Utilisation of Mulberry in Animal Production Systems (Part 1/3)

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I. Forage Trees

Livestock Production and Natural Resources

Numerous traditional land use practices (deforestation, extensive and extractive grazing, lack of erosion control techniques, agriculture in unsuitable zones, etc.) result in alterations to ecological balance and in soil productive capacity (Garríguez, 1983; Jiménez, 1983; Heuveldop and Chang, 1981. Tropical grass yields and quality are affected by climatic factors (Minson and McLeod, 1970; Stobbs, 1975; Cunillos *et al*, 1975) and by land and capital limitations predominant in most small farms (Ávila *et al*., 1982).

Apart from the socio-economic aspects, the later is related to the type of agricultural technology historical practised in Central America from the times of the Spanish colonisation. In pre-Colombian times, the great Pleistocene herbivores had disappeared (Jansen and Martin, 1982) and there were no domestic ruminants. There were only autochthonous deer, which are mostly browsers (Sands, 1983; Morales, 1983). The predominant vegetation was composed of shrubs and trees, and apart from maize, there were few members of the gramineae family, without contributing much to feed the autochthonous herbivores. (Jansen and Martin, 1982; UNESCO, 1979; National Geographic, 1992; Skerman and Riveros, 1992). This indicates that the natural vegetation looked very different then compared to now.

Spanish colonial settlement implied the introduction of land use technologies imported from temperate areas, like the plow and the grasses to feed farm animals (Meza and Bonilla, 1990; Tosi Jr. and Voertman, 1977). Those technologies, still in use, have significantly contributed to the loss of natural soil cover and biodiversity. This has also avoided the rational utilisation of forests aiming at questionable productivity in the medium and long terms. In relation to traditional livestock keeping, "... it is little encouragement fact, for the grass pasture experts, to realise that, there are more animals feeding on shrubs and trees, or in associations in which woody plants have a major role, than on true grass and leguminous pastures" (Commonwealth Agricultural Bureau Publication, No. 10, 1974, cited by Skerman*et al.*, 1991).

The establishment of agricultural areas in virgin land has been part of a process, which starts with cereal planting taking advantage of the high soil fertility right after the slash of the forest. Once this fertility declines, land is abandoned or destined to grazing, mostly extensive and extractive (Sands, 1983). Since the fifties, more than 50% of the forests have substituted by migratory agriculture or by grasslands (Collins, 1990; UNESCO, 1979; National Geographic, 1992), which in most cases, are in scattered plots belonging to small farms, or have low carrying capacity in the large farms (Collins, 1990). In Central America, without large amount of inputs and labour, the productivity of grasslands can not be maintained. This is partly due to invasion of autochthonous woody plants, "..while man insists in keeping grassland, natures fights for establishing forests" (Skerman and Riveros, 1992).

The question then arises: What would have happened in the American Tropics, if instead of introducing the plow and the grasses, appropriate technologies aiming at a rational use of trees and shrubs had been developed? Apart from wood, could other products be extracted from forests to satisfy the demand of expendable goods demanded by the population? To provide a partial response to those questions aims the research on forage trees and shrubs, in particular that of mulberry.

The above considerations, added to the lack of access of small and medium size farmers to appropriate production technologies; to the high population growth; and to other aspects related to the socio-economical situation of Central America, indicate the necessity for novel solutions which allow substantial changes to current production practices. In this changing process, the development of technologies more suitable to the ecological and socio-economic conditions of the regions should play a decisive role in the generation of consumable goods in a sustainable manner and with a rational use of natural resources.

Trees and Shrubs as Feed for Ruminants

The use of trees and shrubs for ruminant feeding is a known practice among producers in Central America from decades. This empirical knowledge about forage proprieties of various species, is of great value for science. In several studies to characterise production systems, producers report a large number of species for browsing and for cut-and-carry systems with animal in confinement (Ammour y Benavides, 1987; Arias, 1987). The more systematic recognition of the resource is the aim of the research work on forage trees carried out in Central America, part of which is reported in this article.

The studies on the subject have been oriented towards the valuation as a source of forage, of trees and shrubs, and their integration into ruminant production systems (Benavides, 1989). The focus has been on agroforestry and farming systems, and the aim has been to develop technological alternatives allowing more sustainable production and rational use of soil and forest resources.

In order to consider a tree or a shrub as forage, it must have advantages from the points of view of its nutritional value, its yield or its agronomic versatility, above traditional forages. In that sense, the requirements to qualify are: i) nutritional content and intake which will allow animal performance improvements; ii) resistance to repeated pruning/harvesting; iii) high biomass yields per unit of area. Apart from these features, it is advisable to select natives species to take advantage of their adaptation to the environment, and species which can be easily established with simple and inexpensive techniques (Benavides, 1991).

Data from producer surveys and the literature indicate the presence of woody forages in the humid tropics of the Atlantic Coasts of Costa Rica and Guatemala's Peten; in semi-arid areas nearby the south coast of Honduras and in the Dominican Republic; in the mountainous regions, with long drought periods and serious erosion problems in the Pacific slopes of Costa Rica; and in zones with temperate climates above 1000m in the high plateau of Guatemala and Costa Rica (Hernández y Benavides, 1993; Araya *et al.*, 1993; Mendizábal *et al.*, 1993; Godier *et al.*, 1991).

Direct observation of animals eating, has allowed to identify species particularly palatable and with high digestibility (*in vitro*) of the organic matter and (IVOMD) and high crude protein (CP). These studies have permitted to value species without current use and to expand the utilisation of others normally used for other purposes (Hernández y Benavides, 1993; Godier *et al.*, 1991; Reyes y Medina, 1992).

The information provided by producers has also allowed knowing simple agronomic management practices, easy to implement. An example of this are the woody forages identified in the Western Plateau of Guatemala, where, in most cases, the propagation is done by vegetative means (stem cuttings) with which a faster biomass can be obtained compared to sexual seed (Ruiz, 1992).

The forage from most of these woody forages shows PC values two and three times higher than tropical grasses and in some cases, even higher than commercial concentrates used to supplement ruminants. At the same time, the IVOMD is very high and comparable or superior to that of concentrates. Two species of the Euforbiaceae family are outstanding in nutritional quality, "Wide Chicasquil" (*Cnidoscolus acotinifolius*) and "Fine Chicasquil (*C. chayamansa*) , which leaves, with more than 30% CP and 75% IVOMD, are edible. Also stand out the nutritive value of two species of the Moraceae family, Mulberry (*Morus spp.*) and Amate (*Ficus*) from Petén, Guatemala; two from the Malvaceae family, the "Amapola" (*Malvaviscus arboreus*) and the "Clavelón" (*Hibiscus rosa-sinensis*); Black Sauco (*Sambucus mexicana*) and Yellow Sauco (*S. canadensis*), belonging to the Caprifoliaceae family; and three species of the Compositeae family, "Chilca" (*Senecio sp.*), "White Tora" (*Verbesina turbacensis*) and "Purple Tora" (*V. myriocephala*). All of these with CP higher than 20% and IVOMD higher than 70% (Araya *et al.*, 1993; Mendizábal *et al.*, 1993).

Animal Performance

In intake trials, "Poró" (*Erythrina poeppigiana*), was the most studied species in the 1980s, with observed values higher than 4% with lactating goats (Benavides, 1993). In other work, acceptability has been sought in forages species growing in semi-arid lands, under forests and in secondary forests, which were identified by means of direct observation of grazing animals (Godier *et al.*, 1991; Hernández y Benavides, 1993; Reyes y Medina, 1993).

