The performance and nutritive value of *Leucaena* in a unimodal rainfall environment in western Tanzania

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Abstract

The productivity and nutritive value of 10 leucaena accessions (1 *L. leucocephala*; 5 hybrids; 1 composite; 2 *L. diversifolia*; 1 *L. pallida*) were compared with that of *L. leucocephala* cv. Cunningham for 6 sampling occasions over 31 months at Tumbi-Tabora, western Tanzania. Total annual yields of 4 accessions and edible dry matter (DM) yields of 5 accessions consistently exceeded that of cv. Cunningham. DM yields of the highest yielding accessions (*L. pallida* CPI 94581; hybrid KX2; and *L. diversifolia* No. 8 CPI 85132) were 2.5 times that of cv. Cunningham for total yield and twice for edible DM yield. Nitrogen and potassium levels were highest in cv. Cunningham and calcium and magnesium concentrations varied between entries but all nutrients except phosphorus in some entries and potassium in all entries were adequate for growth in ruminants. Cultivar Cunningham was more digestible and contained less acid detergent fibre than the other accessions. The superiority in yield of the entries over the commercial cultivar emphasises the need to evaluate them further over a range of environments.

Introduction

The tropical legume *Leucaena leucocephala* is a valuable source of feed for ruminants and considerable research has been directed towards understanding its production capabilities and limitations. The species has been used in agroforestry systems such as alley cropping to boost productivity in areas of low soil fertility, where farmers are resource poor (*Kang et al.* 1990). In eastern Africa, the commercial cultivars, Peru and Cunningham, released in Australia in the early 1960s/70s, are widely grown. In Australia and at the University of Hawaii (USA), other accessions or crosses are now available that have demonstrated superiority in yield over these commercial cultivars (Bray *et al*. 1988; Pfeiffer 1990; Berhe and Tothill 1995) and some have shown tolerance or resistance to the leucaena psyllid (*Heteropsylla cubana*) (Sorensson and Brewbaker 1986; Shelton *et al*. 1991; Wheeler *et al*. 1994). However, this new germplasm has not been evaluated under the unimodal rainfall conditions of east and southern Africa. This paper reports the productivity and nutritive value of 10 accessions and one commercial cultivar of leucaena grown in a unimodal rainfall environment within the miombo woodlands of western Tanzania.

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Materials and methods

Site

The trial was conducted at Tumbi-Tabora, western Tanzania (5°03′S, 32°41′E). The soil was a sandy loam (ferric acrisols-FAO) with pH 4.4 (1:1.25 soil:water), organic carbon 0.4%, total N 0.03% and available P 11 ppm. The mean daily maximum and minimum temperatures for the area during the experimental period were approximately 28°C and 16°C, respectively, which were similar to the long-term averages of 30°C and 15°C. The long-term mean annual rainfall of 880 mm is unimodal in distribution with 93% falling between November and April. Rainfall during the experimental period was 520 mm, 489 mm and 732 mm in 1990/91, 1991/92 and 1992/93 seasons, respectively.

Leucaena accessions

The leucaena accessions tested comprised 5 groups:

- 2 accessions of *L. leucocephala*: cv. Cunningham (a 'common' type) and K88A (representative of El Salvador 'giant' type);
- 5 hybrids: KX1 F1 (*L. pallida* K376 X *L. diversifolia subsp. diversifolia* K156), KX2 F3 (*L. pallida* K376 X *L. leucocephala* K8), KX3A F1 (original), KX3A F2 (new release) and KX3C F3 *(L. leucocephala* K8 X *L. diversifolia subsp. diversifolia* K156);
- 1 leucaena composite K36 (*L. leucocephala* K8 X *L. diversifolia subsp. diversifolia* K156 X *L. pulverulenta* K134);
- 2 accessions of *L. diversifolia subsp. diversifolia*: No8 (CPI 85132) and K156; and
- 1 *L. pallida* CPI 94581.

The details of the source of accessions and some of their responses at the site are given in Table 1.

Experimental procedure

Seedlings were raised in polythene tubes in the nursery for 8 weeks and transplanted into the field on December 16, 1990 in a randomised complete block trial with 3 replications. At planting, 5 g single superphosphate was mixed with the soil in the planting hole for each seedling. There were 45 seedlings per plot, each plot consisting of 5 rows 6 m long and spaced 1 m apart and with 0.75 m spacing between seedlings. Seedlings that died in the first 4 weeks after transplanting were replaced and weeds were controlled by hand weeding.

