² 56.4 3.54 0.57 0.61 0.80 6.21 5.77 4 Taxonomic mean 61.4 4.57 0.74 0.79 1.02 6.20 5.78 4 Violiforae ¹ Carica papav ^a 79.2 3.12 0.51 0.54 0.70 6.17 5.77 4 Passifioras foetida ^b 70.8 5.32 0.85 0.93 1.11 6.25 5.73 4 Passifioras foetida ^b 70.8 5.32 0.85 0.93 1.96 6.22 5.79 4 Taxonomic mean 73.1 4.46 0.71 0.77 0.96 6.22 5.79 4 Mesua ferrea ^b 47.8 2.52 0.21 0.33 6.20 5.73 4 Mesua ferrea ^b 47.4 3.13 0.51 0.55 0.67<	Ficus religiosa ^a	68·9	4.04	0.65	0.70	0.90	6.22	5.80	4 49
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	Hevea brasiliensis ^c	56 ·1	5.81	0.94	1.03	1.26	6.16	5.65	4.61
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Muntingia calabura ^c	59·8	5.93	0.96	1.02	1.31	6.20	5.84	4.53
Taxonomic mean 61-4 4-57 0-74 0-79 1-02 6-20 5-78 4 Violiflorae ¹ Carica pagaya ^b 79-2 3-12 0-51 0-54 0-70 6-17 5-77 4 Passiflora foetida ^b 70-8 5-32 0-85 0-93 1-11 6-22 5-79 4 Salix babylonica ^h 69-3 4-95 0.79 0.85 1-08 6-23 5.86 4 Theifforae ¹ Cartoxylon formosum ^b 58-1 1-93 0.31 0.34 0-41 6-15 5-67 4 Mesua ferrea ^b 47-8 2-52 0.41 0-44 0-55 6-18 5-74 4 Nepenthes rafficsiana ^{aa} 78-6 1-55 0.25 0-27 0-33 6-20 5-73 4 Taxonomic mean 61-5 5-77 4 7 4 7 4 7 7 4 7 7 4 7 7 4 7	Sida rhombifolia ^c	56.4	3.54	0.57	0.61	0.80	6.21	5.77	4.41
$\begin{array}{c} \mbox{Violiflorae}^1 & & & & & & & & & & & & & & & & & & &$	Taxonomic mean	61.4	4.57	0.74	0.79	1.02	6.20	5.78	4.45
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Violiflorae								
Passifiora foetilad 70.8 5.32 0.85 0.93 1.11 6.25 5.73 4.45 Salix babylonicat 69.3 4.95 0.79 0.85 1.08 6.23 5.86 4.45 Taxonomic mean 73.1 4.46 0.71 0.77 0.96 6.22 5.79 4.46 Cratoxylon formosum ^b 58.1 1.93 0.31 0.34 0.41 6.15 5.67 4.4 Mesua ferrea ^b 47.8 2.52 0.41 0.44 0.55 6.18 5.74 4 Nepenthes rafficsiana ^a 78.6 1.55 0.25 0.27 0.33 6.20 5.73 4 Primuliflorae ¹ Maikara zapota ^a 47.4 3.13 0.51 0.55 0.67 6.09 5.67 4 Primuliflorae ¹ Zasuarina equisetifolia ^b 61.0 2.95 0.48 0.51 0.65 6.15 5.77 4 Kalanchoe pinnata 88.4 0.72 0.12 0.13 0.17 6.18 5.74 4 Fabiflorae ¹ Zasia bif	Carica papaya ^b	79 ∙2	3.12	0-51	0.54	0.70	6·17	5.77	4.45
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Passiflora foetida ^o	70 ·8	5.32	0.85	0.93	1.11	6.25	5.73	4 ∙79
Taxonomic mean 73-1 4-46 0-71 0-77 0-96 6-22 5.79 4 Theiflorae ¹ Cratoxylon formosum ^b 58-1 1-93 0-31 0-34 0-41 6-15 5-67 4 Mesua forrea ^b 47-8 2-52 0-41 0-44 0-55 6-18 5-74 4 Nepenthes raffiesiana ^a 78-6 1-55 0-27 0-33 6-20 5-73 4 Taxonomic mean 61-5 2-00 0-32 0-35 0-43 6-17 5-71 4 Primuliflorae ¹ Manikara zapota ^e 47-4 3-13 0-51 0-55 0-67 6-09 5-67 4 Rosiflorae ¹ Casuarina equisetifolia ^h 61-0 2-95 0-48 0-51 0-65 6-15 5-77 4 Kalanchoe pinnata 88.4 0-72 0.12 0-13 0.17 6-18 5-74 4 Adenanthera pavonina 57.1 7.45 1-21 1-32 1-44 6-16 5-64 5 Albizia falcataria 56-3	Salix babylonica ^o	69·3	4.95	0.79	0.85	1.08	6.23	5.86	4.57
Theiflorae ¹ Cratoxylon formosum ^b 58.1 1.93 0.31 0.34 0.41 6.15 5.67 4 Mesua ferrea ^b 47.8 2.52 0.41 0.44 0.55 6.18 5.74 4 Nepenthes raffiesiana ^a 78.6 1.55 0.25 0.27 0.33 6.20 5.73 4 Taxonomic mean 61.5 2.00 0.32 0.35 0.43 6.17 5.71 4 Primuliflorae ¹ Manikara zapota ^e 47.4 3.13 0.51 0.55 0.67 6.09 5.67 4 Rosiflorae ¹ Casuarina equisetifolia ^b 61.0 2.95 0.48 0.51 0.65 6.15 5.77 4 Kalanchoe pinnata 88.4 0.72 0.12 0.13 0.17 6.17 5.46 4 Fabiflorae ^{1.d} Acacia auriculiformis 61.6 3.59 0.58 0.63 0.87 6.18 5.74 4 Adenanthera pavonina 57.1 7.45 1.21 1.32 1.44 6.16 5.64 5 Albizia falcataria 56.3 4.46 0.72 0.77 1.23 6.18 5.80 3 Baphia nitida 61.5 6.31 1.01 1.08 1.49 6.24 5.83 4 Crotalaria retusa 74.2 3.09 0.50 0.53 0.74 6.19 5.78 4 Crotalaria retusa 74.2 3.09 0.50 0.53 0.74 6.19 5.78 4 