Both "Poró" and "Black Wood" (*Gliricidia sepium*), are legumes characterised by high CP content, but with lower IVOMD (Benavides, 1991). In those cases, research has shown that energy supplementation significantly improves animal performance (Benavides y Pezo, 1986) and that starch sources give a better response than simple sugars (Samur, 1984) .

With the species with higher nutritive value, the highest milk yields have been obtained, and a significant response has been observed when the foliage level is increased on grass based diets. That is the case with "Amapola" and Mulberry, with milk yields in goats of 2.2 and 4.0 kg/d, normally only possible with giving commercial concentrates. With these species, intakes higher than 5% of body are reported. With mulberry foliage, increasing weight gains have been observed when raising its proportion in the diet (Rojas y Benavides, 1994; López *et al.*, 1993).

Of the know technologies, vegetative propagation if the most used, since shortens the establishment period, is easy to do and widely known by producers. Germination percentage exceed 95%, when stem cuttings of Mulberry and "Amapola" are used in humid tropic conditions (Araya y Benavides, 1992; Benavides *et al.*, 1993; López *et al.*, 1993). With the Yellow Sauco, nursery planting of stakes and further transplanting seems to be the most adequate propagation method (Araya y Benavides, 1992). In some species is possible to place stakes horizontally, obtaining several plants and sparing material (Esquivel, 1993). However, there are important variations among species, which are important to know before making a decision of which technique to use. (Strehle *et al.*, 1992).

The association of leguminous trees and grasses is a viable alternative with two modalities. In the first, the forage of both grass and tree is utilised. Results of an experiment under humid tropical conditions, using King-grass (*Pennisetum purpureum* x *P. typhoides*) with Poró, where there was not nutrient replenishment, and all biomass was removed, showed that grass yields are not reduced with the presence of the tree, since tree pruning reduce competition for light. It was also found that digestible nutrient yields per area were triple compared with the grass alone. Nevertheless, in a short term for the grass and in the medium term for the "Poró", productivity declines due to lack of nutrient replenishment (Benavides *et al.*, 1989).

The other way is to utilise associated Poro's foliage as green manure for the grass. Also under conditions of the humid tropics, grass yields improved when increasing amounts of Poro's foliage were applied. At the same time, the sole presence of the tree, even without pruning, stimulates grass growth compared to grass in monoculture without trees (Libreros *et al.*, 1993a).

Traditionally in livestock husbandry, there is an unidirectional relationship between animals and plants, the first benefiting by obtaining the feed, but without contribution to its generation. En confined systems, it is possible to establish a two-way relationship, since most manure can be used as fertiliser. In this way a more balance system can be established where the plants benefit from animal excreta.

This particularly applies to those woody species with the best forage features. With their high biomass yields and without being able to fix nitrogen, they require high levels of fertiliser applications. In order to find a rational ecological solution, goats manure has been applied to "Amapola" and Mulberry plantations. The yields have been 18 and 30 t of dry matter per ha, respectively. With mulberry, yields go up with the years (Benavides *et al.*, 1993).

An aspect of great importance, in sites with bimodal rainfall pattern, is tree-pruning techniques which allow abundant biomass production during the dry season. For this, the effects of pruning at the end of the dry period have been studied. In the Dominican Republic, pruning of Black Wood ("Piñon cubano" or *Gliricidia*) in the months of October, November and December, in addition to stop flowering, results in increasingly higher biomass yield during the dry period (Hernández, 1988). Similar results were obtained u other authors working with Amapola and Jocote (*Spondias purpurea*) (Rojas *et al.*, 1992).

Up to now, most of the technologies have been implemented in small farms and in goat production systems oriented to family consumption. In these situations, in addition to the technology aspects, it is essential to know the economic viability of the alternatives developed, both at the station and on farm. For the economic aspects, partial budget analysis of experiments; profitability analysis (flow and net income) of implemented technologies in pilot modules; and analysis of family benefits and flow and net income at the farm level have been used. The analysis made so far, indicates that application of forage tree technologies on farm, is profitable and their presence contributes to improve family economy.

With dairy goats under a basal diet of grass, the use of Poró foliage and other agricultural by-products (e.g. reject bananas) like supplement, is more profitable than the use of concentrates, despite higher yields with the latter (Gutiérrez, 1985).

Total cost of dry matter, from planting to feeding, in some forage species, nutritionally comparable to commercial concentrates, is lower (Rojas, 1992). This in part explained the high profitability of a dairy goat model at CATIE with goats fed exclusively Mulberry and grass (Oviedo *et al.*, 1994).

At the level of the family subsistence units, high profitability has been found when family labour is not considered, even with animal reproductive problems present (Martínez y Froemberg, 1992).

Environmental Impact of Introduced Technologies

Part of the research goals with forage trees is the development of planting techniques which allow soil conservation in erosion risk areas. At the same time, soil nutrient balance indicates if there is a need to add a nutrient with high extraction rate (Libreros *et al.*, 1993).

The shrub species with high forage potential can also be used to control soil loss, since they can be planted at high densities, are perennial and can be associated with other crops. During three years, in a site with steep slope and with serious erosion problems, two types of Amapola plantations were established (Amapola in high density, in contour lines associated with low grass, and Amapola in more separated contour lines associated with maize) and were compared with a traditional maize crop (bare soil). Soil loss was much less with the Amapola plantations (Faustino, 1992).

[END OF PART 1 OF 3]

Utilisation of Mulberry in Animal Production Systems (Part 2/3)

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II. Mulberry

Background

Mulberry is a shrub or a tree traditionally used for feeding the silkworm in various countries. It belongs to the Order Urticales, Moraceae Family and genus *Morus.* The better known species, *Morus alba L.* and *Morus nigra L.*, seem to have their origin in the Himalayas' foothills (Soo-Ho *et al.*, 1990). It has excellent nutritional value as forage. Benavides (1991) reported CP values higher than 20% and IVOMD above 80%.

The literature gives the following climatic ranges for Mulberry cultivation: temperature between 18 to 30°C; rainfall between 600 to 2500mm; photoperiod between 9 to 13 h/d; and relative humidity between 65 to 80% (Ting-Zing *et al.*, 1988). Currently its cultivation is reported from sea level to 4000m, and it is reproduced by seed, stakes and grafting (Soo-Ho *et al.*, 1990).

In Spain, Mulberry was recommended to be planted in association with other crops like maize, potatoes, vegetables, alfalfa and fruit trees, always controlling spacing and pruning to avoid light competition. Some authors recommend planting at 80 cm between plants and rows (González, 1951). In other articles, densities of 30,000 plants per ha for low pruning (below 70cm); 7-12,000 plants for medium pruning (70-170cm); and between 2,250 and 6,000 plants for high pruning (above 170cm) are mentioned (Ting-Zing *et al.*, 1988).

The available yield information is almost exclusively on leaves, since it is the part used to feed the silkworm. In France, fresh leave yields of 17,000 kg/ha are reported with 7 x 7 m spacing. With higher densities, yields of 30,000 kg/ha have been obtained. Yields are related to plantation age and more specifically with trunk diameter (Secretain y Gaddo, 1934 cited by González, 1951). These authors report that annual leaf production in monoculture increases from 6,500 kg to 33,500 kg/ha from the first to the seventh year. In good land, leaf yield per plant varies from 9 to 70 kg when average trunk diameter increases from 7 to 55 cm (Secretain, 1924, cited by González, 1951). With 22.5 tons of human faeces and 300kg of ammonium sulfate, fresh leaf production can reach 13 ton/ha/year (Ting-Zing *et al.*, 1988). In Paraguay, leaf yields of 20,000 kg/ha have been obtained in 4-year plantations harvesting at 30cm from the surface (Narimatsu y Kiyoshi, 1975).

