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Uses, yield and nutritive value of mulberry (*Morus alba*) trees for ruminants in the semi-arid areas of central Tanzania

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Abstract

A study to determine yield and nutritional value of mulberry (*Morus alba*) trees for livestock was conducted at the Livestock Production Research Institute, Mpwapwa in central Tanzania. Mulberry cuttings were planted at 3 spacings, (treatments) S1 (0.5 × 0.7 m), S2 (1 × 2 m) and S3 [Double row (1 × 1 × 0.5 m)]. Randomly selected trees in each block were cut to about 15–30 cm high (2 years after establishment) towards the end of the rainy season, and in the middle of the dry season and harvested material used for yield and nutritive value determination. Regrowth was harvested at different times during the dry season for biomass determination. This study was accompanied by a brief survey to determine distribution and uses of mulberry trees in some villages around Mpwapwa township.

About 5% of farmers had a few (2–5) mulberry trees growing around their homesteads, which were used for shade, fruits and to a lesser extent as vegetables, for medicinal purposes and as fuel wood. Leaves of the trees contained 14.3, 18.6, 24.6, 20.8, 3.8, 8.1, 12.6 and 2.5% ash, crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), hemicellulose (Hem), acid detergent lignin (ADL), cellulose (Cel) and acid detergent insoluble ash (ADIA), respectively. *In vitro* dry matter digestibility (IVDMD) of the leaves was 82.1%. The nutrient composition of the bark was 7.7% ash, 7.8% CP, 46.8% NDF, 36.9% ADF, 9.9% Hem, 7.1% ADL, 29.8% Cel and 1.1% ADIA. The IVDMD of bark was fairly high (60.3%) and the rate of *in sacco* dry matter (DM) degradation of the leaves was very high (70–80% of the DM disappeared after 24 h of incubation). Degradability of the bark after 72 h of incubation was around 70%.

Yield of leaves exceeded 20 t/ha DM when cut at the end of the rainy season and again in the mid-dry season. Corresponding yields of stem and bark were 31 t/ha and 6.6 t/ha, respectively.

Introduction

The major proportion of the feeds for livestock in semi-arid areas is natural pastures and crop residues, which are usually low in protein, energy (Van Soest 1982) and minerals (McDowel 1985). Mature plants are known to contain relatively high levels of lignin and this is associated with reduced palatability (Heady 1964) and digestibility of dry matter through inhibition of microbial activity (Van Soest 1982). As a consequence, dry matter intake is reduced, resulting in a decline in available energy, protein and minerals. Therefore, natural pastures in semi-arid areas will not usually support optimum milk production. Supplementation and/or complementation is necessary to meet the nutrient requirements for normal livestock production and reproduction.

Interest in exotic (introduced) browse species in the semi-arid areas of central Tanzania has increased during the past few decades. *Leucaena leucocephala* and *Sesbania sesban* were considered to be promising browse species. However, the value of leucaena has been limited due to the leucaena psyllid (*Heteropsylla cubana*), which wiped out almost all leucaena trees in most parts of eastern Africa. Similarly, *Sesbania sesban* has shown very poor adaptation in the semi-arid areas of central Tanzania (personal observations).

Native trees and shrubs are still an important source of nutrients for livestock in semi-arid areas because they are adapted to the environment. Unfortunately, most deciduous browse

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species in these areas shed their leaves during the dry season, and during this period, most evergreen species are known to contain some physical structures or chemical compounds, which defend them against herbivory (Coley *et al.* 1985). Lack of sufficient feeds during the dry season forces grazing cattle, sheep and goats to consume plants which contain considerable amounts of phenolic compounds, such as tannins, which may be present at levels of up to 50% of the dry matter (Reed 1986).

Mulberry trees are incorporated into intensive farming systems in some areas of Tanzania (*e.g.* Kilimanjaro region) and are widely used to feed zero-grazed sheep and goats in cut-and-carry systems. Bark of fresh stem is usually stripped and eaten by sheep and goats. There is limited information on the feeding value of mulberry trees for livestock other than the data on chemical composition and digestibility reported by Le Houerou (1980), Casoli *et al.* (1986), Prasad and Reddy (1991) and Deshmukh *et al.* (1993).

This study was one of the first to investigate distribution, uses, yield and nutritive value of mulberry (*Morus alba*) trees for livestock production in the semi-arid areas of central Tanzania.

