# Measurement of mulberry shrubs grazed by cattle

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## INTRODUCTION

The necessity to provide alternative sources of forage in certain periods of the year has encouraged research on new crops. Some deciduous shrubs, including mulberry, can contribute to balancing forage supply during the summer months. Mulberry foliage can be considered a good protein supplement during the summer period, improving the intake of free-range cattle in marginal areas.

The measurement, evaluation and agronomic management of shrubs introduced in the Mediterranean forage system has been problematic. Among the various methods proposed for indirect evaluation of forage shrub production, photography appears to be most valid, both in measurement speed and reliability (Cereti and Rossini, 1992; 1993).

A trial was carried out to evaluate the practicality of the photographic method and to learn about mulberry productivity and relative grazing merit.

## METHODS

A two-year trial was carried out in 1992-93 at Tormancina, centra1 Italy (42° latitude north). In the first ten days of August a herd of Maremmana cows grazed on 50 mulberry plants (*M. alba*). The shrubs had been planted in 1988 at a density of 5 000 plants/ha (2 x 1 m) on the volcanic soil commonly found in Roman hillsides. In 1990 the shrubs were subjected to mechanical pruning at two different heights (10 and 80 cm). The photography and scanner technique for mass evaluation was used (Cereti and Rossini, 1992) with a green filter and a black opaque background to reduce disturbances caused by natura1 illumination (areas of shrubs in shadow, shadow on the screen). Shrub volume difference (?V), before (VI) and after grazing, was used to determine DM (DM) availability and intake. The relationship between the dimensiona1 parameters and the DM was obtained by manually stripping the leaves each year using 15 sample shrubs. Having observed that cattle feed from shrubs up to 180 cm, DM was only considered available up to this height.

## RESULTS AND DISCUSSION

There was more rainfall in 1992 than in 1993. Good soil humidity was maintained up to the second half of July 1993. The relation between standing dry phytomass (g) and mean shrub volume before defoliation or VI (dm3) was:

Standing dry phytomass = 0.71 VI + 3.08 $r^2 = 0.95^{**}$

The relation was not influenced by pruning height of shrubs and, thus was used for the calculation of shrub DM availability (Table 1).

TABLE 1

**DM availability (g/plant) during the two-year trial**

| **Year** | **Pruning height** | | |
|---|---|---|---|
| | **10 cm** | **80 cm** | **Mean** |
| 1992 | 50.2 | 101.2 | 74.6 |
| 1993 | 60.0 | 120.6 | 92.0 |
| Mean | $55.1^{a}$ | $105.8^{b}$ | |

Means were significantly different at the 1 percent level.

Over the two-year trial period the DM availability was far greater in shrubs pruned at 80 cm compared with those pruned at 10 cm. Both the year difference and the interaction year by height were not significant. It is possible that the greater production obtained in 1993, despite the less favourable meteorologica1 conditions, was due to the height reached by the shrubs.

The relationship between the DM removed by the animals (g) and the average volume difference (dm3) of the shrubs taken before and after grazing (V) was the following:

Dry phytomass removed = 1.13V + 9.15 r2 = 0.93**

For this relationship, the dimensional parameters and the DM of the sample shrubs were measured not only before and after total leaf stripping by browsing, but also at intermediate stages in order to include various degrees of use. The DM estimate using this relationship did not differ from that obtained using the previous relation. The shrubs pruned at 80 cm produced, on average, more than double that of those pruned at 10 cm (114.6 g/plant compared with 50.4 g/plant).

In this case the quantity of DM resulted comparable to that actually used by the animals. The explanation could be that during the two years in which the trial was carried out the shrubs were completely stripped by the animals.

## CONCLUSION

The indirect evaluation of shrub forage production determined by a photographic survey could be applied in normal operative conditions while maintaining a high degree of certainty. Moreover, research results show that the higher cutting height enables greater productivity of mulberry, even after three years of pruning. The shrubs pruned at 80 cm need frequent attention (every two or three years) as they tend to increase the average production leve1 rapidly above requirement (Correal, Otal and Sottomayor, 1990). The 10 cm pruning can be practised only during the first or second year after planting to make the shrubs suitable for browsing.