Work with widely spaced plants in Turrialba (Costa Rica) a yield of 2.32 kg of dry matter per plant was calculated per year cutting at a height of 50 cm. Cutting at 1m, the yield decreased to 2.16kg. However, leaf production was 1kg for both cutting heights. With cuts every 60,120 and 180 days, total dry matter production was 1,64, 2,17 and 2,86 kg/plant/year, respectively. However, leaf production declined from 1.11 to 0.84kg between 60 and 180 days (Benavides, Esnaola y Borel, 1986).

Nutritional Value of Mulberry

Dry matter content. The nutritive value of Mulberry is one of the highest found in products of vegetable origin, far superior to traditional forages like alfalfa. Mulberry biomass is remarkable due to one characteristic which is found in very few plants; high levels of CP and high levels of digestible energy. It also notable for good mineral content and above all, its low fibre content.

Table 1. Dry matter, crude protein and IVDMD of Mulberry foliage and other feeds used in Central America (Espinosa , 1996)

Item	DM,%	CP,%	IVDMD,%
Mulberry (*M. alba*)	28.7	23.0	80.0
King grass (*P. purpureum x P. typhoides*)	20.0	8.2	52.7
Star grass (*Cynodon lnemfluensis*)	22.3	8.9	54.9
Commercial concentrate	91.5	17.7	85.0

The content of dry matter (DM) and other components in the leaves of Mulberry is higher when compared to traditional grasses used in animal feeding (Table 1). From Costa Rica there are reports of 25-32% DM in leaves; 23-29% for young stems; and 24-45% for woody stems (Benavides *et al.*,1996; Espinoza, 1996). In plantations of three Mulberry varieties planted at 0.40m between plants and 1m between rows (25,000 plants/ha), in three ecologically different sites in Costa Rica and with various fertilisation levels, it was found that DM content of leaves and edible stem were more affected by the location than by fertilisation level, without differences among varieties (Table 2).

Table 2. Site and nitrogen fertilisation effects on leaf dry matter content in three Mulberry (*M. alba*) varieties in Costa Rica (Espinosa, 1996).

Site	Variety, % DM			Mean[2]
	Criolla	Indonesia	Tigriada	
Puriscal	31.6	32.0	30.7	31.4[b]
Coronado	26.8	25.7	22.2	24.9[c]
Paquera	29.0	36.0	31.9	32.3[a]
N[1], kg/ha/year				
180	29.2	31.4	28.8	29.8[a]
360	28.9	31.5	28.6	29.7[ab]
540	29.2	30.8	27.4	29.1[b]
Mean[2]	29.1[b]	31.2[a]	28.3[c]	

1 = Ammonium nitrate

2 = Values with same letter are not statistically different $p < 0.05$

Table 3. Site and nitrogen fertilisation effects on woody stem dry matter content in three Mulberry (*M. alba*) varieties in Costa Rica (Espinosa 1996)

Site	Variety, % DM			Mean[1]
	Criolla	Indonesia	Tigriada	
Puriscal	45.2	41.9	42.9	43.4[b]
Coronado	31.6	27.1	24.2	27.6[c]
Paquera	48.8	47.8	48.8	48.5[a]
N, kg/ha/year				
180	42.7	39.2	39.8	40.6[a]
360	41.8	39.9	38.4	40.0[a]
540	41.2	37.8	37.8	38.9[b]
Mean[1]	41.9[a]	38.9[b]	38.6[b]	

1 = Values with same letter are not statistically different, p<0,05.

In the woody stems, the differences were still more pronounced, with values between 27 and 48% of DM (Table 3). The small effect of fertilisation on DM was also reported in a plantation where various levels of goat manure were applied (Table 4).

Table 4. Dry matter content of Mulberry (*Morus alba*) by soil manure application (Benavides *et al.*, 1994)

Fraction % de MS	Manure level[1]				NH_4NO_3[1]
	0	240	360	480	480
Leaves[2]	26.4[a]	25.9[bc]	26.0[b]	25.5[d]	25.6[cb]
Young stem	28.0[a]	27.1[b]	26.8[b]	26.0[c]	24.7[d]
Woody stem	42.2[a]	41.5[b]	40.8[c]	40.4[cd]	40.0[d]

1 = kg de N/ha/year.
2 = Values with same letter horizontally do not differ statistically, p<0,001.

Mulberry leaves have high levels of CP and IVOMD when compared to other feed used in ruminant feeding. Data from Central America indicate CP values between 15-25% and IVOMD between 75-90%, which indicates a quality comparable or superior to commercial concentrates (Table 5). Non lignified stem also has a good nutritional quality, with CP values of 7-14% and IVOMD of 56-70% (Benavides *et al.*, 1994; Espinoza, 1996; Rojas y Benavides, 1994)

Table 5. Site and nitrogen fertilisation effect on crude protein in three Mulberry (*Morus alba*) varieties in Costa Rica (Espinosa, 1996)

Site	Variety, % PC			Mean
	Criolla	Indonesia	Tigriada	
Puriscal	20.1	22.2	21.0	21.1[b]
Coronado	22.2	26.3	25.7	24.8[a]
Paquera	17.0	14.8	13.7	15.1[c]
N kg/ha/year				
180	18.9	20.8	20.0	19.9[a]
360	20.5	20.8	19.9	20.4[a]
540	20.0	21.6	20.6	20.7[a]
Average	19.8[a]	21.1[a]	20.1[a]	

As it was the case for DM, CP and IVDMD is similar among varieties and is not affected much by fertilisation nor by cutting frequency (Tables 6, 7, 8, 9, 10 and 11). Although, an effect was observed on CP content of leaves and young stem when ammonium nitrate was added instead of goat manure at iso-nitrogenous levels (Table 9).

Table 6. Site and nitrogen fertilisation effect on crude protein of young stem in three Mulberry (*Morus alba*) varieties in Costa Rica (Espinosa, 1996)

Site	Variety, % CP			Mean
	Criolla	Indonesia	Tigriada	
Puriscal	11.2	13.0	12.1	12.1[a]
Coronado	13.4	13.9	14.3	13.9[a]
Paquera	9.4	10.2	8.7	9.4[b]
N, kg/ha/year				
180	11.2	12.7	11.6	11.4[a]
360	11.8	11.8	11.8	11.7[a]
540	11.3b	12.6a	11.7b	11.9[a]
Mean	11.3[b]	12.4[a]	11.7[b]	

Table 7. Site and nitrogen fertilisation effect of leaf IVDMD in three Mulberry (*Morus alba*) varieties in Costa Rica (Espinosa, 1996).

Site	Variety, % IVDMD			Mean
	Criolla	Indonesia	Tigriada	
Puriscal	78.0	75.5	76.8	76.7[a]
Coronado	75.4	73.8	75.6	74.9[a]
Paquera	71.6	71.2	71.6	71.5b
N, kg/ha/year				
180	74.9	72.6	75.0	74.2[a]
360	74.8	73.6	74.1	74.2[a]
540	75.3	74.2	74.9	74.8[a]
Year	75.0a	73.5a	74.7a	

Table 8. Site and nitrogen fertilisation effect on IVDMD of young stem in three Mulberry (*Morus alba*) varieties in Costa Rica (Espinosa, 1996).

