Foliar nutrient and nutritive content of Central American multipurpose tree species growing at Comayagua, Honduras

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SUMMARY

Seedlings from a collection of 20 Central American dryland tree and shrub species were planted in the Comayagua valley on alluvial soil, within their native range. The species comprise *Moringa oleifera, Leucaena salvadorensis, Mimosa tenuifolia, Gliricidia sepium, Guazuma ulmifolia, Parkinsonia aculeata, Albizia niopoides, Acacia deamii, Acacia farnesiana, Caesalpinia coriaria, Caesalpinia eriostachys, Albizia saman, Senna atomaria, Simarouba glauca, Prosopis juliflora, Crescentia alata, Cordia alliodora, Swietenia humilis, Enterolobium cyclocarpum* and *Hymenaea coubaril.* Their performance and nutritional health in their native range is of interest to foresters growing them as exotics. Foliage samples were collected from the trees in a replicated, designed trial at the end of their second growing season. There were very large variations in foliar nutrient content between species (threefold for nitrogen, phosphorus and potassium; sevenfold for calcium and magnesium and sixfold for boron), which were not related simply to the relative size differences of the plants. There could be an opportunity to use specific species to raise specific soil nutrient levels by mulching or to use fodder to redress animal health problems caused by poor mineral nutrition. Four of the species tested might be poor sources of animal fodder - *Simarouba glauca* and *Crescentia alata* because of low N content and high fibre content and *Caesalpinia coriaria* and *Caesalpinia eriostachys* because of high lignin content.

RÉSUMÉ

De jeunes plants provenant d'une collection de 20 espèces arbustives et d'arbres originaires des régions sèches d'Amérique Centrale ont été plantés dans la vallée de la Comayagua sur des sols alluviaux, dans leur zone bioclimatique. Les espèces représentées sont: *Moringa oleifera, Leucaena salvadorensis, Mimosa tenuifolia, Gliricidia sepium, Guazuma ulmifolia, Parkinsonia aculeata, Albizia niopoides, Acacia deamii, Acacia farnesiana, Caesalpinia coriaria, Caesalpinia eriostachys, Albizia saman, Senna atomaria, Simarouba glauca, Prosopis juliflora, Crescentia alata, Cordia alliodora, Swietenia humilis, Enterolobium cyclocarpum* et *Hymenaea coubaril.* Leur performance et leur état nutritionnel dans leur région d'origine sont d'un intérêt certain pour les forestiers utilisant ces essences en tant qu'espèces exotiques. Des échantillons de feuillage ont été collectés à la fin de leur deuxième saison de croissance selon un dispositif d'essai avec réplication. De très importantes variations interspécifiques de concentration foliaire en éléments nutritifs ont été observés (différence de concentration d'un rapport de trois pour l'azote, le phosphore et le potassium, d'un rapport de sept pour le calcium et le magnesium et d'un rapport de six pour le bore). Ces différences n'étaient pas simplement corrélées aux différences de taille entre plantes. On pourrait sur cette base trouver une opportunité, grâce à la technique du paillage, d'utiliser une espèce donnée pour relever dans le sol le niveau d'un élément nutritif particulier, qui serait déficient. Ou bien, une espèce donnée pourrait être utilisée comme fourrage pour soigner du bétail en mauvaise santé à cause d'une alimentation minérale carencée. Quatre des espèces testées pourraient constituer une source de fourrage pauvre, *Simarouba glauca* et *Crescienta alata*, à cause de leur faible concentration en azote et de leur haute teneur en fibre et, *Caesalpinia coriara* et *Caesalpinia eriostachys*, à cause de leur haute teneur en lignine.