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## Management and utilization of mulberry for forage in Japan. 1. Productivity of the mulberry-pasture association system and nutritive value of mulberry

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# INTRODUCTION

Pastures in Japan are mainly composed of temperate species such as orchard grass, tall fescue, timothy and white clover, which are native to Asia (now Anatolia) and Southern Europe region. The climatic conditions of Japan, unlike Europe, are not always suited to the growth of these temperate grasses and pastures based on them create some problems. One of the most serious concerns is seasonal forage production, which is remarkably uneven compared with Europe. Summer forage production in particular decreases to an extreme low because of high summer temperatures. Consequently, there is insufficient forage for grazing animals from summer to autumn.

Mulberry (*Morus* sp.) was once widely planted for sericulture purposes in Japan. However, since the industry has been on the decline for the last few decades, there are many abandoned mulberry farms all over the country. There is an opportunity to utilize these farms for other purposes, especially for mixed pastures.

In view of the above situation, the authors started research on the use of mulberry in temperate grass pastures in order to reduce the summer-autumn forage shortage and to find alternative uses for the abandoned sericulture farms.

The productivity of mulberry-pasture mixtures and the nutritive value of mulberry leaves and shoots are presented in this paper.

## MATERIALS AND METHODS

This trial was carried out from 1997 to 1999 on a volcanic ash soil at the National Grassland Research Institute (Nishinasuno, Tochigi) located at 36$^{o}$ 55' latitude north, 139$^{o}$ 55' longitude east and at 320 m above sea level.

The mulberry varieties were Shinkenmochi (*M. bombycis*) and Aobanezumi (*M. alba*). Mulberry-pasture association was established as follows: Mulberry was planted at a spacing of 3 m - between rows and 0.7 m between plants (4 762 plants/ha) in the spring of 1996. A mixture of five temperate species - orchard grass, tall fescue, perennial ryegrass, red top and white clover - was sown among mulberry rows the following autumn. The association was compared with a sward of those species and with mulberry in a pure stand. The design was a randomized complete block with three replications. In all three treatments plot size was 84 $m^2$ (7 m x 12 m). Four mulberry rows, two of each mulberry variety, were used in both the association and the pure stand. Harvest times were for 1997: 30 April, 10 June, 11 August, 3 October and 10 November; for 1998: 30 April, 9 June, 10 August, 5 October and 5 November; and for 1999: 30 April, 11 June, 9 August, 6 October and 2 November. As mulberry began sprouting at the end of April and stopped shooting about the middle of October, it was harvested three times from June to October. Mulberry plants were trimmed at 1 m high when they were planted and the new shoots harvested by cutting approximately 1 cm above the old shoots. Swards were cut at 5 cm above ground. Fertilizer was applied at the rate of 68 kg/ha/year of N, P and K.

Forage production and nutritive value were determined in the three treatments. Forage samples from September were used to determine CP, ADF, NDF, ash, organic cellular content (OCC), organic cell wall (OCW), high digestible fibre fraction (Oa), low digestible fibre fraction (Ob), Ca, P, Mg, and K. The K/(Ca+Mg) ratio was calculated.

## RESULTS AND DISCUSSION

### Productivity of mulberry-pasture association

Table 1 shows the results of the DM production of three treatments from 1997 to 1999.

Since, mulberry is very palatable for cattle (Kitahara, 1999) and both new shoots and leaves are well consumed, mulberry production data shown also include shoots.

Excellent yearly DM production of mulberry-pasture association was obtained in all three years. DM production of the mulberry-pasture mix was 13 percent, 32 percent and 57 percent above the grass alone in 1997, 1998 and 1999, respectively, resulting from the contribution of mulberry. In general, grassland productivity in Japan decreases with time. This was the case in this experiment for the temperate sward where the yield decreased from 1997 to 1999. On the contrary, the productivity of the mulberry-pasture association did not drop. This interesting result seems to result from the protective shading effect of mulberry on the grass sward. Seasonal forage production in the mulberry-pasture association was well distributed compared with other treatments. Consequently, a mulberry-pasture association can be a way of solving the problem of the summer-autumn forage deficit in Japan.

None of the mulberry plants was killed by defoliation three times a year during the experiment.

**Nutritive value of mulberry leaves and shoots**

Table 2 shows the nutritive value of mulberry leaves and shoots compared with a temperate sward and Table 3 shows the comparative mineral content.