Site	**Variety, % IVDMD**			**Mean**
	Criolla	**Indonesia**	**Tigriada**	
Puriscal	69.5	70.5	63.9	68.0a
Coronado	70.3	68.6	69.9	69.6[a]
Paquera	65.9	64.7	59.4	63.3b
N, kg/ha/year				
180	68.5	68.2	65.4	67.4[a]
360	68.9	69.0	64.2	67.4[a]
540	68.2	66.6	63.7	66.2[a]
Average	68.6a	67.9a	64.4b	

Table 9. Manure application effect on crude protein content of Mulberry leaf and young stem (Benavides *et al.*, 1994)

Fraction	**Manure level[1]**				**NH_4NO_3[1]**
	0	**240**	**360**	**480**	**480**
Leaves[2]	19.1[c]	19.3[b]	19.3[c]	20.2[b]	22.5[a]
Young stem	7.4[b]	7.1[b]	7.2[b]	7.4[b]	12.3[a]

1 = Equivalence in kg of N/ha/year.
2 = Values with same letter horizontally do not differ statistically, p<0,01.

Table 10. Manure application effect on dry matter digestibility of Mulberry leaf and young stem (Benavides *et al.*, 1994)

Fraction	**Manure level[1]**				**NH_4NO_3[1]**
	0	**240**	**360**	**480**	**480**
Leaves	76.7	77.5	77.0	76.9	77.1
Young stem[2]	56.2[b]	56.4[b]	56.0[b]	55.8[b]	58.6[a]

1 = Equivalence in kg of N/ha/year.
2 = Values with same letter horizontally do not differ statistically, p<0,01.

Table 11. Annual cutting frequency effect on digestibility and crude protein content of Mulberry biomass (Benavides *et al.*, 1994)

Fraction	% CP		% IVDMD	
	3	**4**	**3**	**4**
Leaves[1]	19.2[b]	20.9[a]	77.2	76.9
Young stem	8.1	8.5	56.9	56.2

1 = Values with same letter horizontally do not differ statistically, p<0,01.

In the studies mentioned above, a marked site effect is reported, which is the result of the different soil and climatic conditions of each one. In Paquera, located in the Pacific Coast of Costa Rica, with high luminosity and high temperatures, leaf CP and IVDMD (15.1 and 71.5%, respectively) are reduced compared to higher locations with more clouds and lower temperatures ((24,8 y 74,9%, respectively), like is the case of Coronado and Puriscal, located in the mountainous areas of the country (Espinoza, 1996). The greater luminosity and higher temperature in Paquera can explain the lower water content in all fractions, lower CP and IVDMD levels, and high Dm production, as will be seen later. It is known that high luminosity reduces nitrate levels and increases cell wall components and growth due to larger photosynthetic activity (Van Soest, 1994). Coronado has lower temperatures and more cloudiness and rainfall, which could have limited growth and lignification. But the high soil fertility and the lower growth rates of this site, explain the higher CP and lower biomass DM. In addition to the climatic factors of Paquera, the lower N, copper and zinc soil contents could limit fertility and nutrient content in the plant. On the other side, the clay soils, the lower pH and the low potassium contents can explain low biomass yields in Puriscal.

Working with goats fed exclusively on Mulberry and "Amapola" leaves confined to metabolic cages, apart from high

DM intake values, high levels of *in vivo* DM and CP digestibilities of Mulberry leaves (Table 12). The values reached 90% for leaf CP digestibility (Jegou *et al.*, 1994).

Table 12. Dry matter and crude protein *in vivo* digestibilities of Mulberry and "Amapola" (*Malvaviscus arboreus*) with goats in metabolic cages (Adapted from Jegou *et al.*, 1994)

Forage species	Parameters		
	Intake, % LW	IVDMD, %	IVCPD, %
Mulberry	4.18	79.3	89.5
Amapola	4.35	64.2	54.2

Although statistical comparisons have not been made, nitrogen, potassium and calcium contents of leaves and young stems are high (Tables 13 and 14), reaching values of 3.35, 2.0 and 2.5%, respectively (Espinoza, 1996). In other work (Table 15), no appreciable differences were found in mineral content of leaves and young stems when increasing amounts of legume leaves were added to the soil (Oviedo, 1995).

In a report of the proximate analysis of Kanvas-2 variety of Mulberry (Table 16), levels of protein (29.6%), ash (7.53%) and nitrogen-free extract (50.0%) were considered high. At the same time, low levels of crude fibre were reported (10.1%). In this work, the type and quantity of leaf amino acids were determined. Twenty four amino acids in significant concentrations were detected, plus 6 more at low concentrations (Table 17). The low fibre level and high contents of CP and IVDMD justify future evaluations of Mulberry as an ingredient for high quality meal and compounded feeds.

Table 13. Fertilisation effect on the mineral content of Mulberry (*Morus alba*) leaf in Costa Rica (Espinosa, 1996)

Variety	**Minerals, % of Dry Matter**				
	N	**P**	**K**	**Ca**	**Mg**
Criolla	3.17	0.30	2.07	1.90	0.47
Indonesia	3.37	0.30	1.73	2.87	0.63
Tigriada	3.23	0.40	2.33	2.74	0.55
N, kg/ha/year					
180	3.18	0.33	1.96	2.54	0.55
360	3.26	0.33	2.05	2.49	0.55
540	3.32	0.33	2.12	2.48	0.55
Mean	3.26	0.33	2.04	2.50	0.55

Table 14. Fertilisation effect on mineral content of Mulberry (*Morus alba*) young stem in Costa Rica (Espinosa, 1996)

Variety	**Minerals, % of Dry Matter**				
	N	**P**	**K**	**Ca**	**Mg**
Criolla	1.81	0.30	2.24	1.33	0.39
Indonesia	1.98	0.40	2.99	1.53	0.49
Tigriada	1.87	0.33	2.41	1.38	0.40
N, kg/ha/year					
180	1.89	0.33	2.48	1.43	0.44
360	1.86	0.33	2.60	1.40	0.43
540	1.90	0.37	2.55	1.42	0.41
Mean	1.89	0.34	2.55	1.41	0.43

Table 15. Mulberry leaf mineral content as affected by level of Poro foliage added to the soil (Oviedo, 1995)

Mineral	**Control Without trees**	**Proportion of Poro foliage in the soil**			**Mean**
		0%	**50%**	**100%**	
N	2.90	3.16	3.10	3.09	3.06
P	0.22	0.22	0.22	0.23	0.22
K	1.51	1.37	1.35	1.71	1.49
Ca	1.64	1.82	1.74	1.77	1.74
Mg	0.42	0.44	0.41	0.38	0.41

Table 16. Leaf composition of Mulberry variety Kanvas-1, in El Salvador, Central America (Coto, 1996).

Leaf position	Fractions, % of Dry Matter					
	Dry matter	Crude protein	Crude fat	Crude fibre	Ash	NFE
Terminal	19.5	33.6	3.2	9.4	7.7	46.1
Intermediate	22.5	28.3	2.8	10.2	7.3	51.4
Basal	23.0	26.7	3.4	10.8	7.7	52.6
Average	21.7	29.6	3.1	10.1	7.5	50.0

Table 17. Amino acid concentration in the leaves of Mulberry variety Kanva-1 in El Salvador, Central America (Coto, 1996)

Amino acid	g/100g of DM	Amino acid	g/100g of DM	Amino acid	mg/100g of DM
Alanine	1.2	Methionine	0.4	Glutathione	350 mg
Arginine	1.1	Phenyl–alanine	1.1	5Hydroxy-pipecolic ac.	36 mg
Aspartic acid	2.1	Proline	1.1	Pipecolic acid	10 mg
Cisteine	0.6	Serine	1.2	Sarcosine	0.5 mg
Glutamic acid	2.7	Threonine	0.9	Adenylic acid	Trace
Glycine	1.5	Tryptophan	0.3	Cytidylic acid	Trace
Histidine	0.6	Tyrosine	0.6	Guanylic acid	Trace
Iso-leucine	1.4	Valine	1.4	Hydro-xanthine	Trace
Leucine	1.8	Amino–benzoic ac.	8 mg	Trigoneline	Trace
Lysine	1.8	Choline	112 mg	Uridylic acid	Trace

Animal Response

Evaluations carried out with ruminants (cattle, goats and sheep) show high intakes levels of DM and high animal responses in weight gain and milk yield. Oviedo (1995) when comparing Mulberry foliage with concentrate (Table 18) as supplements to Jersey x Criollo grazing cows, found similar milk yields with both supplement (13.2 and 13.6 kg/animal/day, respectively) at equal DM intake levels (1.0% of LW) and superior to grazing only (11.3 kg/animal/day). Mulberry inclusion did not affect fat, protein and total solids contents in milk (Table 19), but improved net benefits when compared to the concentrate (US$ 3.29 vs. 2.84, respectively).