The first harvest was taken 12 months after planting in December 1991 with regrowth harvested in February (wet season), July (early dry season) and November (late dry season) 1992 and February and July 1993. Fifteen plants were cut to a height of 0.5 m , 5 from each of the 3 centre rows excluding 2 border plants, and then separated into edible yield (leaf plus stem <5 mm diameter and pods if any) and wood (>5 mm diameter). These fractions were weighed fresh in the field, sub-sampled and oven-dried at 100°C for 24 h for determination of dry matter (DM) yield. During the February 1993 harvest, a second set of sub-samples of edible DM yield from 2 replicates was oven-dried at 35°C to constant weight and hammer-milled (Wiley mill) to pass through a 1 mm screen for chemical analyses. Nitrogen (N) concentration was determined by the Kjeldahl method (AOAC 1970). Mineral analyses were conducted after digesting the samples in a mixture of nitric and perchloric acid; calcium (Ca) and magnesium (Mg) were determined by atomic absorption spectrophotometry, potassium (K) by flame photometry and phosphorus (P) colorimetrically. Acid detergent fibre (ADF) and lignin analyses were carried out by the procedures outlined by Goering and Van Soest (1970) and *in vitro* dry matter digestibility (IVDMD) by the method of Moore and Mott (1976) using a 4-weeks regrowth napier grass (*Pennisetum purpureum* cv. Bana; 51% IVDMD) as the standard. The rumen inoculum for IVDMD determination was obtained from a Friesian cow maintained on rhodes grass (*Chloris gayana*) hay.

Table 1. Details of accessions tested.

Accession	Identification	Source	Comment
Leucaena leucocephala	cv. Cunningham	CSIRO (Australia)	susceptible to psyllid
	K88A	University of Hawaii (USA)	susceptible to psyllid
Leucaena hybrids	KX1	University of Hawaii (USA)	high psyllid resistance
	KX2	University of Hawaii (USA)	high psyllid resistance, rapid growth rate
	KX3 A F1(original)	University of Hawaii (USA)	moderate psyllid resistance, rapid growth rate
	KX3A F2 (new release)	University of Hawaii (USA)	moderate psyllid resistance
	KX3C F3	University of Hawaii (USA)	moderate psyllid resistance, rapid growth rate
L. composite	K36	University of Hawaii (USA)	susceptible to psyllid
L. diversifolia	No8[1] (CPI85132)	CSIRO (Australia)	moderate psyllid resistance, rapid growth rate
	K156	University of Hawaii (USA)	high psyllid resistance
L. pallida	CPI 94581	CSIRO (Australia)	high psyllid resistance, rapid growth rate

[1] Introduction number at Katumani Dryland Farming Research Station, Machakos, Kenya.

Results

Dry matter yields

The DM yields are shown in Tables 2 and 3. Four entries outyielded (P<0.05) cv. Cunningham in total yields. Overall, the highest yielding entries were *L. pallida* CPI 94568, hybrid KX2 and *L. diversifolia* No 8 (CPI 85132) with average yields at least 2.5 times that of cv. Cunningham. The ranking in edible DM yield was generally similar to that of total DM yield. There was a major depression in yield of all entries following the arrival of leucaena psyllid in June 1993. However, the yield of the best performing entries still exceeded that of cv. Cunningham. Edible DM exceeded 50% of total DM for all accessions. Values for most entries were similar to that for cv. Cunningham (60.7%) with only *L. diversifolia* No 8 (CPI 85132) (51.4%) and *L. leucocephala* K88A (75.0%) being either significantly (P<0.05) lower or higher.

Table 2. Total dry matter yields of leucaena grown in a unimodal rainfall environment, western Tanzania.