RESUMEN

Plántulas de una colección de 20 árboles y especies arbustivas de la zona seca de América Central fueron plantadas en el valle de Comayagua en suelos aluviales, dentro de su rango nativo. Las especies comprenden *Moringa oleifera, Leucaena salvadorensis, Mimosa tenuifolia, Gliricidia sepium, Guazuma ulmifolia, Parkisonia aculeata, Albizia niopoides, Acacia deamii, Acacia farnesiana, Caesalpinia coriaria, Caesalpinia eriostachys, Albizia saman, Senna atomaria, Simarouba glauca, Prosopis juliflora, Crescentia alata, Cordia alliflora, Swietenia humilis, Enterolobium ciclocarpum* y *Hymenaea coubaril.* El comportamiento y salud nutricional de estas especies en su rango nativo es de interés para los silvicultores quienes las cultivan como exóticas. Se tomaron muestras del follaje de estos árboles en duplicado de un ensayo diseñado al final de su segunda estación de crecimiento. Se encontraron variaciones muy grandes en el contenido de nutrientes foliares entre especies (variaciones de tres veces en los contenidos de nitrógeno, fósforo y potasio; siete veces en calcio y magnesio y seis veces en boro) las cuales no estaban relacionadas con las relativas diferencias de tamaño de las plantas. Podría ser conveniente el uso de especies específicas para aumentar los niveles de nutrientes en suelos específicos a través de su uso como abono verde o del uso del forraje para remediar problemas de salud animal causados por una pobre nutrición mineral. Cuatro de las especies estudiadas podrían ser fuentes pobres de forraje para animales - *Simarouba glauca* y *Crescentia alata* a causa de su bajo contenido de nitrógeno y alto contenido de fibra y *Caesalpinia coriaria* y *Caesalpinia eriostachys* por su alto contenido de lignina.

KEYWORDS: Multi-purpose-species, nutrition, fodder, mulching, Honduras

INTRODUCTION

There has been growing world-wide interest in the domestication of trees and shrubs especially in dry environments. The flora of Central America contains many previously under-utilized and some unknown species (Stewart *et al.* 1992), many of which grow naturally in a low rainfall environment. A paper by Hughes and Styles (1984) reviews early work on collection of seeds from a number of Central American species and their characteristics, (see also Dunsdon *et al.* 1991 and Stewart *et al.* 1992). Seedlings of twenty such species have now been raised and planted out in trials around the world (Stewart *et al.* 1992). Of the species planted there is inadequate general information about characteristics and performance for any other than *Gliricidia sepium, Cordia alliodora* and *Prosopis juliflora*. There is almost no information about the nutrition of any species. There is a large and growing body of literature about the nutrition of *Leucaena leucocephala* but none about the related species. Budelman (1989) gives a review of the foliar nutrient content of *Gliricidia sepium* foliage collected from a range of locations. Sharma (1984) and Maghembe *et al.* (1983) give the foliar nutrient contents of *Prosopis juliflora*. Sitaubi (1990) gives the foliar nitrogen content of *Crescentia alata, Enterolobium cyclocarpum, Senna atomaria, Guazuma ulmifolia,* and *Acacia farnesiana* in Malawi.

The soils of Central America are derived from a wide range of parent materials (US Army 1964), some of which - derived from recent pumice and limestone - occur infrequently in the rest of the tropical world. The nutritional performance of Central American species on soils similar to those to which they are adapted, may therefore provide a 'yardstick' against which the performance of these species on other soil-types can be judged and nutritional deficiencies identified.

In addition, the uses of multi-purpose trees and shrubs for fodder and mulch are affected by the intrinsic properties of the material collected (Budelman, 1989). These trees and shrubs may be grown with the intention of maintaining soil fertility (Dreschel *et al.* 1991), or cut foliage and branches may be fed to livestock as a food supplement (Roder, 1992). In both cases the nutrient content is important.

Foliage samples were collected from the most recently matured upper-crown foliage of twenty species of one-year-old trees and shrubs growing at a trial site in Honduras and were chemically analysed in order to augment the sparse knowledge about these species.

METHODS

Seedlings of twenty Central American multipurpose tree species were planted at Los Mangos in the Comayagua valley in Honduras during the rainy season of 1990 in a randomized block experiment with two replications. The Comayagua valley is a broad alluvial valley drained by the Rio Humuya and its tributaries (Ffolkes, 1980), with a flat bottom situated in the middle of Honduras at 14° 27' N, 87° 41' W and at an altitude of 600m asl and with a variable annual rainfall averaging 1000 mm, 90% of which falls between May and October. The average annual temperature is 24°C (Ffolkes, 1980). In November 1991 the seedlings were at the end of their second rainy season from planting. All surviving seedlings had grown well and overall survival per plot exceeded 80%. A complete list of the species studied is given in Table 1.