Table 18. Milk yield and dry matter intake of Jersey x Criollo cows grazing Star grass (*Cynodon nlemfuensis*) and supplemented with Mulberry or concentrate (Oviedo, 1995)

Feed consumed, % LW	Supplement		
	Concentrate	Mulberry	Nothing
Milk, kg/animal/day	12.45	12.08	10.34
Concentrate	1.0		
Mulberry		1.0	
Star grass	3.7	3.4	3.7
Total	4.7	4.4	3.7

Table 19. Milk chemical composition from grazing cows supplemented with Mulberry or concentrates (Oviedo, 1995)

Component	Supplement		
	Concentrate	Mulberry	Nothing
Fat	3.95	3.81	3.63
Protein	3.53	3.51	3.31
Total solids	12.53	12.39	12.31

Esquivel *et al*. (1996), when replacing 0, 40 and 75% of the concentrate by Mulberry foliage, did not find significant differences ($p<0.05$) in milk production (14.2; 13.2 and 13.8 kg/animal/day, respectively) in Holstein cows grazing Kikuyo grass (*Pennisetum clandestinum*) without appreciable effects on milk quality (Table 20). Also in this work, considering only feeding costs, net income per animal was 11.5% higher with the maximum level of Mulberry than that obtained with concentrate only.

Table 20. Effect of the substitution of concentrate by Mulberry foliage on milk yield of Holstein cows grazing Kikuyo grass (*Pennisetum clandestinum*) (Esquivel *et al*., 1996)

Parameter	**Relation Concentrate:Mulberry**		
	100/0	**60/40**	**25/75**
Milk, kg/animal/day	14.2	13.2	13.8
Intake, kg DM/animal/day			
Concentrate	6.4	4.2	1.9
Mulberry	0	2.8	5.5
Grass	9.3	7.8	6.2
Total	15.7	14.8	13.6

With cattle, attractive liveweight gains have been obtained when using Mulberry foliage as supplement. In the humid tropics of Turrialba (Costa Rica), Jersey x Criollo heifers grazing Star grass (*Cynodon nlemfuensis*) and supplemented with concentrate, Mulberry and concentrate or only Mulberry, no statistically differences were detected ($p<0,05$) among supplements (Table 21). The combination with Mulberry and concentrate gave the highest gains (742 g/animal/day) (Oviedo and Benavides, 1994).

Table 21. Intakes and liveweight gains of grazing dairy heifers supplemented with concentrate and Mulberry foliage (Oviedo, 1995)

Parameter	Only concentrate	Concentrate + Mulberry	Mulberry
Liveweight gain	0.620	0.742	0.600
Intake of Mulberry, %LW	-	0.5	1.0
Intake of concentrate, % LW	1.0	0.5	-

With young Romo-sinuano bulls in total confinement and fed a basal diet of Elephant grass (*Pennisetum purpureum*), gains of 40, 690, 940 y 950 g/animal/day were observed with whole Mulberry DM intakes of 0, 0.90, 1.71 and 2.11% of LW as supplement (González *et al*, 1996). In this study, the benefit/cost relations were 0.10, 1.11, 1.18 and 0.97 for each of gain levels, respectively. The study lasted 70 days and animals were between 13-16 months old, with initial liveweight between 118 and 250 kg (Table 22).

Table 22. Effect of Mulberry supplementation on intake and liveweight gains of Romo-sinuano cattle in confinement and fed a basal diet of Elephant grass (González *et al*., 1996).

DM intake, % LW[1]	Mulberry dry matter offered, % LW			
	0	**1.0**	**1.9**	**2.8**
Fresh Mulberry	0.00[d]	0.90[c]	1.71[b]	2.11[a]
Elephant grass	2.04[a]	1.79[a]	1.29[b]	0.95[b]
Total diet	2.04[c]	2.69[b]	3.00[a]	3.06[a]
Weight gain, g/animal/day	0,04[c]	0,69[b]	0,94[a]	0,95[a]

1. Values with same letter horizontally do not differ statistically ($p<0.05$) with Tukey test.

With crossbred dairy goats of 40kg liveweight, Rojas and Benavides (1994) found milk yield increases of 2.0 and 2.5 kg/animal/day when Mulberry supplementation was raised from 1.0 to 2.6% of LW on DM basis (Table 23). There were slight increases of fat, protein and total solids contents (Table 24). In this study, high DM intakes and additive effect of Mulberry supplementation were observed. King grass was clearly substitute by Mulberry (Table 25).

Table 23. Effect of Mulberry supplementation on milk yield (kg/animal/day) of dairy goats (Rojas and Benavides, 1994).

Production level	**Level of Mulberry DM, % LW**				**Mean[1]**
	1.0	**1.8**	**2.6**	**3.4**	
High	2.04	2.38	2.51	2.47	2.35
Low	1.64	1.82	1.91	2.12	1.87
Mean[2]	1.84[b]	2.10[b]	2.21[ab]	2.29[a]	

1 = Group averages differ statistically, p<0,0001.

2 = Values with same letter horizontally do not differ statistically, p<0,0001

Table 24. Effect of Mulberry supplementation on fat, protein and total solid contents of goats fed King grass (Adapted from Rojas and Benavides, 1994).

Fraction	**Intake of Mulberry DM, % LW**				
	1.0	**1.8**	**2.6**	**3.4**	**Mean[1]**
Fat	3.1	3.2	3.2	3.3	3.2
Protein	3.3	3.4	3.4	3.5	3.4
Total solids	10.7[b]	11.0[b]	11.4[a]	11.2[ab]	11.1

1 = Group means differ statistically, p<0,007.

Table 25. Effect of Mulberry supplementation on dry matter intake of confined dairy goats (Rojas and Benavides, 1994)

Forage	**Dry matter intake, % LW**			
Mulberry	1.0	1.8	2.6	3.4
King grass	3,2[a]	2.9[ab]	2.6[b]	2.1[c]
Total	4.2[c]	4.7[b]	5.2[ab]	5.5[a]

1 = Group means differ statistically, p<0,0003.
2 = Values with the same letter horizontally do not differ statistically, p<0,0006

With Black Belly lambs receiving a basal diet of King grass, liveweight gains of 60, 75, 85 and 101 g/animal/ day were reported when Mulberry was given as supplement at 0, 0.5, 1.0 and 1.5% of LW on DM basis, respectively (Benavides, 1986). In this study, rather than a substitution effect, there was an additive effect of Mulberry on total DM intake (Table 26).