The characteristics of the nutritive component of mulberry were as follows. The contents of crude protein and OCC in the leaves were high, but those of ADF and NDF were low compared with the sward. Mulberry leaves were more digestible than the sward. On the other hand, the contents of ADF, NDF and OCW in the mulberry shoots were relatively high. This shows that mulberry shoots might have low digestibility. As the ratio of DM production of mulberry leaves to the shoots is 3:1, whole nutritional quality of the mulberry foliage, likely to be consumed by cattle, seems to be high.

With regard to mineral content, Ca, P and Mg in mulberry leaves were higher than in the sward. K content and K/(Ca+Mg) in mulberry leaves were markedly lower than in grass.

Grass tetany is a significant disease during the grazing season, and has generally been related to low Mg, high K, and high K/(Ca+Mg) equivalent ratios in the forage (Karlen *et al*., 1978). Gross (1973) reported that generally accepted values of less than 0.2 percent Mg, more than 2.5 percent K, and K/(Ca+Mg) equivalent ratios greater than 2.2 could cause forage to be tetany prone. It is apparent that mulberry has good mineral components that prevent grass tetany.

TABLE 1

## The productivity of mulberry and temperate sward in the three treatments (kg of DM/10a)

| **Year/ treatment** | **Fraction** | **Date** | | | | | **Total** |
|---|---|---|---|---|---|---|---|
| **1997** | | **30/04** | **10/06** | **11/08** | **03/10** | **10/11** | |
| *Association* | Sward | 531 | 394 | 223 | 162 | 69 | 1 380 |
| | Mulberry leaves | | 83 | 86 | 71 | | 239 |
| | Mulberry shoots | | 26 | 38 | 23 | | 86 |
| | Subtotal | | 109 | 124 | 94 | | 325 |
| | Total | 531 | 503[a] | 347[a] | 256[a] | 69 | 1 706[a] |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Sward* | Sward | 588 | 434[a] | 232[b] | 203[a] | 57 | 1 514[a] |
| *Mulberry pure stand* | Mulberry leaves | | 111 | 152 | 86 | | 349 |
| | Mulberry shoots | | 48 | 84 | 24 | | 156 |
| | Total | | 160[b] | 236[b] | 110[b] | | 505[b] |
| **1998** | | **30/04** | **09/06** | **10/08** | **05/10** | **05/11** | **Total** |
| *Association* | Sward | 228 | 213 | 192 | 172 | 36 | 841 |
| | Mulberry leaves | | 43 | 72 | 58 | | 173 |
| | Mulberry shoots | | 14 | 21 | 16 | | 51 |
| | Subtotal | | 57 | 93 | 74 | | 224 |
| | Total | 228 | 271[Aa] | 285[Aa] | 246[Aa] | 36 | 1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | [illegible] | [illegible] | [illegible] | | $065^{a}$ |
| *Sward* | Sward | 181 | $203^{Bab}$ | $196^{Bab}$ | $183^{Ba}$ | 44 | $807^{b}$ |
| Mulberry pure stand | Mulberry leaves | | 90 | 126 | 51 | | 267 |
| | Mulberry shoots | | 32 | 50 | 15 | | 97 |
| | Total | | $122^{Cb}$ | $177^{Bb}$ | $66^{Cb}$ | | $364^{c}$ |
| **1999** | | **30/04** | **11/06** | **09/08** | **06/10** | **02/11** | **Total** |
| Association | Sward | 128 | 286 | 183 | 85 | 39 | 722 |
| | Mulberry leaves | | 31 | 84 | 101 | | 216 |
| | Mulberry shoots | | 7 | 34 | 35 | | 75 |
| | Subtotal | | 38 | 118 | 136 | | 291 |
| | Total | 128 | $324^{Aa}$ | $301^{A}$ | $221^{Aa}$ | 39 | 1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | $013^{a}$ |
| Sward | Sward | 121 | $194^{Bab}$ | $206^{B}$ | $93^{Bb}$ | 32 | $647^{b}$ |
| Mulberry pure stand | Mulberry leaves | | 63 | 111 | 94 | | 268 |
| | Mulberry shoots | | 18 | 39 | 24 | | 82 |
| | Total | | $82^{Cb}$ | $150^{B}$ | $118^{Bab}$ | | $350^{c}$ |

Statistical comparisons were among treatments within same year. Values with the same letter do not differ (A <0.05, a <0.01).