Crotalaria retusa 74.2 3.09 0.50 0.53 0.74 6.19 5.78 4 <i>Lucaena leucocephala</i> 62.8 7.01 1.12 1.30 1.89 6.24 5.84 33 <i>Lucaena leucocephala</i> 62.8 7.01 1.12 1.30 1.89 6.24 5.84 33 <i>Lucaena leucocephala</i> 62.8 7.01 1.12 1.30 1.89 6.24 5.84 33 <i>Lucaena leucocephala</i> 62.8 7.01 1.12 1.30 1.89 6.24 5.84 33 <i>Lucaena leucocephala</i> 62.8 7.01 1.12 1.50 0.87 6.23 5.80 4 Millettia atropurpurea 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 <i>Millettia atropurpurea</i> 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 <i>Millettia atropurpurea</i> 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 <i>Millettia atropurpurea</i> 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 <i>Millettia atropurpurea</i> 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 <i>Millettia atropurpurea</i> 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 <i>Millettia atropurpurea</i> 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 <i>Millettia atropurpurea</i> 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 <i>Millettia atropurpurea</i> 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 <i>Millettia atropurpurea</i> 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 <i>Millettia atropurpurea</i> 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 <i>Millettia atropurpurea</i> 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 <i>Millettia atropurpurea</i> 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 <i>Millettia atropurpurea</i> 52.6 5.2 0.57 0.61 0.83	Taxonomic mean	73-1	4.46	0.71	0 ·77	0.96	6.22	5.79	4.60
$\begin{array}{cccc} Cratoxylon formosum" & 58.1 & 1.93 & 0.31 & 0.34 & 0.41 & 6.15 & 5.67 & 44 \\ Mesua ferrea^h & 47.8 & 2.52 & 0.41 & 0.44 & 0.55 & 6.18 & 5.74 & 4 \\ Nepenthes raffiesiana" & 78.6 & 1.55 & 0.25 & 0.27 & 0.33 & 6.20 & 5.73 & 4 \\ Taxonomic mean & 61.5 & 2.00 & 0.32 & 0.35 & 0.43 & 6.17 & 5.71 & 4 \\ \hline Primuliflorae^l & & & & & & & & & & & & & & & & & & &$	Theiflorae								
Mesua ferrea"47.82.520.410.440.556.185.744Nepenthes raffiesiana"78.61.550.250.270.336.205.734Taxonomic mean61.52.000.320.350.436.175.714Primuliflorae ¹ </td <td>Cratoxylon formosum^o</td> <td>58.1</td> <td>1.93</td> <td>0.31</td> <td>0.34</td> <td>0.41</td> <td>6.15</td> <td>5.67</td> <td>4.68</td>	Cratoxylon formosum ^o	58.1	1.93	0.31	0.34	0.41	6.15	5.67	4.68
Nepenthes raffiesiana"78-61.55 0.25 0.27 0.33 6.20 5.73 4 Taxonomic mean $61-5$ 2.00 0.32 0.35 0.43 6.17 5.71 4 Primuliflorae!Manikara zapota" 47.4 3.13 0.51 0.55 0.67 6.09 5.67 4 Rosiflorae!Casuarina equisetifoliab 61.0 2.95 0.48 0.51 0.65 6.15 5.77 4 Kalanchoe pinnata 88.4 0.72 0.12 0.13 0.17 6.17 5.46 4 Fabiflorae! d Acacia auriculiformis 61.6 3.59 0.58 0.63 0.87 6.18 5.74 4 Adenanthera pavonina 57.1 7.45 1.21 1.32 1.44 6.16 5.64 5 Albizia falcataria 56.3 4.46 0.72 0.777 1.23 6.18 5.80 33 Baphia nitida 61.5 6.31 1.01 1.08 1.49 6.24 5.83 4 Cotalaria retusa 74.2 3.09 0.50 0.53 0.74 6.19 5.78 4 Cotalaria retusa 74.2 3.09 0.50 0.53 0.74 6.19 5.78 4 Cotalaria retusa 74.2 3.09 0.50 0.53 0.74 6.19 5.78 4 Cotalaria retusa 74.2 3.09 0.50 0.53 0.74 6.19 5.79 4	Mesua ferrea ^o	47.8	2.52	0.41	0.44	0.55	6.18	5.74	4.55