Accession	1991	1992	1993
		(t/ha)	
Leucaena pallida CPI 94581	2.0	25.9	13.6
L. hybrid KX2	1.5	32.1	13.8
L. diversifolia No 8 (CPI85132)	1.3	26.2	15.7
L. hybrid KX3C	1.2	21.7	9.3
L. diversifolia K156	0.8	16.0	6.0
L. hybrid KX1	0.8	15.8	5.9
L. hybrid KX3A (original)	0.7	15.8	5.9
L. composite K36	0.7	14.5	3.8
L. hybrid KX3A (new release)	0.6	17.6	6.9
L. leucocephala K88A	0.5	14.4	2.3
L. leucocephala cv. Cunningham	0.5	12.8	3.4
Mean	1.0	17.3	7.5
LSD (P<0.05)	0.3	4.7	3.1

Table 3. Yield of edible dry matter for leucaena grown in a unimodal rainfall environment, western Tanzania.

Accession	1991	1992	1993
		(t/ha)	
Leucaena pallida CPI 94581	1.2	15.8	8.3
L. hybrid KX2	0.9	17.6	8.5
L. diversifolia No 8 (CPI85132)	0.7	13.6	7.7
L. hybrid KX3C	0.7	13.3	5.8
L. diversifolia K156	0.4	9.6	3.2
L. hybrid KX1	0.5	9.3	2.8
L. hybrid KX3A (original)	0.6	10.9	3.8
L. composite K36	0.4	8.7	2.3
L. hybrid KX3A (new release)	0.5	9.8	2.2
L. leucocephala K88A	0.4	10.0	2.2
L. leucocephala cv. Cunningham	0.4	7.8	2.1
Mean	0.6	11.5	4.4
LSD (P<0.05)	0.3	2.6	1.3

Chemical composition

There were significant (P<0.05) differences between entries in concentrations of N, K, Ca, Mg, the fibre fractions and IVDMD (Table 4). Nitrogen and K levels were highest (P<0.05) in cv. Cunningham and there was smaller but significant (P<0.05) variation between the other entries. Ca and Mg levels varied (P<0.05) among the entries with *L. leucocephala* K88A containing the highest levels of Ca. Level of ADF was lowest (P < 0.05) in cv. Cunningham but this same entry had the highest lignin concentration. Lignin levels varied significantly between the entries. *In vitro* DMD of both *L. leucocephala* entries was superior (P<0.05) to that of all other entries whose values varied from 37.8–49.0%. Higher IVDMD values did not appear to be consistently related to lower ADF or lignin values.

Table 4. Mineral element compositions, fibre and lignin concentrations and *in vitro* dry matter digestibility of leucaena grown in a unimodal rainfall environment, western Tanzania.

Accession	N	P	K	Ca	Mg	ADF	ADL	IVDMD
					(%)			
L. pallida CPI 94581	2.2	0.19	0.5	1.0	0.5	43.1	13.4	43.2
Leucaena hybrid KX2	2.1	0.19	0.4	1.0	0.4	44.3	13.4	49.0
L. diversifolia No 8 (CPI 85132)	2.5	0.20	0.6	1.2	0.4	44.0	12.9	38.9
L. hybrid KX3C	3.1	0.18	0.5	1.0	0.5	44.1	13.4	46.2
L. diversifolia K156	2.5	0.22	0.5	0.8	0.3	44.9	14.3	37.8
L. hybrid KX1	2.3	0.21	0.5	0.6	0.4	43.9	12.8	45.3
L. hybrid KX3A (original)	2.0	0.16	0.5	0.8	0.3	47.6	15.1	40.9
L. composite K36	2.9	0.18	0.4	0.5	0.3	47.4	14.9	39.7
L. hybrid KX3A (new release)	2.4	0.21	0.6	1.0	0.4	43.2	12.9	38.6
L. *leucocephala* K88A	2.4	0.18	0.5	1.5	0.5	44.2	14.2	54.5

Table 4. Mineral element compositions, fibre and lignin concentrations and *in vitro* dry matter digestibility of leucaena grown in a unimodal rainfall environment, western Tanzania.

L. leucocephala cv. Cunningham	3.7	0.21	1.2	1.1	0.4	38.4	15.5	57.3
Mean	2.5	0.19	0.6	1.0	0.4	44.1	13.9	46.5
LSD (P<0.05)	0.5	0.05	0.2	0.3	0.1	1.8	1.3	4.5

Discussion

Broadly, the results confirm the superiority in yield of some recent selections over cv. Cunningham, which agrees with other reported observations (Wheeler and Brewbaker 1990; Berhe and Tothill 1995) but contrasts with some reports (Mureithi *et al*. 1994; Austin *et al*. 1995). The magnitude of difference in yields obtained indicates that there is potential for selecting for higher yielding accessions in this genus suited to the test environment in western Tanzania. Overall, the highest yielding accessions (*L.pallida* CPI 94581, hybrid KX2 and *L. diversifolia* No 8 CPI85132) produced more than twice and 1.5 times the total and edible DM yields, respectively, of cv. Cunningham during the moderate (1992) and heavy (1993) psyllid infestation periods. The proportion of wood (25–50%) in total DM of most accessions also indicates that they have potential both as forage plants and as high yielding plants for biomass production.