Table 1. *Summary information about the tree species represented in the Comayagua trial*

Species	Family	Form	N_2fix	Tree Ht. Class[1]	L.F.V.[2]
Acacia deamii (Britton & Rose) Standl.	Leguminoseae Mimosoideae	multi-stemmed tree	Unc. YES	3	-
Acacia farnesiana (L.) Willd.	Leguminoseae Mimosoideae	shrubby tree	YES	3	3
Albizia niopoides (Spurce ex Benth) Burkart	Leguminoseae Mimosideae	large spreading tree	YES	3	-
Albizia saman (Jacq.) F.v.M.	Leguminoseae Mimosoideae	large spreading tree	YES	3	-
Caesalpinia coriaria (Jacq.) Willd.	Leguminoseae Caesalpinoideae	spreading small tree	NO	3	1
Caesalpinia eriostachys (Benth.)	Leguminoseae Caesalpinoideae	spreading small tree	NO	3	2
Cordia alliodora (Ruiz & Pavon)	Boraginaceae	large spreading tree	NO	3	-
Crescentia alata H.B.K.	Bignoniaceae	shrubby small tree	NO	3	1
Enterolobium cyclocarpum (Jacq.) Griseb.	Leguminoseae Mimosoideae	large tree	YES	4	2
Gliricidia sepium (Jacq.) Walp.	Leguminoseae Papilionoideae	small, multi-stemmed tree	YES	2	3
Guazuma ulmifolia (Lam.)	Sterculiaceae	medium sized tree	NO	2	3
Hymenaea coubaril L.	Leguminoseae Caesalpinoideae	large tree	NO	4	-
Leucaena salvadorensis Standley	Leguminoseae Mimosoideae	medium tree	YES	1	-
Moringa oleifera Lam.	Moringaceae	small-medium tree	NO	1	
Mimosa tenuifolia (Wild.) Poir	Leguminoseae Mimosoideae	small, shrubby bush	YES	2	1
Parkinsonia aculeata L.	Leguminoseae Caesalpinoideae	small tree	NO	3	1
Prosopis juliflora (Swartz) DC	Leguminoseae Mimosoideae	small tree	YES	4	2
Simarouba glauca DC	Simaroubaceae	medium tree	NO	3	-
Swietenia humilis Zucc.	Meliaceae	large tree	NO	3	-
Senna atomaria (L.) Irwin & Barneby	Leguminoseae Caesalpinoideae	small tree	Un NO	3	-

1. Tree height class, from experimental data
   1 = > 3m
   2 = 2.3 m
   3 = 1.2 m
   4 = < 1 m
2. Leaf fodder values (source: Hughes and Styles, 1984)
   1 = poor
   2 = acceptable
   3 = good

Leaf forms of the species differed markedly. It is difficult to determine a common time and method to foliage-sample such variable material such that the sample constitutes a fair representation of the plant's nutrition. However, foliage was collected from the most recently fully-matured leaves (and frequently including leaf stalks) in the upper crown and in full sun, at the end of the most active growth period. Nutrient content figures are likely to vary according to the part of the plant sampled; complete shoots or prunings show lower nutrient levels than samples of foliar material only (Budelman, 1989).

A sub-sample of foliage was oven dried at 70°C, ground and digested. Samples were analysed for N, P, K, Mg, Ca and B contents. Colourmetric methods were used to determine N and P contents, and atomic absorption spectroscopy used to determine K, Mg and Ca content. Boron content was determined by colourmetric determination using azomethine H (Baker *et al.* 1991). Results were subjected to analysis of variance and differences between species tested by a studentized range test.

Another sub-sample of foliage from some of the species was analysed for fibre content, using the methods given in Van Soest and Wine (1967); for protein precipitating activity of tannins, using the method given in Hagerman (1987), and for condensed tannin content (Porter *et al.* 1986).

To ensure comparability of measurement between species with very variable form, the length of the longest shoot was measured on 10 trees per plot, randomly chosen. The species were placed into 4 productivity classes: average height < 1m (4); between 1 and 2m (3); between 2 and 3m (2); and > 3m (1).

The soils in the valley were described by Simmons (1969) as 'well-drained, coarse textured alluvial soils' with a sandy texture. Soil samples were collected from within the trial area, from plots containing slow growing non N-fixing species. Three depths of soil were sampled: 0-10 cms, 10-30 cms, and 30-60 cms. One aggregated sample was collected for each depth. Soils were analysed for particle size, electrical conductivity, pH, Bray P, Total N, exchangeable cations, TEB, CEC and base saturation (Baker *et al.* 1991). A test for presence of allophane was conducted, because it was suspected that the soil might contain weathered volcanic ash. The results of the analyses are presented in Table 2.

RESULTS

The soils of the Comayagua valley are only slightly acid (Table 2). The river depositing the alluvium flows through mixed rocks including calcareous deposits (Fairbridge 1972). They appear to be adequate in both total nitrogen and in available phosphorus. They have a fairly high CEC and a high base saturation, dominated by calcium. The soil texture is loamy and the bulk density low. There are no obvious limitations to plant growth. The allophane test was negative indicating that weathered volcanic material apparently plays a very small part in soil composition.