Table 26. Performance of Black Belly lambs fed various Mulberry levels (Benavides 1996)

Parameters	**Mulberry level, DM as % of LW**				**Significance**
	0	**0.5**	**1.0**	**1.5**	
Initial weight, kg	15.7	15.8	15.8	15.1	
Final weight, kg	21.5	22.6	24.4	25.6	
Gain, g/day	60c	75b	85b	101[a]	**
DM intake (kg/day)					
King grass	0.66	0.60	0.62	0.60	
Mulberry leaf	0	0.09	0.19	0.28	
Total DM intake	0.66	0.69	0.81	0.88	**
DM intake, % LW	3.54	3.72	3.99	4.34	**
DM intake, g/kg/PV$^{0.75}$	73.5	75.1	84.5	92.2	**

In a three-year evaluation (Table 27), in an agroforestry model with goats fed exclusively (at 3% LW in DM basis) with King grass and Mulberry, a lactation yield of 900 kg per 300 days was reported (Oviedo *et al.*, 1994). This is equivalent to a mean of 3 kg/day and to 4.1 kg/day at the beginning of lactation. Forage came from a Mulberry and grass plantation associated with Poro (*Erythrina poeppigina*) measuring 1,100 m2, fertilised with goat manure, Poro foliage and feed rejects.

Table 27. Milk yield (kg/animal/day) in dairy goats fed exclusively grass and Mulberry foliage in the agroforestry model (Oviedo *et al.*, 1994)

Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Goat 1	3.22	3.46	3.47	3.41	2.65	2.69	2.23	2.44	2.53
Goat 2	3.41	3.93	3.53	3.44	2.91	2.67	2.68	1.86	1.71

During the third year, the module reached 5.0 kg/day, equivalent to 16,500 kg/ha/year (Table 28). The economic analysis indicated a benefit/cost relation of 1.27, 1.39 and 1.45 for each year, respectively (Table 29).

Ensiled Mulberry

One of the most serious problems of livestock husbandry in the tropics is the rapid decline of grass quality during the dry season. Among the most used alternatives is the conservation of forage by ensiling during the rainy season in order to use it in the dry season. However, silage is traditionally made with tropical grasses rich in fibre and low in soluble carbohydrates, which affects fermentation and results in a low quality product. Due to its low fibre and high level of carbohydrates, Mulberry foliage can be ensiled without additives, showing a lactic fermentation pattern and low CP losses (between 16-21% of CP in the final product) while maintaining between 66 ad 71% IVDMD (Vallejo, 1995; González et al., 1996). These parameters are far superior to silages made with tropical forages. Vallejo (1994), using 40kg plastic bags and three 30-day storage periods, compared the silage made from three tree foliages (Mulberry, Amapola and Jocote). Mulberry showed the highest levels of IVDMD, good CP content, acceptable loses of ammonium nitrogen and higher lactic acid levels (Table 30). Acetic and butyric acids levels were also high with Mulberry in the first period, but they rapidly declined (Table 31).

Table 28. Zootechnical parameters of confined goats in the agroforestry model in Turrialba, Costa Rica (Oviedo*et al.*, 1994)

Parameter	**Average**	**Year1**	**Year2**	**Year3**
Lactation, months	14.6[1]			
Kids per parturition	2.0			
Kid weight at birth, kg	3.7			
Milk,, kg/animal/day	2.0[2]			
Dry period, days	37.3			
Goat weight, kg	50.0			
Total milk, kg/year		1223,0[3]	1505,9[4]	1110,5[5]
Milk production, kg Per module/day	4.0	3.4	4.2	5.0
Maximum monthly		42.8	71.4	122.7
Minimum monthly		145.1	189.1	207.9
Minimum per module/day		1.4	2.3	4.0
Maximum per module/day		5.2	6.1	6.7

1 = 3 lactations per goat.
2 = Data of 31.5 months.
3 = from 03/91 to 03/92.
4 = From 03/92 to 03/93.
5 = From 03/93 to 10/93.

Table 29. Financial analysis (in US$) of the goat agroforestry module at Turrialba, Costa Rica (Oviedo *et al.*, 1994)

Description	**Years**		
	1991/92	**1992/93**	**1993***
A. Costs			
A.1 Investments			
Mulberry x Poro plantation	4.61	4.61	2.88
Grass x Poro plantation	1.66	1.66	1.04
Facilities	16.07	16.07	9.37
Animals	50.00	50.00	31.25
Subtotal	72.34	72.34	45.21
A.2 Fixed, land opportunity cost	21.17	21.17	13.23
A.3 Variables (labour)			
Cut&carry, weeding, pruning	182.65	176.19	109.77
Forage chopping and feeding	138.45	133.55	83.20
Milking	89.05	85.90	53.52
Cleaning facilities	54.60	52.67	32.81
Manure application	26.00	25.08	15.63
Mineral salts	30.66	30.66	19.16
Antelmintic	1.40	1.40	1.40
Maintenance	6.50	6.27	3.90
Subtotal	455.31	511.72	319.39
Total cost	527.65	584.06	377.83
Updated cost	610.82	643.92	396.72
B. Income			
B.1 Milk production	672.66	813.99	549.03
Updated income	778.68	897.42	576.48
C. B - A updated	167.86	253.50	179.76
B/C	1.27	1.39	1.45

* 7,5 months of 1993.

Table 30. Chemical characterisation of silage made from shrubs and trees (Vallejo, 1994)

Species	% DM			% IVDMD			% CP		
Period	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Mulberry	22.1	28.7	34.3	60.5	61.6	76.9	17.9	17.0	16.7
Amapola	28.9	30.9	35.7	51.1	55.5	68.5	16.3	16.0	16.9
Jocote	20.6	22.0	19.8	49.3	58.0	74.2	17.0	17.5	15.9

Table 31. Fermentation indicators of ensiled foliage of three woody forages (Vallejo, 1994)

Variable	Period	Species		
		Mulberry	**Amapola**	**Jocote**
pH	1	5.4	5.0	2.9
	2	4.6	5.0	3.1
	3	5.1	5.0	2.8
% Total NH_3-nitrogen	1	2.27	0.96	1.00
	2	1.56	0.81	1.28
	3	1.26	0.16	0.91
% Acetic acid	1	5.71	1.49	1.11
	2	1.97	1.25	1.57
	3	0.85	0.16	1.10
% Butyric acid	1	6.84	0.24	0.03
	2	0.56	0.24	0.01
	3	0.32	0.02	0.00
% Lactic acid	1	5.14	4.64	0.71
	2	9.00	4.26	1.84
	3	6.22	1.38	0.63

González *et al.* (1996), in two 9 ton Mulberry silage pits for feeding young bulls, found better fermentation indicators than Vallejo (1994). They noted high levels of lactic acid and low concentrations of propionic and butyric acids (Table 32). pH remained close to the values reported before by Vallejo (1994) and, when opening the silo, the organoleptic characteristics were excellent: green colour and lactic smell. Nevertheless, once in the feeder the silage lost within two hours its characteristic colour and smell.

Table 32. Fermentation indicators of Mulberry silage used as supplement for Romo-sinuano cattle (González*et al*., 1996).

Indicator	**Silo 1**	**Silo 2**	**Average**
pH	4.45	5.25	4.85
NH_3, % of total N	7.70	4.16	5.93
Acetic acid, %	3.95	1.82	2.89
Propionic acid, %	0.27	0.08	0.18
Butyric acid, %	0.02	0.03	0.03
Lactic acid, %	12.93	17.15	15.04

The use of this Mulberry silage to supplement young bulls fed a basal diet of Elephant grass, liveweight gains of 600g/day were obtained (Table 33) with silage intake of 1.1% of LW on DM basis (González *et al*., 1996). However, although Mulberry silage intake was similar to that observed with other grass silages (Esperance and Guerra, 1978), there was a lot of refusal. The low intake was not expected due to CP and IVDMD contents. The explanation could be in the physical and chemical aspects of the silage, like high pH and high compaction which might have reduced consumption. Thos forage without additive does not reach the desirable pH levels to assure stability. Gonzalez (1996) observed this in a study with micro-silos, where after 60 days the pH never dropped below 4.5.