Taxonomic mean 61.5 2.00 0.32 0.35 0.43 6.17 5.71 4 Primuliflorae ¹ Manikara zapota ^e 47.4 3.13 0.51 0.55 0.67 6.09 5.67 4 Rosiflorae ¹ Casuarina equisetifolia ^b 61.0 2.95 0.48 0.51 0.65 6.15 5.77 4 Kalanchoe pinnata 88.4 0.72 0.12 0.13 0.17 6.18 5.74 4 Acacia auriculiformis 61.6 3.59 0.58 0.63 0.87 6.18 5.74 4 Acacia auriculiformis 61.6 3.59 0.58 0.63 0.87 6.18 5.74 4 Adenanthera pavonina 57.1 7.45 1.21 1.32 1.44 6.16 5.64 5.64 Albizia falcataria 56.3 4.46 0.72 0.77 1.23 6.18 5.80 33 Baphia nitida 61.5 6.31 1.01 1.08 1.49 6.24 5.83 4 Crotalaria retusa 74.2 3.09 0.50 0.53 0.74 6.19 5.79 4 Delonix regia 52.4 5.65 0.91 0.97 1.51 6.24 5.80 33 Millettia atropurpurea 52.6 4.24 0.68 0.73 0.87 6.23 5.80 43 Lucaena leucocephala 62.8 7.02 1.13 1.22 1.40 6.21 5.78 4 </td <td>Nepenthes raffiesiana^a</td> <td>78.6</td> <td>1.55</td> <td>0.25</td> <td>0.27</td> <td>0.33</td> <td>6.20</td> <td>5.73</td> <td>4.63</td>	Nepenthes raffiesiana ^a	78.6	1.55	0.25	0.27	0.33	6.20	5.73	4.63
Primuliflorae ¹ Manikara zapota ^e 47.4 3.13 0.51 0.55 0.67 6.09 5.67 4Rosiflorae ¹ Casuarina equisetifolia ^b Casuarina equisetifolia ^b Casuarina equisetifolia ^b Acacia auriculiformis61-6 2.95 0.48 0.51 0.65 6.15 5.77 4 Acacia auriculiformis61-6 3.59 0.58 0.63 0.87 6.18 5.74 4 Acacia auriculiformis61-6 3.59 0.58 0.63 0.87 6.18 5.74 4 Ademanthera pavonina 57.1 7.45 1.21 1.32 1.44 6.16 5.64 5 Albizia falcataria 56.3 4.46 0.72 0.77 1.23 6.18 5.80 3 Baphia nitida 61.5 6.31 1.01 1.08 1.49 6.24 5.83 4 Cortalaria retusa 74.2 3.09 0.50 0.53 0.74 6.19 5.79 4 Delonix regia 52.4 5.65 0.91 0.97 1.51 6.24 5.84 33 Lucaena leucocephala 62.8 7.01 1.12 1.30 1.89 6.24 5.39 3 Mimosa pudica 72.8 7.02 1.13 1.22 1.40 6.21 5.7	Taxonomic mean	61.5	2.00	0.32	0.35	0.43	6.17	5.71	4.62
Manikara zapota ^e 47.4 3.13 0.51 0.55 0.67 6.09 5.67 4 Rosiflorae ¹ Casuarina equisetifolia ^b 61.0 2.95 0.48 0.51 0.65 6.15 5.77 4 Kalanchoe pinnata 88.4 0.72 0.12 0.13 0.17 6.17 5.46 4 Fabiflorae ^{1.d} Acacia auriculiformis 61.6 3.59 0.58 0.63 0.87 6.18 5.74 4 Adenanthera pavonina 57.1 7.45 1.21 1.32 1.44 6.16 5.64 5 Albizia falcataria 56.3 4.46 0.72 0.77 1.23 6.18 5.80 3 Baphia nitida 61.5 6.31 1.01 1.08 1.49 6.24 5.83 4 Cassia biflora 59.5 5.42 0.88 0.94 1.16 6.15 5.78 4 Cassia biflora 52.4 5.65 0.91 0.97 1.51 6.24 5.84 3 Lucaena leucocephala 62.8 7.01	Primuliflorae ¹								
Rosiflorae ¹ Casuarina equisetifolia ^b 61.0 2.95 0.48 0.51 0.65 6.15 5.77 4 Kalanchoe pinnata 88.4 0.72 0.12 0.13 0.17 6.17 5.46 4 Fabilitorae ^{1.d} Acacia auriculiformis 61.6 3.59 0.58 0.63 0.87 6.18 5.74 4 Adenanthera pavonina 57.1 7.45 1.21 1.32 1.44 6.16 5.64 5 Albizia falcataria 56.3 4.46 0.72 0.77 1.23 6.18 5.80 33 Baphia nitida 61.5 6.31 1.01 1.08 1.49 6.24 5.83 4 Cassia biflora 59.5 5.42 0.88 0.94 1.16 6.15 5.78 4 Cassia biflora 52.4 5.65 0.91 0.97 1.51 6.24 5.80 33 Delonix regia 52.4 5.65 0.91 0.97 1.51 6.24 5.80 4 Millettia atropurpurea 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 Millettia atropurpurea 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 Millettia atropurpurea 52.6 4.24 0.68 0.73 0.87 $6.$	Manikara zapota ^e	47·4	3.13	0.51	0.55	0.67	6.09	5.67	4.49
Casuarina equisetifolia ^b 61·0 2·95 0·48 0·51 0·65 6·15 5·77 4 Kalanchoe pinnata 88·4 0·72 0·12 0·13 0·17 6·17 5·46 4 Fabiflorae ^{1.d} Acacia auriculiformis 61·6 3·59 0·58 0·63 0.87 6·18 5·74 4 Adenanthera pavonina 57·1 7·45 1·21 1·32 1·44 6·16 5·64 5 Albizia falcataria 56·3 4·46 0·72 0·77 1·23 6·18 5·80 3 Baphia nitida 61·5 6·31 1·01 1·08 1·49 6·24 5·83 4 Crotalaria retusa 74·2 3·09 0·50 0·53 0·74 6·19 5·79 4 Delonix regia 52·4 5·65 0·91 0·97 1·51 6·24 5·80 3 Millettia atropurpurea 52·6 4·24 0·68 0·73 0·87 6·23 5·80 4 Mimosa pudica 72·8 7·02 1·13	Rosiflorae ¹								
Kalanchoe pinnata 88.4 0.72 0.12 0.13 0.17 6.17 5.46 4 Fabiflorae ^{1,d} Acacia auriculiformis 61.6 3.59 0.58 0.63 0.87 6.18 5.74 4 Adenanthera pavonina 57.1 7.45 1.21 1.32 1.44 6.16 5.64 5 Baphia nitida 61.5 6.31 1.01 1.08 1.49 6.24 5.83 4 Cassia biflora 59.5 5.42 0.88 0.94 1.16 6.15 5.78 4 Crotalaria retusa 74.2 3.09 0.50 0.53 0.74 6.19 5.79 4 Delonix regia 52.4 5.65 0.91 0.97 1.51 6.24 5.84 3 Millettia atropurpurea 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 Parkia javanica 65.8 3.52 0.57 0.61 0.83 6.24 5.39 3 Millettia atropurpurea 52.6 4.24 0.68 <td>Casuarina equisetifolia^b</td> <td>61.0</td> <td>2.95</td> <td>0.48</td> <td>0.51</td> <td>0.65</td> <td>6.15</td> <td>5.77</td> <td>4.52</td>	Casuarina equisetifolia ^b	61.0	2.95	0.48	0.51	0.65	6.15	5.77	4.52