The N and mineral concentrations, except K, were similar to those reported by Austin *et al.* (1992) and the superiority in N and IVDMD of *L. leucocephala* entries is in agreement with findings of several other authors (Tergas *et al*. 1989; Austin *et al*. 1995) . The variation in Ca and Mg may have little implication for animal production since the levels were all high. Levels of P could support maintenance to low levels of production in ruminants (NRC 1975, 1978; TCORN 1991), whereas supplementation with K would be needed with all forages except cv. Cunningham. These low levels of K in plant tissue may also suggest a need to apply K fertiliser to improve forage yield. Although the N levels suggest moderate to high quality forage, presence of condensed tannins (Telek 1982) could result in overestimation of their nutritive value. Condensed tannins are known to form complexes with dietary proteins (Barry and Manley 1984). These tannin-protein complexes may dissociate in the lower tract of the ruminant to provide additional amino-acids for absorption, but Wheeler *et al*. (1994) cite evidence that some protein-tannin complexes of leucaena origin remain undigested.

The IVDMD for *L. leucocephala* was similar to that recorded by Tergas *et al*. (1989) and Berhe and Tothill (1995) but the digestibility of the other entries was lower than those reported by Gupta *et al*. (1991). This may be associated with the greater maturity in the forage analysed in our experiment. Regrowth harvested at 4-weekly intervals was more digestible than the regrowth in this experiment (M. Karachi, unpublished data). The high concentrations of polyphenols in these forages (Wheeler *et al.* 1994), which are believed to interfere with digestion (Akin 1989), may also have contributed to the low IVDMD values. As feed intake is positively related to herbage digestibility (Minson 1971), our data suggest that consumption of the non-leucocephala entries may be limited by low digestibility. Therefore, continued promotion of these materials for forage production, especially in smallholder farms where there is a strong dependency on leucaena as supplementary protein feed, and in breeding programs for tolerance to psyllid, should be evaluated in light of the potential effects of the secondary compounds on the forage nutritive value. A similar conclusion was reached by Hove *et al.* (1996).

After the establishment year, more than 80% of the annual edible DM yield from leucaena germplasm previously tested at the site was produced during the wet and early dry season periods (Karachi and Shirima 1997). Four of the accessions tested yielded considerably more than the average yields of 3.5–5.5 t/ha recorded from leucaena during this period. Further testing in a range of environments and including a wider collection from the species *L. diversifolia* and *L. pallida* that appear to have tolerance to psyllid may be worthwhile. For example, Pfeiffer (1990) reported that, on high altitude ridges of the Usambala mountains in Tanzania, *L. diversifolia* out-yielded *L. Leucocephala*.

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References

AKIN, D.E. (1989) Histological and physical factors affecting digestibility of forages. *Agronomy Journal*, **81**, 17–25.

AOAC (Association of Official Analytical Chemists) (1970) *Official Methods of Analysis.* 11th Edn. (NAS: Washington, DC).

AUSTIN, M.T., WILLIAMS, M.J., HAMMOND, A.C. and SUN, W. (1992) Mineral nutrient concentrations in edible forage fractions of 20 leucaena genotypes at Wainamalo, Hawaii. *Leucaena Research Reports*, **13**, 77–81.

AUSTIN, M.T., WILLIAMS, M.J., HAMMOND, A.C., FRAN, J.H. and CHAMBLISS, C.G. (1995) Establishment, forage production and nutritive value of leucaena in central Florida. *Agronomy Journal*, **87**, 915–920.

BARRY, T.N. and MANLEY, T.R. (1984) The role of condensed tannins in the nutritional value of *Lotus pedunculatus* for sheep. 2. Quantitative digestion of carbohydrates and protein. *British Journal of Nutrition*, **51**, 493–503.