Materials and methods

Study area

The study was conducted at the Livestock Production Research Institute (LPRI), Mpwapwa, in the semi-arid area of central Tanzania (36° 30′E, 6° 20′S; altitude 1100 m). Average annual rainfall is 550 mm and varies greatly in distribution and amount from year to year. About 90% of the rain falls from December–April, and there is usually a dry spell in February. The average minimum temperature is 15.5°C, the coolest month being August (13.8°C). The average maximum temperature is 27.5°C, the warmest month being November (30.2°C).

The soils are sandy loams on the slopes and clay loams along the valley bottoms. Soils are low in nitrogen and phosphorus but adequate in potassium. The pH of the topsoil ranges between 5.6–7.7, while that of the sub-soil lies between 5.3–8.6.

Survey

Visits were made to 10 randomly selected farmers in each of 6 villages surrounding Mpwapwa township to determine distribution and uses of mulberry trees. This was accomplished through a short questionnaire.

Mulberry tree establishment

One ha of land at LPRI was ploughed, harrowed and subdivided into 9 plots each measuring 30 × 30 m. Mulberry cuttings were obtained from neighbouring farms and planted in plastic bags and later transferred to the field at 3 different spacings/treatments [S1 = 0.5 × 0.7 m; S2 = 1 × 2 m; and S3 = Double rows (0.5 × 1 × 1 m)]. Each treatment was randomly allocated into 3 plots. The rooted cuttings were transferred to the field at the end of March 1994, towards the end of the rainy season, and to ensure survival, were irrigated during the dry season (from July–November 1994).

Data collection

First cutting. In March 1996, 2 years after establishment, 36 randomly selected trees from each plot were harvested. The cutting height was about 15–30 cm above ground level. All harvested material from each tree was weighed (fresh) and bulked. About 10% of the harvested trees were sub-sampled. Leaf and bark from the sub-sampled material were separated from stem. The separated leaf and bark were weighed (fresh), and sub-sampled for further analyses (chemical composition and digestibility determinations). The sub-sampled stem was cut into small pieces followed by further sub-sampling. These and some leaf and bark material were weighed and dried at 105°C overnight. The proportions of the post-dried weight to the pre-dried weight of the leaf, stem and bark were recorded as percent dry matter (% DM) and were used to calculate DM yield (kg) of leaf, stem and bark per tree and consequently DM yield/ha as follows:

DM yield/tree = DM% × weight of fresh material (leaf, bark and stem)/tree, and DM yield/ha = DM yield/tree × number of trees/ha.

Leaf and bark from different parts of the tree were collected for *in sacco* dry matter degradability. The parts sampled were: the 1st–10th leaf from the tip of the branch; leaves starting from the 15th leaf from the tip of the branch; 1st–10th leaf and bark from the tip of the branch; bark from the top branch; and bark from older branches.

Chemical composition

The feed samples intended for chemical analysis and *in vitro* dry matter digestibility (IVDMD) determinations were pre-dried in a forced-air oven at 65°C for 12 h and ground to pass through a 1 mm screen, except those intended for *in sacco* degradation, which were milled through a 3 mm screen.

Dry matter (DM), ash and crude protein (CP) concentrations were determined according to procedures of AOAC (1985). Neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and acid detergent insoluble ash (ADIA) concentrations were determined according to the procedure of Goering and Van Soest (1970). Hemicellulose (Hem) was calculated as the difference between NDF and ADF, while cellulose (Cel) was presented as the difference between ADF and ADL.

In sacco *degradability and* in vitro *digestibility*

Nylon bags, measuring 8 × 15 cm and containing 3–5 g ground feed samples, were suspended from a nylon string in the rumen of a fistulated Boran steer which was provided with *ad libitum* hay, water and mineral licks. The bags were tied together with a lead weight to hold the samples in the liquid layer of the rumen. Duplicate bags were removed from the rumen after incubation for 6, 12, 18, 24, 48 and 72 h, washed with running tap water for about 5 min, dried at 100°C overnight and weighed. The difference in pre-incubation and post-incubation weight was deemed to be the amount of feed degraded.

Rumen liquor from the fistulated steer was collected and used to incubate the feed samples for *in vitro* digestibility determination. The procedure involved incubation of the samples for 48 h followed by neutral detergent extraction for 12 h according to Van Soest *et al.* (1966). *In vitro* DM digestibility (IVDMD) was the percent of DM that disappeared, expressed on a DM basis.

Second cutting. Twenty trees, which had grown for 190 days (at the peak of the dry season, October 1996) longer than the trees harvested at the first cutting, were harvested for the first time from each plot for determination of biomass production of leaves, stems and bark. Each fresh tree was weighed and samples of leaf, stem and bark were taken and dried for DM and yield determinations (see 1st cutting).