Fabiflorae ^{1.d} Acacia auriculiformis 61.6 3.59 0.58 0.63 0.87 6.18 5.74 4 Adenanthera pavonina 57.1 7.45 1.21 1.32 1.44 6.16 5.64 5 Albizia falcataria 56.3 4.46 0.72 0.77 1.23 6.18 5.80 3 Baphia nitida 61.5 6.31 1.01 1.08 1.49 6.24 5.83 4 Cassia biflora 59.5 5.42 0.88 0.94 1.16 6.15 5.78 4 Crotalaria retusa 74.2 3.09 0.50 0.53 0.74 6.19 5.79 4 Delonix regia 52.4 5.65 0.91 0.97 1.51 6.24 5.84 3 Lucaena leucocephala 62.8 7.01 1.12 1.30 1.89 6.24 5.39 3 Millettia atropurpurea 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 Mimosa pudica 72.8 7.02 1.13 1.22 1.40 6.21 5.78 4 Parkia javanica 65.8 3.52 0.57 0.61 0.83 6.20 5.75 4 Parkia javanica 65.8 3.52 0.57 0.61 0.83 6.20 5.75 4 Parkia javanica 65.8 3.52 0.57 0.61 0.83 6.21 5.76 4 Psophocarpus indicus	Kalanchoe pinnata	88.4	0.72	0.12	0.13	0·17	6.17	5.46	4.34
Acacia auriculiformis 61.6 3.59 0.58 0.63 0.87 6.18 5.74 4 Adenanthera pavonina 57.1 7.45 1.21 1.32 1.44 6.16 5.64 55 Albizia falcataria 56.3 4.46 0.72 0.77 1.23 6.18 5.80 33 Baphia nitida 61.5 6.31 1.01 1.08 1.49 6.24 5.83 44 Cassia biflora 59.5 5.42 0.88 0.94 1.16 6.15 5.78 44 Cassia biflora 59.5 5.42 0.88 0.94 1.16 6.15 5.78 44 Crotalaria retusa 74.2 3.09 0.50 0.53 0.74 6.19 5.79 44 Delonix regia 52.4 5.65 0.91 0.97 1.51 6.24 5.84 33 Lucaena leucocephala 62.8 7.01 1.12 1.30 1.89 6.24 5.39 33 Millettia atropurpurea 52.6 4.24 0.68 0.73 0.87 6.23 5.80 44 Mimosa pudica 72.8 7.02 1.13 1.22 1.40 6.21 5.78 44 Parkia javanica 65.8 3.52 0.57 0.61 0.83 6.20 5.75 44 Pierocarpus indicus 60.0 6.47 1.02 1.09 1.55 6.32 5.93 44 Saraca thaipingensis 59.7 <th< td=""><td>Fabiflorae^{1,d}</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></th<>	Fabiflorae ^{1,d}								
Adenanthera pavonina $57 \cdot 1$ $7 \cdot 45$ $1 \cdot 21$ $1 \cdot 32$ $1 \cdot 44$ $6 \cdot 16$ $5 \cdot 64$ 55 Albizia falcataria $56 \cdot 3$ $4 \cdot 46$ $0 \cdot 72$ $0 \cdot 77$ $1 \cdot 23$ $6 \cdot 18$ $5 \cdot 80$ 33 Baphia nitida $61 \cdot 5$ $6 \cdot 31$ $1 \cdot 01$ $1 \cdot 08$ $1 \cdot 49$ $6 \cdot 24$ $5 \cdot 83$ 44 Cassia biflora $59 \cdot 5$ $5 \cdot 42$ $0 \cdot 88$ $0 \cdot 94$ $1 \cdot 16$ $6 \cdot 15$ $5 \cdot 78$ 44 Crotalaria retusa $74 \cdot 2$ $3 \cdot 09$ $0 \cdot 50$ $0 \cdot 53$ $0 \cdot 74$ $6 \cdot 19$ $5 \cdot 79$ 44 Delonix regia $52 \cdot 4$ $5 \cdot 65$ $0 \cdot 91$ $0 \cdot 97$ $1 \cdot 51$ $6 \cdot 24$ $5 \cdot 84$ 33 Lucaena leucocephala $62 \cdot 8$ $7 \cdot 01$ $1 \cdot 12$ $1 \cdot 30$ $1 \cdot 89$ $6 \cdot 24$ $5 \cdot 80$ 44 Millettia atropurpurea $52 \cdot 6$ $4 \cdot 24$ $0 \cdot 68$ $0 \cdot 73$ $0 \cdot 87$ $6 \cdot 23$ $5 \cdot 80$ 44 Mimosa pudica $72 \cdot 8$ $7 \cdot 02$ $1 \cdot 13$ $1 \cdot 22$ $1 \cdot 40$ $6 \cdot 21$ $5 \cdot 78$ 55 Parkia javanica $65 \cdot 8$ $3 \cdot 52$ $0 \cdot 57$ $0 \cdot 61$ $0 \cdot 83$ $6 \cdot 20$ $5 \cdot 75$ 44 Pierocarpus indicus $60 \cdot 0$ $6 \cdot 47$ $1 \cdot 02$ $1 \cdot 09$ $1 \cdot 16$ $1 \cdot 57$ $6 \cdot 21$ $5 \cdot 82$ 44 Mimosa pudica $70 \cdot 2$ $6 \cdot 75$ $1 \cdot 09$ $1 \cdot 16$ $1 \cdot 57$ $6 \cdot 21$ $5 \cdot 82$ 44 Pierocarpus ind	Acacia auriculiformis	61.6	3.59	0.58	0.63	0.87	6·18	5.74	4.10