TABLE 2

**The nutritive value of mulberry leaves and shoots compared with temperate species**

| Fraction | CP | ADF | NDF | Ash | OCC | OCW | Oa | Ob |
|---|---|---|---|---|---|---|---|---|
| Mulberry | | | | | | | | |
| Leaves | 25.8 | 21.0 | 31.6 | 11.8 | 51.8 | 36.5 | 10.0 | 26.5 |
| Shoots | 12.1 | 45.6 | 60.5 | 8.8 | 32.8 | 58.5 | 9.4 | 49.1 |
| Sward | 20.4 | 27.9 | 53.5 | 11.6 | 34.0 | 54.4 | 12.3 | 42.1 |

Harvesting month: September 1997. The mulberry variety was Shinkenmochi.

TABLE 3

**Mineral content of mulberry leaves and shoots compared with the temperate sward**

| Fraction | Ca | P | Mg | K | K/(Ca+Mg) |
|---|---|---|---|---|---|
| Mulberry | | | | | |
| Leaves | 2.98 | 0.44 | 0.43 | 2.84 | 0.41 |

| | | | | | |
|---|---|---|---|---|---|
| Shoots | 1.01 | 0.37 | 0.36 | 3.78 | 1.21 |
| Sward | 0.28 | 0.37 | 0.30 | 4.99 | 3.29 |

Harvesting month: September 1997. The mulberry variety was Shinkenmochi.

## CONCLUSION

This study has demonstrated that the productivity of mulberry-pasture association is very high and has even seasonal distribution compared with a sward of temperate species. The nutritive value of the mulberry leaves was also high and mineral content was excellent. A mulberry-pasture system seems to be a promising grazing method. However, that further studies on this system need to be conducted to solve further practical problems.

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# Evaluation and utilization of mulberry for poultry production in Japan

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## INTRODUCTION

Mulberry is an indispensable crop for silkworm production. In Japan, sericulture need to be such an important industry that mulberry was not used for other purposes. However, with the recent decline of sericultural industry, mulberry has been re-evaluated for other purposes, such as medicinal, fruit and animal production. This paper reviews its evaluation and utilization for animal production, with special reference to poultry production in Japan.

## FOWLS RAISED IN MULBERRY GARDENS

If domestic and guinea fowls were to be raised in mulberry gardens, multiple useful effects could be expected such as weeding; pest control; extra fertilizer (from manure); high quality and natural egg and/or meat; and feed cost reduction (Watanabe, 1985). With these points in mind, several experiments were carried out in various regional sericulture experiment stations in Japan.

## Weeding effect

Uchino *et al*. (1988) utilized guinea and domestic fowls (New Hampshire breed) for weed control. A small poultry house was built in the corner of a mulberry garden. Eleven domestic fowl were put in a mulberry garden of 0.025 ha and ten guinea fowl in one of 0.012 ha. Commercial feed was given, 140-150 g/dY for each domestic fowl and 70 g/day for each guinea fowl. The amount of weeds growing after seven months was measured. Table 1 shows that there were no weeds in the guinea fowl plot, and only a few weeds in the domestic fowl plot, whereas a large number of weeds, such as *Polygonum longisetum* De Bruyn, *Digitaria adscendens* Henr. (large crab-grass), *Malachium aquaticum* Fries (Mater mouse-ear chickweed), *Senecio vulgaris* L. (common groundsel) and *Veronica persica* Poir. (Byzantine speedwell) grew in the control plot. These results indicate that raising guinea and domestic fowls in mulberry gardens controls weeds that would otherwise cause serious damage to mulberry growth. Similar results were obtained in the Oita Prefecture (Urushima, Iguchi and Sato, 1984; 1987).

TABLE 1

**Amount of weeds growing after seven months, fresh matter (g/m$^2$) and percentage relative to control in parenthesis**

| Treatment | Amount | Weed species |
| --- | --- | --- |

| | | |
|---|---|---|
| | **of weeds** | |
| Control | 1 064 (100 %) | *Polygonum longisetum, Digitaria adscendens*, *Malachium aquaticum*, *Senecio vulgaris, Veronica persica* |
| Domestic fowl | 11 (11 %) | *Senecio vulgaris, Erigeron philadelphicus* |
| Guinea fowl | 0 (0 %) | |

**Source:** Uchino *et al*., 1988.

## Fertilizing effect of manure

The daily excrement of domestic fowls is about 150 g, corresponding to 54.8 kg annually. It contains 1.6 percent of N, 1.7 percent P and 0.8 percent K (Maeda *et al*., 1978). Uchino et al. (1988) measured non-organic nitrogen in three places in a mulberry garden. They found 12-14 times more in the front of the fowl house and two to five times more in between rows than in the control garden (Table 2). However, the quantity between stumps was almost the same as in the control garden. This study shows that both guinea and domestic fowls hang around their shelter. Spreading manure would be necessary to get a uniform fertilizing effect.