Regrowth. All trees in an area measuring 10 × 10 m in each plot were harvested in March 1996. After 120 (mid-dry season, July 1996) and 190 days (peak of dry season, October 1996) some of these trees were randomly selected and re-harvested. Biomass production of regrown leaves, stem and bark was determined following the above-mentioned procedures (see 1st cutting).

Statistical analysis

Data on yield of leaf, bark and stem were analysed using Minitab statistical software (Minitab 1994) using the following model:

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

where μ = Overall mean

α_i = Effect due to treatments

ε_{ij} = Residual (Error term).

For the treatments which showed significant differences, the means were compared using Tukey's procedure at $P < 0.05$.

Results and discussion

Survey

Mulberry trees were found in few (5%) households in villages around Mpwapwa township in the semi-arid areas of central Tanzania. The trees are grown close to the dwelling and the number of trees per household does not usually exceed 5 (average = 2). Some trees are found away from the living places, where they were left by farmers who previously occupied the land. The trees produce fruits and are used for a range of purposes by people (*e.g.* for shade and to a lesser extent as vegetables, for medicinal purposes and as fuel wood) but the leaves are seldom used for livestock feeding.

Yield

Results of biomass production and proportions of different parts of the trees and regrowth are presented in Tables 1 and 2. The trees harvested at the end of the rainy season had significantly ($P < 0.05$) more leaf than those harvested at the peak of the dry season, indicating that there is a considerable loss of leaf due to shedding during the dry season. Similarly, the regrowth harvested at the middle of the dry season had significantly ($P < 0.05$) more leaf than regrowth harvested towards the end of the dry season.

Table 1. Mean yield (± s.e.m.) of some parts of mulberry (*Morus alba*) trees and regrowth under different spacings harvested at different periods of the year.

Type	Cutting	Treatment[1]	Yield/tree				Yield/ha			
			Leaf	Stem	Bark	Total	Leaf	Stem	Bark	Total
			(kg DM)				(t DM)			
Trees	1st[3]	S1	0.59ab[2] ±0.032	0.97a ±0.053	0.18a ±0.010	1.74a ±0.095	16.93a ±0.924	28.17a ±1.540	5.29a ±0.289	50.39ab ±2.750
		S2	0.65a ±0.043	1.37bc ±0.091	0.28b ±0.019	2.30b ±0.153	3.35b ±0.222	7.05b ±0.468	1.44b ±0.096	11.84c ±0.786
		S3	0.63a ±0.032	1.12ab ±0.058	0.22ab ±0.012	1.97ab ±0.101	8.46c ±0.437	15.10c ±0.780	3.03c ±0.156	26.60d ±1.370
	2nd[4]	S1	0.08c ±0.015	1.65bd ±0.308	0.46c ±0.085	2.19ab ±0.408	2.29b ±0.426	47.82d ±8.920	13.21d ±2.46	63.31b ±11.800
		S2	0.31bc ±0.045	2.14d ±0.315	0.54c ±0.079	2.98b ±0.439	1.57b ±0.231	11.02bc ±1.620	2.78bc ±0.409	15.37cd ±2.260
		S3	0.14c ±0.024	2.00cd ±0.335	0.49c ±0.082	2.64ab ±0.442	1.95b ±0.326	27.10a ±4.540	6.64a ±1.110	35.68ad ±5.970
Regrowth	120 days[5]	S1	0.14a ±0.010	0.12 ±0.009	0.05a ±0.004	0.31 ±0.023	4.02a ±0.297	3.54a ±0.261	1.43a ±0.106	8.99a ±0.663
		S2	0.13a ±0.012	0.14 ±0.013	0.06a ±0.006	0.33 ±0.031	0.66bc ±0.063	0.71b ±0.067	0.31bc ±0.029	1.68b ±0.159
		S3	0.11a ±0.013	0.14 ±0.017	0.06a ±0.007	0.30 ±0.037	1.48b ±0.179	1.86bc ±0.225	0.75d ±0.091	4.09c ±0.495
	190 days[6]	S1	0.05b ±0.003	0.16 ±0.009	0.02b ±0.001	0.22 ±0.013	1.31b ±0.078	4.48d ±0.266	0.60cd ±0.035	6.39d ±0.378
		S2	0.06b ±0.005	0.17 ±0.016	0.02b ±0.002	0.25 ±0.023	0.31c ±0.028	0.87b ±0.080	0.12b ±0.011	1.31b ±0.119
		S3	0.05b ±0.003	0.17 ±0.011	0.02b ±0.001	0.23 ±0.016	0.64c ±0.043	2.25c ±0.153	0.25b ±0.017	3.13bc ±0.213

[1] Plant spacings: S1 — 0.5 × 0.7 m; S2 — 1 × 2 m; S3 — Double row (1 × 1 × 0.5 m).
[2] Means within type in the same column with different letters are significantly different ($P < 0.05$).
[3] Trees harvested 2 years after establishment (1st cutting, end of the rainy season).
[4] Trees harvested for the first time, 190 days after the 1st cutting (peak of the dry season).
[5] Regrowth harvested 120 days after the 1st cutting (mid–dry season).
[6] Regrowth harvested 190 days after the 1st cutting (peak of the dry season).