Albizia falcataria $56\cdot3$ $4\cdot46$ 0.72 0.77 $1\cdot23$ $6\cdot18$ $5\cdot80$ 33 Baphia nitida $61\cdot5$ $6\cdot31$ $1\cdot01$ $1\cdot08$ $1\cdot49$ $6\cdot24$ $5\cdot83$ 44 Cassia biflora $59\cdot5$ $5\cdot42$ $0\cdot88$ $0\cdot94$ $1\cdot16$ $6\cdot15$ $5\cdot78$ 44 Cassia biflora $74\cdot2$ $3\cdot09$ $0\cdot50$ $0\cdot53$ 0.74 $6\cdot19$ $5\cdot79$ 44 Delonix regia $52\cdot4$ $5\cdot65$ $0\cdot91$ $0\cdot97$ $1\cdot51$ $6\cdot24$ $5\cdot84$ 33 Lucaena leucocephala $62\cdot8$ $7\cdot01$ $1\cdot12$ $1\cdot30$ $1\cdot89$ $6\cdot24$ $5\cdot39$ 33 Millettia atropurpurea $52\cdot6$ $4\cdot24$ $0\cdot68$ $0\cdot73$ $0\cdot87$ $6\cdot23$ $5\cdot80$ 44 Mimosa pudica $72\cdot8$ $7\cdot02$ $1\cdot13$ $1\cdot22$ $1\cdot40$ $6\cdot21$ $5\cdot78$ 55 Parkia javanica $65\cdot8$ $3\cdot52$ $0\cdot57$ $0\cdot61$ $0\cdot83$ $6\cdot20$ $5\cdot75$ 44 Psophocarpus tetragonolobus $70\cdot2$ $6\cdot75$ $1\cdot09$ $1\cdot16$ $1\cdot57$ $6\cdot21$ $5\cdot82$ 44 Pierocarpus indicus $60\cdot0$ $6\cdot47$ $1\cdot02$ $1\cdot09$ $1\cdot55$ $6\cdot32$ $5\cdot93$ 44 Sesbania grandiflora $70\cdot5$ $6\cdot42$ $1\cdot03$ $1\cdot11$ $1\cdot55$ $6\cdot26$ $5\cdot77$ 44 Correstant diagonal flora $6\cdot10$ $2\cdot75$ $0\cdot45$ $0\cdot48$ $0\cdot61$ $6\cdot16$ $5\cdot70$ 44	Adenanthera pavonina	57.1	7.45	1.21	1.32	1.44	6.16	5.64	5.12
Baphia nitida 61.5 6.31 1.01 1.08 1.49 6.24 5.83 4 Cassia biflora 59.5 5.42 0.88 0.94 1.16 6.15 5.78 4 Crotalaria retusa 74.2 3.09 0.50 0.53 0.74 6.19 5.79 4 Delonix regia 52.4 5.65 0.91 0.97 1.51 6.24 5.84 33 Lucaena leucocephala 62.8 7.01 1.12 1.30 1.89 6.24 5.39 33 Millettia atropurpurea 52.6 4.24 0.68 0.73 0.87 6.23 5.80 44 Mimosa pudica 72.8 7.02 1.13 1.22 1.40 6.21 5.78 55 Parkia javanica 65.8 3.52 0.57 0.61 0.83 6.20 5.75 44 Psophocarpus tetragonolobus 70.2 6.75 1.09 1.16 1.57 6.21 5.82 44 Pterocarpus indicus 60.0 6.47 1.02 1.09 1.55 6.32 5.93 44 Saraca thaipingensis 59.7 3.32 0.54 0.58 0.80 6.21 5.76 44 Sesbania grandiflora 70.5 6.42 1.03 1.11 1.55 6.26 5.77 44 Tamarindus indica 69.1 2.75 0.45 0.48 0.61 6.16 5.70 44	Albizia falcataria	56.3	4.46	0.72	0.77	1.23	6.18	5.80	3.62
Cassia biffora 59.5 5.42 0.88 0.94 1.16 6.15 5.78 4 Crotalaria retusa 74.2 3.09 0.50 0.53 0.74 6.19 5.79 4 Delonix regia 52.4 5.65 0.91 0.97 1.51 6.24 5.84 33 Lucaena leucocephala 62.8 7.01 1.12 1.30 1.89 6.24 5.39 33 Millettia atropurpurea 52.6 4.24 0.68 0.73 0.87 6.23 5.80 44 Mimosa pudica 72.8 7.02 1.13 1.22 1.40 6.21 5.78 55 Parkia javanica 65.8 3.52 0.57 0.61 0.83 6.20 5.75 44 Psophocarpus tetragonolobus 70.2 6.75 1.09 1.16 1.57 6.21 5.82 44 Pierocarpus indicus 60.0 6.47 1.02 1.09 1.55 6.32 5.93 44 Saraca thaipingensis 59.7 3.32 0.54 0.58 0.80 6.21 5.76 44 Sesbania grandiflora 70.5 6.42 1.03 1.11 1.55 6.26 5.77 44 Tamarindus indica 69.1 2.75 0.45 0.48 0.61 6.16 5.70 44	Baphia nitida	61.5	6.31	1.01	1.08	1.49	6.24	5.83	4.24
Crotataria retusa $/4.2$ 3.09 0.50 0.53 0.74 6.19 5.79 4 Delonix regia 52.4 5.65 0.91 0.97 1.51 6.24 5.84 33 Lucaena leucocephala 62.8 7.01 1.12 1.30 1.89 6.24 5.39 33 Millettia atropurpurea 52.6 4.24 0.68 0.73 0.87 6.23 5.80 44 Mimosa pudica 72.8 7.02 1.13 1.22 1.40 6.21 5.78 55 Parkia javanica 65.8 3.52 0.57 0.61 0.83 6.20 5.75 44 Psophocarpus tetragonolobus 70.2 6.75 1.09 1.16 1.57 6.21 5.82 44 Pterocarpus indicus 60.0 6.47 1.02 1.09 1.55 6.32 5.93 44 Saraca thaipingensis 59.7 3.32 0.54 0.58 0.80 6.21 5.76 44 Sesbania grandiflora 70.5 6.42 1.03 1.11 1.55 6.26 5.77 44 Tamarindus indica 69.1 2.75 0.45 0.48 0.61 6.16 5.70 44	Cassia diffora	39.5	5.42	0.88	0.94	1.16	6.15	5.78	4.68