TABLE 2

**Non-organic soil nitrogen, mg/g of dry soil**

| Sampling site | Guinea fowl | Domestic fowl | Control |
|---|---|---|---|
| Front of fowl house | 21.3 | 17.8 | - |
| Between mulberry rows | 7.3 | 3.7 | 1.5 |
| Between mulberry stumps | 1.3 | 1.9 | - |

**Source**: Uchino *et al*., 1988.

However, a report from the Oita Prefecture indicated that the leaf yield in a garden that received only a quarter of N fertilizer and had domestic fowls, was the same as the control with 30 kg/10 area of N (Urushima, Iguchi and Sato, 1987). Similar results were obtained in the Saitama Prefecture (Hachisu, 1989). It can thefore be concluded that domestic fowls in mulberry garden had a fertilizing effect.

**Pest control effect**

Uchino *et al*. (1988) investigated the pest control effect of guinea fowls by dissecting two birds in June and examining the insects inside their crops. They found that guinea fowls had eaten *Japyx japonicum* Enderlein, *Aphodium rectus* Motschusky, *Arge similis* Vollenhoven (azalea sawfly) and others. Moreover, daily observation confirmed that guinea fowls consumed *Scotinophara lurida* Burmeister (black bug), *Spilarctia imparilis* Butler mulberry tiger moth), *Apriona japonica* Tomson (mulberry borer), grasshopper, cicada, fry and earthworms. *Apriona japonica,* for example, is an insect that causes serious damage to mulberry growth in Japan.

## Quality of egg and meat produced

Yearly egg production was 170 for a domestic fowl and 90 for a guinea fowl. Guinea fowl do not lay in winter. As shown in Table 3, guinea fowl eggs are smaller compared with those of domestic fowls, but they have a thicker eggshell and better preservation. Moreover, guinea fowl eggs are higher in Haugh unit and yolk colour. New Hampshire hens raised in a mulberry garden produced eggs with a greater proportion of yolk and higher Haugh unit and yolk colour, compared with eggs from commercial White Leghorn hens. These results demonstrate that eggs produced by guinea and domestic fowls raised in mulberry gardens are superior to those commercially available.

TABLE 3

## Egg quality of guinea and domestic fowl raised in a mulberry garden

| Species | Egg (g) | Yolk (%) | Yolk white | Shell (%) | Haugh unit | Yolk colour |
|---|---|---|---|---|---|---|
| *Guinea fowl* | 39.2 | 31.4 | 0.60 | 16.6 | 83.1 | 13 |
| *Domestic fowl:* | | | | | | |
| New Hampshire | 60.3 | 29.5 | 0.48 | 9.3 | 67.1 | 12 |
| White Leghorn* | 59.0 | 27.5 | 0.44 | 9.5 | 61.4 | 10 |

*Commercially purchased as a control. Source:

Uchino *et al*., 1988.

In this experiment, after 23 weeks, domestic fowls, on average, reached 2.0 kg and guinea fowl 1.5 kg, their normal adult weight (Uchino *et al*., 1988).

Guinea fowl meat has an excellent taste good and is relished as a high-quality meat in France and Italy, where it represents 30 percent of poultry meat products (Uchino *et al*., 1988). On the contrary, guinea fowl meat is rarely eaten in Japan. However, since Japanese food customs are changing and there is a growing demand for high-quality meat, guinea fowl meat might be a welcome addition to the Japanese table.

## MULBERRY LEAF FOR POULTRY FEEDING IN JAPAN

This section reviews the effects of mulberry on poultry production when leaves were fed to domestic fowls.

## Quality of domestic fowl

Several reports on the utilization of mulberry leaves for poultry production have been published recently (Tateno, Yatabe and Iso, 1998, 1999; Suda, 1999; Sudo, Kuramoto and Iso, 2000). When feeds containing 3 percent, 6 percent and 9 percent of mulberry leaf were fed to the domestic fowls (White Leghorn), egg quality (e.g. egg weight and egg production ratio) was almost the same as the control with commercially available feed (Suda, 1999). However, when the feed contained 15 percent of mulberry leaves, egg quality was significantly lowered (Tateno, Yatabe and Iso, 1999). However, yolk was more yellow because of the mulberry leaves (Table 4).