Table 2. Proportion of some parts of mulberry (*Morus alba*) trees and regrowth at different spacings harvested at different periods.

Type	Treatment[1]	Part of the tree		
		Leaf	Stem	Bark
			(%)	
Trees at 1st cutting	S1	33.6	55.9	10.5
	S2	28.3	59.6	12.2
	S3	31.8	56.8	11.4
	Mean	31.2a[2]	57.4a	11.4a
Trees at 2nd cutting	S1	3.6	75.5	20.9
	S2	10.2	71.7	18.1
	S3	5.5	75.9	18.6
	Mean	6.4b	74.4b	19.2b
Regrowth at 120 d	S1	44.7	39.4	15.9
	S2	39.3	42.5	18.2
	S3	36.1	45.4	18.4
	Mean	40.0c	42.4c	17.5b
Regrowth at 190 d	S1	20.5	70.1	9.3
	S2	23.7	66.8	9.5
	S3	20.3	71.9	8.0
	Mean	21.5d	69.6b	8.9a

[1] Plant spacing: S1 — 0.5 × 0.7 m; S2 — 1 × 2 m; S3 — Double row (1 × 1 × 0.5 m).
[2] Type means in the same column with different letters are significantly different ($P < 0.05$).

The number of trees/ha in S1, S2 and S3 was estimated to be 28 900, 5150 and 13 530, respectively. This resulted in large variations in biomass production/ha, yields in S1 being significantly ($P < 0.05$) higher than those in S2 and S3. This is in agreement with the findings of Choudhury *et al.* (1991) who obtained maximum mulberry leaf yield/ha at a spacing of 60 × 60 cm and sharp declines in leaf yield as spacing was increased beyond 60 × 60 cm. In this study, leaf yield /ha in S1 at the end of the rainy season was similar to the mean annual yield of 4 varieties of mulberry trees established at a spacing of 60 × 30 cm and 60 × 60 cm, harvested 3 times/yr in the West Bengal hills in India, which were reported to be 16 718–21 877 kg/ha (Tikader *et al.* 1993). In their study, leaf yield at a spacing of 60 × 30 cm was higher than at a spacing of 60 × 60 cm for all varieties.

This study has shown that high yields of mulberry leaf, bark and stem per unit area in the production systems of the semi-arid areas can be obtained by planting the trees at a spacing of 50 × 70 cm and harvesting the trees towards the end of the rainy season and the regrowth at about 4 months of age.

Nutritive value

The results show that the leaves of mulberry trees are highly digestible, contain high CP and mineral concentrations and have a low cell wall concentration (Table 3), suggesting that the leaf could be used to minimise nutrient deficiencies faced by grazing animals in the semi-arid areas of central Tanzania. The bark was reasonably digestible, with CP concentrations higher than those of pastures and crop residues available during the dry season. Crude protein concentration in the bark was around the critical level (6.5–8.5% DM) below which the activities of microorganisms in the rumen are reduced and hence depress voluntary intake of dry matter (Blaxter and Wilson 1963; Milford and Minson 1966).

Young leaf and bark were more degraded *in sacco* than older leaf and bark, respectively (Figure 1). The rate of *in sacco* DM degradation

Table 3. Chemical composition and *in vitro* dry matter digestibility (IVDMD) of mulberry (*Morus alba*) leaf and bark.

Part of the tree	Composition[1]								IVDMD
	Ash	CP	NDF	ADF	Hem	ADL	Cel	ADIA	
				(% DM)					(%)
Leaf	14.3	18.6	24.6	20.8	3.8	8.1	12.6	2.5	82.1
Bark	6.1	7.8	46.8	36.9	9.9	7.1	29.7	1.1	60.3

[1] CP — crude protein; NDF — neutral detergent fibre; ADF — acid detergent fibre; Hem — hemicellulose; Cel — cellulose; ADL — acid detergent lignin; ADIA — acid detergent insoluble ash.