Detontx regid 52.4 5.65 0.91 0.97 1.51 6.24 5.84 33 Lucaena leucocephala 62.8 7.01 1.12 1.30 1.89 6.24 5.39 33 Millettia atropurpurea 52.6 4.24 0.68 0.73 0.87 6.23 5.80 44 Mimosa pudica 72.8 7.02 1.13 1.22 1.40 6.21 5.78 55 Parkia javanica 65.8 3.52 0.57 0.61 0.83 6.20 5.75 44 Psophocarpus tetragonolobus 70.2 6.75 1.09 1.16 1.57 6.21 5.82 44 Pterocarpus indicus 60.0 6.47 1.02 1.09 1.55 6.32 5.93 44 Saraca thaipingensis 59.7 3.32 0.54 0.58 0.80 6.21 5.76 44 Sesbania grandiflora 70.5 6.42 1.03 1.11 1.55 6.26 5.77 44 Tamarindus indica 69.1 2.75 0.45 0.48 0.61 6.16 5.70 44	Crotalaria retusa	/4·2	3.09	0.50	0.53	0.74	6.19	5.79	4.20
Lacuena leacocepnala 62.8 7.01 1.12 1.50 1.89 6.24 5.39 3 Millettia atropurpurea 52.6 4.24 0.68 0.73 0.87 6.23 5.80 4 Mimosa pudica 72.8 7.02 1.13 1.22 1.40 6.21 5.78 55 Parkia javanica 65.8 3.52 0.57 0.61 0.83 6.20 5.75 4 Psophocarpus tetragonolobus 70.2 6.75 1.09 1.16 1.57 6.21 5.82 4 Pterocarpus indicus 60.0 6.47 1.02 1.09 1.55 6.32 5.93 4 Saraca thaipingensis 59.7 3.32 0.54 0.58 0.80 6.21 5.76 4 Sesbania grandiflora 70.5 6.42 1.03 1.11 1.55 6.26 5.77 4 Tamarindus indica 69.1 2.75 0.45 0.48 0.61 6.16 5.70 4	Deionix regia	52·4	5.65	0.91	0.97	1.51	6.24	5.84	3.75
Mineria arropurpurea 52-6 4-24 0-68 0-73 0-87 6-23 5-80 4 Mimosa pudica 72-8 7-02 1-13 1-22 1-40 6-21 5-78 55 Parkia javanica 65-8 3-52 0-57 0-61 0-83 6-20 5-75 4 Psophocarpus tetragonolobus 70-2 6-75 1-09 1-16 1-57 6-21 5-82 4 Pterocarpus indicus 60-0 6-47 1-02 1-09 1-55 6-32 5-93 4 Saraca thaipingensis 59-7 3-32 0-54 0-58 0-80 6-21 5-76 4 Sesbania grandiflora 70-5 6-42 1-03 1-11 1-55 6-26 5-77 4 Tamarindus indica 69-1 2-75 0-45 0-48 0-61 6-16 5-70 4	Lucuena leucocephala Millattia attonumente	02·8 52 4	/.01	1.12	1.30	1.89	6.24	5.39	3.72
Minosa pualca 12.6 1.02 1.13 1.22 1.40 6.21 5.78 5 Parkia javanica 65.8 3.52 0.57 0.61 0.83 6.20 5.75 4 Psophocarpus tetragonolobus 70.2 6.75 1.09 1.16 1.57 6.21 5.82 4 Pterocarpus indicus 60.0 6.47 1.02 1.09 1.55 6.32 5.93 4 Saraca thaipingensis 59.7 3.32 0.54 0.58 0.80 6.21 5.76 4 Sesbania grandiflora 70.5 6.42 1.03 1.11 1.55 6.26 5.77 4 Tamarindus indica 69.1 2.75 0.45 0.48 0.61 6.16 5.70 4	Mimosa nudica	52°0 72.8	4.24	0.00	0.73	U·8/	0.23	5.80	4.88
Psophocarpus tetragonolobus 70·2 6·75 1·09 1·16 1·57 6·20 5·75 4 Psophocarpus tetragonolobus 70·2 6·75 1·09 1·16 1·57 6·21 5·82 4 Pterocarpus indicus 60·0 6·47 1·02 1·09 1·55 6·32 5·93 4 Saraca thaipingensis 59·7 3·32 0·54 0·58 0·80 6·21 5·76 4 Sesbania grandiflora 70·5 6·42 1·03 1·11 1·55 6·26 5·77 4 Tamarindus indica 69·1 2·75 0·45 0·48 0·61 6·16 5·70 4	Munosa puaica Parkia javanica	12.0 65.8	1.02	1.13	1.22	1.40	0.21	5.78	5.03
P sophocarpus infragonoloous 102 6.73 1.09 1.16 1.57 6.21 5.82 4 P terocarpus indicus 60.0 6.47 1.02 1.09 1.55 6.32 5.93 4 Saraca thaipingensis 59.7 3.32 0.54 0.58 0.80 6.21 5.76 4 Sesbania grandiflora 70.5 6.42 1.03 1.11 1.55 6.26 5.77 4 Tamarindus indica 69.1 2.75 0.48 0.61 6.16 5.70 4	Psonhocarnus totrazonalate	03.0 m 70.2	5°52 6.75	1.00	U·01 1 1 4	0.83	0·20	5.75	4.23
Saraca thaipingensis 59.7 3.32 0.54 0.58 0.80 6.21 5.76 4 Sesbania grandiflora 70.5 6.42 1.03 1.11 1.55 6.26 5.77 4 Tamarindus indica 69.1 2.75 0.45 0.48 0.61 6.16 5.70 4	Pterocarnus indians	60.0	6.47	1.02	1.10	1.57	0.21	5.82	4.29
Subactive indiputions 577 532 0.54 0.58 0.60 0.21 5.76 4 Sesbania grandiflora 70.5 6.42 1.03 1.11 1.55 6.26 5.77 4 Tamarindus indica 69.1 2.75 0.45 0.48 0.61 6.16 5.70 4	Sarara thainingensis	59.7	3.37	0.54	0.52	0.80	6.21	5.95	4.17
Tamarindus indica 69·1 2·75 0·45 0·48 0·61 6·16 5·70 4	Sesbania grandiflora	70.5	6.47	1.03	1.11	1.55	6.26	5.10 5.77	4.15
	Tamarindus indica	69.1	2.75	0.45	0.48	0.61	6.16	5.70	4·13 4.40
1 axonomic mean 62.9 5.22 0.84 0.91 1.22 6.21 5.76 A	Taxonomic mean	62.9	5.22	0.84	0.91	1-22	6.21	5.76	4.30

Table 2. Moisture, protein and nitrogen analyses of the leaves of Angiospermae-Subclass Dicotyledonae

contd.