TABLE 2. *Results of analyses carried out on soil samples from Comayagua valley, Honduras*

Analysis performed		Sample depth (cms)		
		0 to 10	10 to 30	> 30
Moisture	% o.d.s.	2.6	3.0	3.3
W/V Ratio g/cm^3 a.d.s.		1.0	1.0	1.03
E.C. 1:5 dS/m (mS/cm)		0.05	0.04	0.03
pH 1:5 H20		6.4	6.4	6.4
Exchangeable	Na	0.1	0.1	0.1
cations	K	1.2	0.8	0.8
cmol(p+)/kg (me/100 g)	Mg	2.0	2.0	2.1
1M Amm Ac pH 7	Ca	8.8	8.8	8.8
T.E.R. cmol(p+)/kg a.d.s.		12.1	11.7	11.8
C.E.C. cmol(p+)/kg (me/100 g)		13.2	13.1	13.6
Base saturation %		92	89	87
Kjeldahl N %		0.16	0.13	0.11
Available P (Bray)	mg/dm^3	11	7	9
Stones % (whole soil basis)		>5	14	21
Particle size	2000-500	16	12	13
Analysis	500-250	15	14	14
(dry mineral soil)	250-106	12	13	12
micrometer fractions	106-50	6	7	6
(%)	50-20	12	13	13
	20-2	21	21	20
	<2	18	20	22
Texture		loam	loam	loam
Allophane test		Negative	Negative	Negative

Kellman *et al.* (1982) showed that the central part of Honduras had very low atmospheric inputs of nutrients compared to elsewhere in the tropics.

Foliage analysis

The species generally displayed no visual symptoms that might be indicative of nutrient deficiency. The exceptions were the two Caesalpinias which had yellow margins to their older leaves, and *Senna atomaria* which had a yellow and pale brown mottling of its older leaves.

The species were significantly different one from another in nitrogen content (Table 3), the non N-fixers tending to have lower contents than the N-fixers. However, the range test indicated that *Crescentia alata* was indistinguishable from the lowest N content and *Guazuma ulmifolia* from the highest.

TABLE 3. *Foliar nitrogen content (% dry weight), fibre content in cell wall (as indicated by the acid detergent and neutral detergent fibre), and tannin content (as indicated by radial diffusion and acid butanol methods). Species sorted in descending order of N content.*

Species	Nitrogen content % d.w.	% Acid detergent fibre	% Neutral detergent fibre	Radial diffusion (cm^2/g)	Acid butanol (Absorption/g)
Mornga oleifera	4.66	-	-	-	-
Prosopis juliflora	4.39	21.31	28.79	0	0
Acacia farnesiana	4.33	32.93	50.87	0	0
Leucaena salvadorensis	3.74	-	-	-	-
Parkinsonia aculeata	3.68	34.68	49.45	0	0
Acacia deamii	3.62	-	-	-	-
Gliricidia sepium	3.55	21.60	28.02	119.4	0
Enterolobium cyclocarpum	3.55	30.20	37.94	10.50	0
Senna atomaria	3.53	22.14	38.97	0	0
Albizia niopoides	3.47	-	-	-	-
Albizia saman	3.45	-	-	-	-
Cordia alliodora	3.30	-	-	-	-
Caesalpinia coriaria	3.21	13.73	30.88	1336.9	0
Guazuma ulmifolia	3.21	19.47	27.63	146.6	181.9
Crescentia alata	2.81	43.57	53.53	448.2	0
Hymenaea coubaril	2.76	-	-	-	-
Swietenia humilis	2.65	-	-	-	-
Mimosa tenuifolia	2.65	-	-	-	-
Caesalpinia eriostachys	2.60	19.52	37.14	1202.5	0
Simarouba glauca	1.46	32.00	43.63	815.3	123.3

The acid detergent fibre (Table 3) gives a measure of lignocellulose whilst the neutral detergent fibre measures the total fibre in the cell walls. High total fibre content and low nitrogen content are undesirable for livestock fodder. Thus, *Simarouba glauca* and *Crescentia alata* would make poor animal fodders, but leaf material with high nitrogen and high fibre contents are acceptable. The radial diffusion gives a measure of the biochemical activity of all extractable tannins (both hydrolysable and condensed) and the acid butanol test indicates the amount of condensed tannin present. The two Caesalpinias have very high levels of tannin which is all hydrolysable. High levels of tannin have been associated with decreased digestibility of fodder and, hence, reduced fodder value.