TABLE 4

**Egg yolk colour of domestic fowl with mulberry leaves in the feed**

| Feed | Yolk colour | | |
|---|---|---|---|
| | Beginning | After 3 weeks | After 7 weeks |
| Control | 8.0 | 8.5* | 9.2* |
| 15 percent mulberry leaves | 7.8 | 9.6* | 10.1* |

* shows significant difference in 1 percent level between two food plots.
**Source:** Tateno, Yatabe and Iso, 1999.

## Mulberry effect on health-related compounds in egg yolk and blood serum.

Mulberry leaf in the feed increased vitamin K1 in the yolk (Table 5) but did not have an effect on the content of gamma-aminobutyric acid (GABA), which has a role in reducing human blood pressure (Table 5) (Machii, 1990). There was no significant difference in the cholesterol content of egg yolk (Table 5). However, lipid peroxide content in the yolk significantly decreased after seven weeks of feeding mulberry leaves. It is known that lipid peroxide is closely related to active oxygen species, which have a role in causing diseases.

TABLE 5

**Health-related compounds in the egg yolk of domestic fowl fed with mulberry leaves**

| Compound | Feed | |
|---|---|---|
| | Control | 15% mulberry leaf |
| GABA (ppm) | 1 | 1 |
| Vitamin K1 | 1* | 54* |
| Vitamin K2 | 22 | 29 |

| | | |
|---|---|---|
| Cholesterol (mg/100 mL): | | |
| Before | 15.1 | 15.1 |
| After 3 weeks | 13.9 | 15.6 |
| After 7 weeks | 12.9 | 14.3 |
| Lipid peroxide (nmol/mL): | | |
| Before | 52.6 | 40.8 |
| After 3 weeks | 49.5 | 44.6 |
| After 7 weeks | 57.9* | 41.1* |

*Significant differences between feeds at 1% level.
Source: Tateno, Yatabe and Iso, 1999.

TABLE 6

**Health-related compounds in blood serum of domestic fowl fed with mulberry leaves**

| Compound | Feed | |
|---|---|---|
| | Control | 15% mulberry leaf |
| Cholesterol (mg/100 mL): | | |
| Before | 130.7 | 146.9 |
| After 3 weeks | 150.4* | 117.7* |
| After 7 weeks | 156.4 | 135.7 |
| Lipid peroxide (nmol/mL): | | |
| Before | 11.6 | 12.1 |
| After 3 weeks | 12.8 | 13.2 |
| After 7 weeks | 13.9 | 11.3 |

* Significant difference between feeds at 1 percent level.

**Source:** Tateno, Yatabe and Iso, 1999.

Moreover, Sudo, Kuramoto and Iso, (2000) measured the effect of mulberry on the quantity of betacarotene contained in the egg yolk and blood serum of domestic fowls fed with mulberry leaves only. Beta-carotene content in mulberry leaves was 29 mg/100 g, which corresponds to the level in tea leaves. Betacarotene in the egg yolk and blood serum of domestic fowls fed with mulberry feed was 0.02 mg/100 g and 0.055 microg/100 g, respectively; meanwhile, in the birds receiving feed without mulberry (control) it was not detected. Betacarotene has an important antioxidant and anti-cancer effect and, when converted to retinol or vitamin A, has an anti-nyctalopia effect. Retinol concentration in the egg yolk and blood serum was the same in both treatments.

**Mulberry leaves to reduce odour in manure**

Odours emitted from poultry manure, especially in peri-urban farms, have become a social problem in Japan. Ammonium and hydrogen sulphate are major odours in manure. Sudo, Kuramoto and Iso, (2000) tested whether mulberry leaves had an inhibitory effect on ammonium and hydrogen sulphate emissions from manure. Ammonium emission was significantly reduced by feeding mulberry, but hydrogen sulphate was not affected (Table 7). Suda (1999) obtained similar results on the inhibitory effect of mulberry leaves on ammonium emission. Thus, it can be concluded that mulberry leaves included in poultry feed have an odour reduction effect in manure.