Species	Moisture (g% fr. wt)	Protein (g% fr. wt)	Nitrogen recovery			Nitrogen-to-protein		
			Amino acids	Amino acids and NH ₃ (g% fr. wt)	Kjeldahl nitrogen	k_A	k' _A	
Myrtiflorae ¹								
Lagerstroemia speciosa	74.9	2.28	0.37	0.40	0.47	6.17	5.75	4 ⋅88
Melastoma malabathricum	65.6	4.24	0·69	0.73	0.92	6.17	5.82	4 ·61
Rutiflorae ¹								
Averrhoa carambola ^a	67·0	4 .72	0.76	0.81	0.99	6.23	5.85	4.75
Mangifera indica ^c	56.3	3.17	0.51	0.59	0.72	6.18	5.76	4.39
Murrava koenioir	71.1	4.06	0.65	0.70	1.04	6.25	5.76	3.92
Nenhelium lannaceum ^c	57.0	2.79	0.45	0.49	0.63	6.19	5.74	4.46
Malnighia coccigera	56.5	2.77	0.46	0.51	0.76	5.99	5.43	3.65
Taxonomic mean	61.6	3.50	0.57	0.62	0.83	6.19	5·71	4·23
Δ steriflorae ²								
Mikania cordata ^g	83.5	1.78	0.29	0.31	0.38	6.20	5.77	4.69
Solaniflorae ²								
Inomora aquatica ^e	80.5	3.10	0.50	0.54	0.62	6.10	5.74	4.07
Montoria tridontato ^e	80.0	2.18	0.35	0.34	0.02	6.24	5.76	4.97
Merremia triaentata	80.0	2.10	0.33	0.30	0.43	0.74	3.70	4.65
Gentianiflorae ²								
Adina rubescens ^e	57.5	3.53	0.57	0.61	0.78	6.17	5.80	4.54
Cebera odollum ^e	77·9	3.18	0.51	0.55	0.69	6.19	5.77	4.58
Dischida nummularia ^e	91·8	0.20	0.03	0.04	0.05	6·18	5.15	4.00
Morinda citrifolia ^e	75.9	3.45	0.56	0.60	0.70	6.14	5.74	4.90
Taxonomic mean	75.8	2.59	0.42	0.45	0.56	6.17	5.62	4.51
Lamiiflorae ²								
Lantana aculeata ^f	62.6	5.47	0.87	0.93	1.09	6.28	5.86	5.02
Mentha arvensis ^f	84·0	1.73	0.28	0.30	0.35	6.20	5.75	5.00
Spathodea campanulata ^f	70 ·7	3.98	0.64	0.68	0.82	6.20	5.82	4.87
Taxonomic mean	72.4	3.73	0.60	0.64	0.75	6.23	5.81	4.96
Corniflorae ²								
Cantella asiatica ^h	83.5	2.51	0.40	0.43	0.68	6.23	5.86	3.68
Taxonomic mean								
for subclass	67.3	3.78	0.61	0.66	0.86	6.19	5.74	4.43
	0,0	210	~ ~ .	~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	0.00	0.17		. 15

Table 2—contd.

Scheme after Dahlgren (1980). 1 and 2 denote Young and Watson's crassinucelli and tenuinucelli, superscript letters follow Young and Watson's classification as caryophylloids (a), magnolioids (b), celestroids (c), Leguminosae (d), asclepioids (e), acanthoids (f), Compositae (g) and Umbelliferae (h), respectively (Young & Watson, 1970). k_A , ratio of protein to amino acid nitrogen; k'_A , ratio of protein to nitrogen from amino acids and ammonia; k_p , ratio of protein to Kjeldahl nitrogen.

from individual amino acids and it excluded the amide–N of glutamine and asparagine. For lack of specific amide–N determination, the total ammonia from acid hydrolysis could be used to approximate the amide–N of glutamine and asparagine (Mosse, 1990). However, it must be cautioned that the unbound forms are always present in the leaves. Nonetheless, this second type nitrogen calculated from individual amino acids and ammonia recovered from acid hydrolysis might account better for the nitrogen recovered from proteins. For the 90 plant species investigated, the nitrogen recovered from amino acids alone averaged 93% of the nitrogen from amino acids and ammonia, suggesting that the amide–N contributed not more than 7% of the total protein nitrogen. The third type of nitrogen content (Kjeldahl nitrogen) reflected the contribution from both proteins and non-protein sources. Assuming the recovery of nitrogen from amino acid analysis was close to 100 %, the data then showed that, on the average, 76% of the nitrogen in these plants came from protein sources.