The conclusions that can be reached from the use of silage of woody forages relate to the species used. This observation also comes from a study with dairy goats fed silage made from three woody forages (Table 34), where a very high Mulberry silage intake (near 5% of LW on DM basis) was found and a milk yield of 1.9 kg/day (Vallejo, 1994).

Table 33. Effect of Mulberry silage supplementation on intake and weight gain of Romo-sinuano cattle fad a basal diet of Elephant grass (González *et al.*, 1996).

Dry matter intake	Mulberry dry matter offered, % LW			
	0	0.8	1.7	2.5
Ensile Mulberry, % LW[1]	0[c]	0.66[b]	1.05[a]	1.11[a]
Total dry matter, % LW	2.16[b]	2.42[a]	2.61[a]	2.64[a]
Weight gain, g/animal/day	117[b]	404[a]	490[a]	601[a]

1 = Values with same letter horizontally do not differ statistically (p<0,05), using Tukey test.

Table 34. Intake, milk yield and characteristics of goats fed silage of three woody forages as sole diet (Vallejo, 1994).

Species	DM intake, %LW	Milk, kg/day[1]	Milk chemical composition			
			Protein, %	Fat, %	Total solids, %	Titratable acidity
Mulberry	4.90[a]	1.88[a]	3.2[a]	3.4[a]	11.8[a]	0.16[a]
Amapola	4.35[ab]	1.83[a]	3.1[a]	3.2[a]	11.1[a]	0.16[a]
Jocote	3.23[b]	1.29[b]	3.4[a]	2.8[a]	12.0[a]	0.17[a]

1 = Values with same letter horizontally do not differ statistically (P<0.05)

Agronomy

Mulberry also shows high biomass production, as shown in several experiments where the effects on yield and quality of cutting frequency, level and type of fertilisation and location have been study. Due to its high production capacity, Mulberry extracts a lot of nutrients from the soil. This is why, a combination of organic and inorganic fertilisers has been emphasised.

One of the obvious worries on the agronomy of Mulberry is related stake planting. For this purpose an experiment was conducted to compare three woody forages and different planting methods (Table 35). In all cases Mulberry showed a high germination percentage, superior to other forages. Placing stakes in vertical position was better than horizontally.

Table 35. Effect on planting method on germination and number of shoots per stake of Mulberry, Amapola and Sauco (Esquivel, 1993).

Species	Horizontal stake			Vertical stake		
	% Germ.	Number of shoots	Length of shoots (cm)	% Germ.	Number of shoots	Length of shoots (cm)
Amapola	58.0[b]	1.0[b]	7.2[b]	87.5[b]	4.3[a]	7.5[b]
Mulberry	90.4[a]	2.1[a]	15.9[a]	100.0[a]	3.1[b]	22.5[a]
Sauco	53.8[b]	1.1[b]	4.4[b]	60.4[c]	1.5[c]	6.8[b]

In an evaluation of cutting height (0.5 and 1.0 m) of isolated 2 year-old plants (Table 36), differences in DM and CP production were no found, although there was a significant effect on the proportion of leaf (Benavides, Esnaola and Borel, 1986). In this same study (Table 37), greater yields were observed with longer cutting frequencies (60, 120 y 180 days). However, this increase was due to more stem production, with leaf production no being affected.

Table 36. Dry matter yields (kg/plant/year) of Mulberry at two cutting heights (Benavides, Esnaola and Borel, 1986).

Plant fraction	Cutting height		p <
	0.5 m	1.0 m	
Total	2.32	2.16	NS
Leaf	1.00	1.02	NS
Stem	1.32	1.14	NS
Leaf fraction	0.21	0.21	NS
Leaf:stem	1.04	1.29	**

Table 37. Dry matter yields (kg/plant) of Mulberry under different cutting frequencies (Benavides, Esnaola and Borel, 1986)

Fraction	Cutting frequency, days			p <
	60	**120**	**180**	
Total	1.64[c]	2.17[b]	2.86[a]	**
Leaf	1.11[a]	1.04[a]	0.84[b]	**
Stem	0.52[c]	1.08[b]	2.01[a]	**
Leaf fraction	0.26[a]	0.23[a]	0.15[b]	**
Leaf:stem	2.11[a]	1.06[b]	0.45[c]	**

Under humid tropical condition in Costa Rica, for three years a Mulberry plantation with 25,000 plants/ha, has produced 35 ton DM/ year using goat manure as fertiliser (Benavides et al., 1994). It was also observed 20% higher production with goat manure than with ammonium nitrate, at equal levels of nitrogen application (Table 38). Significant increments in production were observed with greater manure applications. Overall yields increased 10% a year, reaching 38 ton of DM/ha by the third year. Greater total biomass yields were obtained (Table 39) with a 4 month cutting frequency compared with 3 month, although leaf yield was not different (Benavides *et al*., 1994).

Table 38. Yearly total Mulberry biomass (ton of DM/ha) when applying goat manure as fertiliser and cutting every 4 months.

Year	Level of manure[1]				NH_4-NO_3
	0	**240**	**360**	**480**	**480**
1[2]	23,0[c]	24,4[bc]	26,6[b]	31,1[a]	26,7[b]
2	21,3[c]	25,2[b]	27,6[ab]	33,4[a]	29,7[b]
3	22,9[d]	28,2[c]	32,6[b]	38,2[a]	29,2[b]

1 = kg of N/ha/year.
2 = Values with same letter horizontally do not differ statistically, p<0,001.

Table 39. Dry matter yields of Mulberry (ton/ha/year) per year and cutting frequency (Benavides, Lachaux and Fuentes, 1994)

Fraction	**Year**			**Cuttings / year**	
	1	**2**	**3**	**3**	**4**
Leaves[1]	10.8[ab]	10.9[a]	10.4[b]	11.0	10.4
Young stem	1.6[a]	0.9[b]	0.8[c]	1.0[b]	1.3[a]
Woody stem	11.8[c]	13.2[b]	14.4[a]	16.0[a]	10.3[b]
Total	24.2[b]	25.0[ab]	25.6[a]	28.0[a]	21.9[b]
Edible	12.4[a]	11.8[b]	11.2[c]	12.0	11.6

1 = Values with same letter horizontally do not differ statistically, p<0,001.

In another study, always under hum2id tropical conditions, Oviedo (1995) found Mulberry biomass yields of 8.0, 9.4 and 10.6 ton of DM/ha when using Poro foliage as mulch equivalent to 0, 160 and 300 kg of N/ha/year, respectively.

Working with three Mulberry varieties (Criolla, Indonesia and Tigriada) in three sites of Costa Rica (Puriscal, Coronado and Paquera), Espinoza *et al.* (1996) reported important differences among varieties in total DM yields, with one variety with almost half of the yields of the other two. Nitrogen application also affected yields according to site (Table 40). In Paquera, despite the long dry period and less fertile soils, average yields for all three varieties were almost double those of Coronado, where it rains all year. Edible biomass yield differences were smaller (Table 41). In Paquera lower leaf:stem proportion was observed (Tables 42 and 43) at similar cutting frequencies. This indicates that more frequent cuts can be given in Paquera conditions.

Table 40. Site and nitrogen fertiliser effect on dry matter production of three Mulberry varieties in Costa Rica (Espinosa, 1996).