BERHE, K. and TOTHILL, J.C. (1995) Performance, feed quality and P response of *Leucaena* and *Calliandra* species grown on an acidic Nitosol at Soddo, Ethiopia. *Tropical Grasslands*, **29**, 1–8.

BRAY, R.A., COOKSLEY, D.G., HALL, T.J. and RATCLIFF, D. (1988) Performance of fourteen leucaena lines at five sites in Queensland, *Australian Journal of Experimental Agriculture*, **29**, 69–76.

GOERING, H.R. and VAN SOEST, P.J. (1970) Forage fibre analysis (apparatus, reagents, procedures and some applications). *Agricultural Handbook No.379, Washington, DC*.

GUPTA, B.K., AHUJA, A.K. and KHAJURIA, H.N. (1991) Fodder analysis of new leucaena varieties. *Leucaena Research Reports*, **12**, 40–41.

HOVE, L., CHAKOMA, C. and DZOWELA, B.H. (1996). Comparative evaluation of *Leucaena diversifolia*, *L. pallida (syn. L. esculenta ssp. paniculata*) and *L. leucocephala* cv. Cunningham as supplements to veld hay. *Leucnet News*, **3**, 24–26.

KANG, B.T., REYMONDS, L. and ATTA-KRAH, A.N. (1990) Alley farming. *Advances in Agronomy*, **43**, 315–359.

KARACHI, M. and SHIRIMA, D. (1997) Agronomic evaluation of eleven leucaena lines at Tumbi-Tabora, western Tanzania. *Agroforestry Systems* (in press).

MINSON, D.J. (1971) The digestibility and voluntary intake of six varieties of *Panicum maximum*. *Australian Journal of Experimental Agriculture and Animal Husbandry*, **12**, 21–27.

MOORE, J.E. and MOTT, G.O. (1976) Fermentation tubes for *in vitro* digestion of forages. *Journal of Dairy Science*, **59**, 167–169.

MUREITHI, J.G., THORPE, W., TAYLER, R.S. and REYMOLDS, L. (1994) Evaluation of leucaena accessions for semi-humid lowland tropics of East Africa. *Tropical Agriculture*, **71**, 83–87.

NRC (National Research Council) (1975) *Nutrient Requirements of Sheep*. 5th Edn. (NAS: Washington, DC).

NRC (National Research Council) (1978) *Nutrient Requirements of Dairy Cattle*. 5th Edn. (NAS: Washington, DC).

PFEIFFER, R. (1990) Investigating possibilities of combining fodder production with erosion control and agroforestry in west Usambala mountains of Tanzania. In :Kotschi, J. (ed.) *Ecofarming Practices for Tropical Smallholdings. Tropical Agroforestry*, **5**, 81–106. (Verlag Josef Margraf: Germany).

SHELTON, H.M., LOWRY, J.B., GUTTERIDGE, R.C., BRAY, R.A. and WILDIN, J.H. (1991) Sustaining productive pastures in the tropics.7. Tree and shrub legumes in improved pastures. *Tropical Grasslands*, **25**, 119–128.

SORENSSON, C.T. and BREWBAKER, J.L. (1986) Psyllid resistance of *Leucaena* species and hybrids. *Leucaena Research Reports*, **7**, 13–17.

TCORN (Technical Committee on Responses to Nutrients) (1991) A reappraisal of the calcium and phosphorus requirements of ruminants. *Nutrition Abstracts and Reviews*, **61**, 573–612.

TELEK, L. (1982) Preparation of leaf protein concentrates from *Leucaena leucocephala*. *Leucaena Research Reports*, **3**, 13–17.

TERGAS, L.E., MARTINES, R.E. and MENDEZ-CRUZ, A.V. (1989) Forage production and nutritive value of *Leucaena leucocephala* in southern Puerto Rico. *Proceedings of XVI International Grassland Congress, Nice, France, 1989*. pp. 937–938.

WHEELER, R.A. and BREWBAKER , J.A. (1990) An evaluation of results from the leucaena psyllid trial network. *Leucaena Research Reports*, **11**, 23–31.

WHEELER, R.A., CHANEY, W.R., BUTLER, L.G. and BREWBAKER, J.L. (1994) Condensed tannins in leucaena and their relation to psyllid resistance. *Agroforestry Systems*, **26**, 139–146.

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