Bearing the above in mind, we considered three types of conversion factors. These are (i) k_A , the ratio of protein to total nitrogen from amino acids (excluding the amide-N), (ii) k_A ', the ratio of protein to total nitrogen recovered from amino acids and ammonia, and (iii) k_P , the ratio of protein to Kjeldahl nitrogen. The values for these conversion factors were independent of the nitrogen or protein content of the plant material (Tables 1, 2 and 3).

Species	Moisture (g% fr. wt)	Protein (g% fr. wt)	Nitrogen recovery			Nitrogen-to-protein		
			Amino acids	Amino acids and NH ₃ (g% fr. wt)	Kjeldahl nitrogen	k	k' _A	k _p
Alismatiflorae Sagittaria sagittifolia	81.2	2.17	0.35	0.39	0.53	6.14	5.52	4.08
Ariflorae								
Allocasia macrorrhiza	81.3	2.95	0.48	0.51	0.59	6.14	5.73	4.97
Differbachia reginae	83.8	1.95	0.32	0.34	0.43	6.16	5.75	4.55
Soindansus aurous	80.0	0.91	0.15	0.17	0.24	6.18	5.46	3.83
Taxonomic mean	84.7	1.94	0.32	0.34	0.42	6·16	5.65	4.45
Lilliflorno								
Aranda 'Christine'	83.0	0.59	0.10	0.11	0.12	6.14	5.57	4.76
Dandrobium crumanatum	91.5	0.52	0.08	0.09	0.13	6.22	5.57	4.02
Fichhornia crassinas	80.8	1.93	0.31	0.34	0.52	6.18	5.75	3.68
Clorioga guperha	82.0	2.79	0.45	0.48	0.58	6.16	5.79	4.77
Haemanthus multiflorus	01.0	1.31	0.21	0.24	0.31	6.16	5.50	4.23
Taooa oristata	91.9 81.6	1.07	0.63	0.67	0.91	6.11	5.72	4.23
Taxonomic mean	85·1	1.51	0·30	0.32	0.43	6.16	5.65	4.28
Zingiberiflorae								
Languas galanga	77.0	2.10	0.34	0.34	0.43	6.11	5.71	4.25
Musa paradisiaca	85.5	2.10	0·34	0.37	0.41	6.17	5.72	5.16
Commeliniflorae								
Ananas comosus	85.9	0.34	0.06	0.06	0.08	6.17	5.45	4.38
Cynerus aromaticus	65.3	2.36	0.38	0.41	0.52	6.24	5.79	4.58
Rhoeo spathacea	91.2	0.44	0.07	0.08	0.10	6.13	5.53	4.43
Taxonomic mean	80.8	1.05	0.17	0.18	0.23	6.18	5.59	4.46
Areciflorae								
Archontophoenix alexandri	ae 69·0	2.32	0.38	0.41	0.54	6.12	5.65	4.33
Areca catechu	76.8	2.46	0.40	0.43	0.63	6.15	5.78	3.91
Pandanus odorus	80.9	1.82	0.29	0.32	0.40	6.24	5.73	4.57
Taxonomic mean	75.6	2.20	0.36	0.39	0.52	6.17	5.72	4.27
Taxonomic mean								
for subclass	82.1	1.72	0.30	0.32	0.42	6.16	5.65	4.37

Table 3. Moisture, protein and nitrogen analyses of leaves of the Angiospermae-Subclass Monocotyledonae

Scheme after Dahlgren (1980). k_A , ratio of protein to amino acid nitrogen; k'_A , ratio of protein to nitrogen from amino acids and ammonia; k_p , ratio of protein to Kjeldahl nitrogen.

The conversion factor k_A had values ranging from 5.99 to 6.32, with an average of 6.18±0.05 for the 90 plants. Group by group comparison showed that the three major taxonomic groups gave very similar values for k_A . Nonetheless, the monocotyledonous plants as a group showed a lower conversion value (6.16±0.04) than that for the dicotyledonous plants (6.19±0.05; Tables 2 and 3). Differences in the leaf amino acid compositions of these two major groups could account for the difference in the conversion factor (Yeoh *et al.*, 1986, 1992).

The conversion factor k_A ' ranged from 5.15 to 5.93 for the 90 plants (Tables 1, 2 and 3). The average value was 5.72±0.12. Comparison by taxonomic grouping showed closely similar k_A ' values for the Gymnospermae and Angiospermae (5.69±0.07 and 5.72±0.13, respectively). k_A ' for Pteridophyta, on the other hand, was higher (5.78±0.10). Within the Angiospermae, the k_A ' for the Dicotyledonae (5.74 ± 0.13) was higher than that of the Monocotyledonae (5.65 ± 0.13) . It is interesting that the values for k_A and k_A ' were different from the traditional factor of 6.25. However, this is not surprising as the factor of 6.25 was derived from animal protein composition studies.

The conversion factor $k_{\rm P}$ has a practical value. It permits rapid estimation of protein content from Kjeldahl nitrogen analysis. From our study of 90 plants, this factor ranged from 3.28 to 5.16, with an average of 4.43 ± 0.40 . This value is closely similar to that reported by Milton and Dintzis (1981). Based on a taxonomic mean value, the $k_{\rm P}$ for Gymnospermae was 4.21 ± 0.52 , that for Pteridophyta was 4.66 ± 0.34 and for Angiospermae it was 4.41 ± 0.39 (Tables 1, 2 and 3). Variations were also observed in the $k_{\rm P}$ values among the major taxonomic groups of the Angiospermae but they were not significantly different (Tables 2 and 3). From these data it is clear that the factor 6.25 is unsuitable for estimating leaf protein contents of plants from Kjeldahl nitrogen analyses. To obtain a better estimate of protein content, the results suggest the use of k_p values derived from related taxonomic groups. However, a k_p of 4.43 should give a reliable estimate of the leaf protein content for plants in general.

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