Parameter	Variety, ton DM/ha/year			Average
	Criolla	Tigriada	Indonesia	
Site:				
Puriscal[1]	11.1	15.6	19.0	15.2[b]
Coronado	8.9	19.5	18.0	15.5[b]
Paquera	22.4	31.9	39.2	31.2[a]
Fertilization[2]				
180 kg N/ha	11.2	18.0	19.2	16.1[b]
360 "	13.7	22.8	28.3	21.6[a]
540 "	17.4	26.3	28.7	24.1[a]
Average	14.1[c]	22.3[b]	25.4[a]	

1 = Values with same letter horizontally do not differ statistically (p<0,05) with Duncan test.
2 = ammonium nitrate
Maximum production = 45.2 ton/ha/year (Indonesia at Paquera with 360 kg N/ha/year).
Minimum production = 6.5 ton/ha/year (Criolla at Puriscal with 180 kg N/ha/year).

Table 41. Site and nitrogen fertiliser effect on edible dry matter percentage of three Mulberry varieties in Costa Rica (Espinosa, 1996)

Parameter	Variety			Average[1]
	Criolla	Tigriada	Indonesia	
Site				
Puriscal	53.8	50.8	38.6	47.7[b]
Coronado	64.7	56.4	48.5	56.5[a]
Paquera	40.0	42.0	32.0	38.0[c]
N, kg/ha/year				
180	52.8	51.5	41.3	48.5[a]
360	52.8	49.1	38.6	46.8[a]
540	52.9	48.7	39.6	47.1[a]
Average[1]	52.8[a]	49.7[b]	39.7[c]	

1 = Values with same letter horizontally do not differ statistically, p<0,05 (Duncan, 1955).

Table 42. Site and nitrogen fertiliser effect on leaf:stem relation in three Mulberry varieties in Costa Rica (Espinosa, 1996)

Parameter	**Variety**			**Average**[1]
	Criolla	**Indonesia**	**Tigriada**	
Site				
Puriscal	1.00	0.56	0.89	0.82[b]
Coronado	1.40	0.71	0.87	0.99[a]
Paquera	0.61	0.44	0.67	0.57[c]
N, kg/ha/year				
180	1.03	0.60	0.87	0.83[a]
360	0.99	0.54	0.81	0.78[b]
540	1.00	0.57	0.75	0.77[b]
Average[1]	1.00[a]	0.57[c]	0.81[b]	

1 = Values with same letter horizontally do not differ statistically, p<0,05 (Duncan, 1955).

Table 43. Site and nitrogen fertiliser effect on growth rates (ton DM/ha/year) of three Mulberry varieties in Costa Rica (Espinosa, 1996)

Parameters	**Variety**			**Average**
	Criolla	**Tigriada**	**Indonesia**	
Site				
Puriscal[1]	92.5	130.0	158.3	126.9[b]
Coronado	74.2	162.5	150.0	128.9[b]
Paquera	186.7	265.8	326.7	259.7[a]
Fertilization[2]				
180 kg N/ha	93.3	150.0	160.0	134.4[b]
360 "	114.2	190.0	235.8	180.0[a]
540 "	145.0	219.2	239.2	201.3[a]
Average	117.8[c]	186.1[b]	211.7[a]	

1 = Values with same letter horizontally do not differ statistically, p<0,05 (Duncan, 1955).

Conclusions

From the evaluations carried out for more than 14 years on shrub and tree forages at CATIE, Mulberry is one of the best for ruminant feeding. The high levels of CP and digestibility are far superior that those of most commonly used tropical forages and are comparable to concentrates.

This plant shows a high capacity to shoot and to survive up to two years. The results show that with adequate fertilisation Mulberry produces high edible biomass yields per unit area. The levels of production shown in this work exceed any data in the literature from temperate climates in Asia and South America.

With adequate fertilisation, yields increase with time as shown in the studies reviewed. Due to its effect on soil physics and to the presence of other nutrients, animal manure is superior to ammonium nitrate in terms of yield per unit area. Although Mulberry extract a lot of nutrients from the soil, it is very efficient in their utilisation when applied organically, particularly in the case of nitrogen.

Nutrient yield is greater with more frequent cuttings, however the most appropriate cutting frequency should be determined for each site depending on soil conditions, fertilisation and rainfall.

Recommendations

Several agronomic management factors must be studied in the future according with the various production systems and ecological and topographic conditions of each site. Above all, evaluations on the effect that factors can have on sustainability and soil conservation. The following are some criteria and recommendations along these lines.

Punning

There is information on the effect of cutting height on dry matter yields, but in some case the information is contradictory and preliminary (Benavides, 1986 and Blanco, 1992). Due to the effect that cutting height seems to have on leaf:stem proportion, it is important to validate this work in new studies and conditions.

In plantations destine to the production of forage for ruminants, the frequency has been studied for humid tropical conditions. However, it is in the dry tropics where this factor could be more relevant. Under these conditions, it is possible that cutting should be determined by rainfall patterns in specific for each place. Plant height could be the criteria for harvesting.

According to the literature, the number of main branches maintained when pruning has important effects on biomass yields. However, these studies refer to the use of Mulberry to feed the silkworm, and there is no information for application in plantations to produce forage for ruminants.

One of the main problems of tropical livestock husbandry is the feeding during the dry period. In relation to this, it is advisable to conduct studies on the effect of pruning at the end of the dry season on yields during the dry period.

Other constraints for the use of this plant in large plantations could be lack of mechanical harvesting and manure spreading techniques. These are no a problem for the small producers.

Planting

Planting period is more important in the dry tropics than in areas with well-distributed rainfall. This effect has received little attention, and it is possible that it exerts on root development and seed survival.

Planting distance has been studied under bimodal rainfall conditions in Guatemala, where higher densities yield more biomass. However, this type of work needs to be continued to know the effect on production persistence. Obviously, spacing will depend on whether Mulberry is planted as monoculture or in association.

According with field observations, it is possible the Mulberry stakes could be placed horizontally, saving planting material and labour.

The development of planting systems for slopes is of great importance for appropriate soil use and protection, since erosion problems are very serious in the region.

One of the greatest difficulties in small and medium size farms is to convince owners to substitute crops for forages. In this case, evaluation of associations of Mulberry with other crops could allow greater total productivity without affecting yield of traditional crops.

Fertilisation

Without doubt the most important constraint for Mulberry production is its high dependency on soil nutrients. For this reason in the work at CATIE, the fertilisation received special attention. However, a lot remains to be done, in particular with the use of other organic fertilisers and with associations with other nitrogen fixing plants. Although, high yields can be expected with chemical fertilisers, their use could be restricted by cost and possible environmental impact. Associations with herbaceous and tree legumes in order to use the foliage as green manure could be an interesting alternative. In particular tree can be interesting considering their capacity to for soil retention and nutrient recycling.

Evaluations of species and varieties

There are several species or varieties of Mulberry that are being planted in different locations and countries. However, comparative studies on advantages and disadvantages of each depending on climate and soil type have not been made. Breeding and selection work of species and varieties seem to be one of the most important disciplines for this species, in particular due to its high forage potential and the existence a lot of germplasm.

Forage conservation

Reiterating that is in the dry areas with bimodal rainfall where Mulberry can have a most relevant role, it is advisable to continue the studies on ensiling techniques. In particular means of reducing pH. Also mixture of Mulberry and tropical grasses should be evaluated in other to stabilise the silo and to have a better quality product for the animals in the dry season.

Economic evaluations

Although there is some information on the economics of mulberry production and use under humid tropical conditions (Rojas, 1992), it is necessary that the research work with Mulberry include an economic analysis as an important factor to define recommendations for its utilisation.

[END OF PART 2 OF 3]

Utilisation of Mulberry in Animal Production Systems (Part 3/3)

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[END OF PART 3 OF 3]