There were highly significant differences between species in foliar P, K, Ca, Mg and B contents, (Table 4). Phosphorus content varied from 0.1% in *Simarouba* to 0.31% in *Moringa*. Potassium content varied from 0.68% in *Caesalpinia eriostachys* to 2.11% in *Senna*. Calcium content varied by a factor of 7 from 0.6 in *Caesalpinia coriaria* to 3.71 in *Cordia*. Boron contents varied by a factor of 6 from 73 mg/kg in *Prosopis* to 12 in *Parkinsonia*.

TABLE 4. *Foliar P, K, Ca, Mg and B contents of 1 year-old Central American multi-purpose tree species growing in Honduras*

Species	Tree Height Class	P %	K %	Mg %	Ca %	B mg/kg
Moringa oleifera	1	0.31	1.96	0.32	3.29	29
Leucaena salvadorensis	1	0.21	1.43	0.18	2.28	57
Mimosa tenuifolia	2	0.15	0.86	0.27	1.02	31
Gliricidia sepium	2	0.22	2.11	0.41	1.56	59
Guazuma ulmifolia	2	0.20	1.85	0.34	2.44	48
Parkinsonia aculeata	3	0.23	1.66	0.20	1.36	12
Albizia niopoides	3	0.15	0.94	0.13	1.44	57
Acacia deamii	3	0.22	1.43	0.38	1.52	67
Acacia farnesiana	3	0.24	1.74	0.23	1.40	42
Caesalpinia coriaria	3	0.15	0.89	0.10	0.60	48
Caesalpinia eriostachys	3	0.14	0.68	0.13	2.44	49
Albizia saman	3	0.16	1.11	0.15	1.84	35
Senna atomaria	3	0.18	1.20	0.09	1.97	21
Simarouba glauca	3	0.10	0.92	0.33	1.19	28
Crescentia alata	3	0.22	1.31	0.32	1.69	48
Cordia alliodora	3	0.20	1.87	0.84	3.71	38
Swietenia humilis	3	0.17	1.18	0.20	2.56	31
Prosopis juliflora	4	0.27	1.92	0.32	2.19	73
Enterolobium cyclocarpum	4	0.21	1.81	0.71	0.66	27
Hymenaea coubaril	4	0.25	1.12	0.15	0.69	18

The species separated into distinct groups for magnesium content with two species (*Cordia* and *Enterolobium*) having markedly higher contents than the others. A group of species had particularly low Mg contents ;- *Senna*, the two *Caesalpinias* and *Albizia niopoides*. On balance, and considering absolute levels of other nutrients, a low Mg content seems the most likely cause of the yellow leaf edges and mottles seen in three of these four species.

The productivity class information had little impact on the interpretation. For each nutrient, high contents were as likely to be associated with fast growing species as with slow growing ones. The observed differences are therefore not just a reflection of differential nutrient demand from a constant source.

The average N,P,K,Ca and Mg contents for *Gliricidia sepium* published by Budelman (1989) are very similar (within ± 10%) to those found in this study. The nutrient contents of *Prosopis juliflora* published by Maghembe *et al.* 1983, and Sharma 1984 differ markedly one from another and from this study. In this study *Prosopis* has higher N, higher P but lower K than in the other two studies.

DISCUSSION

These results indicate the foliar nutrient content of this range of species, when growing rapidly on a site within the native range of most of the species. In a separate study comparing a similar range of species at 15 sites throughout the world, the Comayagua valley had the second highest growth rate (Hunter I.R. 1992 unpubl. data). Therefore similar analyses of material collected at poorer sites could help to identify any nutritional factors affecting growth and help explain the factors restricting growth.

It is worth emphasizing just how different the soil conditions are in the Comayagua valley from those existing in the widespread tropical latosol. Many of these species accumulated high contents of P, Ca, Mg and K in this soil and would have difficulty doing so in a typical latosol with a very low available P, low CEC and very low base saturation. These data do not establish, however, that such high uptake is essential to plant health.

Many of these species are used where the dead foliage is expected to make a contribution to soil fertility or the living foliage and fine branches are cut as a mulch. Clearly some species in this collection are much more effective at accumulating some nutrients than others. Many of the species have a potential as fodder. Selection of the right species could improve animal health. In all cases the species contained high enough levels of P to satisfy animal needs, but Kearl (1982) cites Honduras as having magnesium deficiency in ruminants and, *ceteris paribus*, some of these species would be much better fodder supplements where Mg is scarce than others.

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