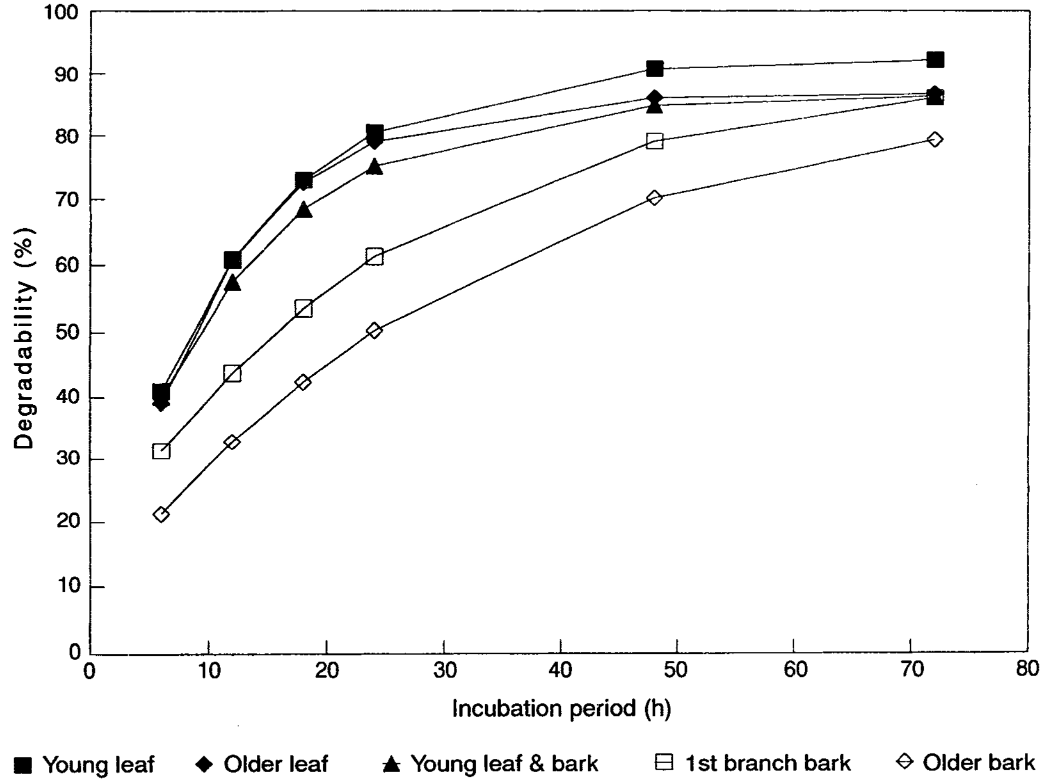

Figure 1. *In sacco* DM degradability of some parts of mulberry (*Morus alba*) trees. Young leaf = 1st–10th leaf from the tip of the branch; Older leaf = leaves starting from the 15th leaf from the tip of the branch; Young leaf & bark = 1st–10th leaf and bark from the tip of the branch; 1st branch bark = bark from the top branch; Older bark = bark from older branches.

of leaf was high, 70–80% of the dry matter having disappeared after 24 h of incubation. Degradability of the older bark was maximal (about 70% of the DM) after 72 h of incubation. These results suggest that mulberry trees are a potential source of nutrients for ruminant animals.

Pests and weeds

No flying insects were observed to attack the trees throughout the period after establishment. However, termites, which are very common in the semi-arid regions of Tanzania, affected and killed some trees. No weeds (herbaceous grasses, legumes and forbs) grew under the trees in the S1 and S3 treatments. On the other hand, there was a considerable amount of weeds in S2. This suggests that farmers in the production systems of the semi-arid areas may avoid expenses involved in weeding by planting mulberry trees at closer spacing (*e.g.* 50 × 70 cm).

Conclusions

The agronomic results obtained in this study show that mulberry trees can survive in semi-arid areas of central Africa and possibly other areas of the world with a similar climate. The leaves and bark were shown to be a good source of energy and protein. The trees are easily established from cuttings and can also be used for shade, vegetables, fuel wood, fruits and medicinal purposes. This study showed that optimum productivity for ruminant feeding is obtained if the trees are harvested towards the end of the rainy season and the regrowth at about 4 months of age. The multi-purpose nature of the mulberry tree makes it a suitable tree to incorporate into the agro-forestry systems of central Africa. To confirm this, further studies on the agronomic characteristics of mulberry trees at different locations and adopting different pruning methods are suggested. In addition, studies to determine intake and optimal levels of supplementation and/or complementation with mulberry leaves and bark for growth and milk yield should be carried out.

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