TABLE 7

**Ammonium and hydrogen sulphate emitted from poultry manure**

| **Feed** | **Odour compound (ppm)** | |
|---|---|---|
| | Ammonium | Hydrogen sulphate |
| Control | 2.67* | 9.14 |

| | | |
|---|---|---|
| Control | [illegible] | [illegible] |
| 10 percent mulberry leaf | 0.29* | 10.89 |

* Significant differences between treatments at 1 percent level.

## CONCLUSION

It was found that raising domestic and guinea fowls in mulberry gardens benefits mulberry growth through their weeding, pest control and fertilizer effects. The egg Haugh unit was also higher. Moreover, when mulberry leaves were given as part of the feed to domestic fowls, vitamin K1 content was increased and odour from manure decreased. Therefore, it is relevant to evaluate and utilize mulberry as a feed for poultry as well as for the sericulture industry.

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# Conservation of mulberry as silage. 1. Effect on nitrogenous compounds

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## INTRODUCTION

Because of its high edible biomass yield of 16-18 tonnes DM/ha/year; its high percentages of CP (15-25 percent) and IVDMD (75-85 percent); and its perennial nature and adaptation to various soil types (CATIE, 1986), mulberry is beginning to be used extensively for livestock and is likely to become a forage of excellence for feeding and supplementing ruminants.

Even if it is true that with the use of forage trees the seasonality of production is attenuated, in order to guarantee feeding in dry periods, it is indispensable that the ratio of production to unit of land be established on the basis of the periods with less yield.

In the case of mulberry, which has a cutting interval of three months, there is a surplus in the rainy season. If this additional forage is not harvested, there is an imbalance in the nutritional quality of the shoot through ageing, a decrease in edible biomass and a waste of productive potential (Martín, 1999, unpublished).

One way to avoid this situation is by conserving all the green material non-utilized as silage. However, it is known that tree forages have certain characteristics with regard to the conservation technologies established to date (Vallejo *et al*., 1994). In fact, tree forages contain much higher levels of CP (Oviedo *et al*., 1994) but, at the same time, this protein degrades during conservation and the animal performance decreases significantly in comparison with fresh forage

(González *et al*., 1997).

To date, few studies have been conducted on the conservation of mulberry as silage, (Vallejo, 1995), and the dynamics of protein degradation during conservation have not been observed. In addition, research carried out in temperate forages has shown protein hydrolysis differs according to the type of forage, irrespective of whether silage is made with fresh or wilted material (Messman, Weiss and Koch, 1994). This explains why only with individual studies of forages species is possible to elucidate the changes in nitrogenous compounds during conservation.

The objective of this research was to conduct a study on the evolution of nitrogenous compounds in mulberry silages and on their transformation over time, taking into account the main indicators and how the inclusion of different doses of conserving agents and prewilting interact.

# MATERIALS AND METHODS

## Experiment 1. Fermentation dynamics in mulberry silage

Mulberry forage for this experiment was taken from a 3-year old plantation that had a homogenization cut in May, at the beginning of the rainy season and a fertilizer dose of 60 kg of N/ha. Forage was collected manually after 90 days of re growth, in the month of July. The green material was chopped to 1-2 cm and carefully mixed. Double nylon bags, with 3 kg capacity, were used as experimental units. Five bags per treatment were filled and sealed within two hours. Treatments were the opening times: 2, 8, 14, 30, 60, 90, 120 and 180 days.

Parameters measured were: DM, determined in an oven with forced ventilation at 70$^{o}$C for 48 hours; total CP (TCP) determined by the methodology of AOAC (1965); soluble CP (SCP) and ammonia from silage juice extracted by a hydraulic press (Dulphy and Demanquilly, 1984).

Results were analysed with multiple regression equations using the Excel statistical analysis.

## Experiment 2. Effect of additives and wilting

Mulberry utilized in this study was obtained from the same plantation as experiment 1, except that forage was collected in September, 60 days after the previous cut, and the fertilizer dose was 60 kg of N/ha. The procedure was similar to experiment 1, but the treatments were those shown in Table 1. Bags were opened after 60 days.

TABLE 1

## Treatments for experiment 2

| Control | Wilting |
|---|---|

| | |
|---|---|
| Final molasses 2 percent | Formic acid 0.1 percent |
| Final molasses 4 percent | Formic acid 0.2 percent |
| Final molasses 6 percent | Formic acid 0.3 percent |

The experimental design was a complete randomized block and mean differences were determined by the Duncan (1955) test.

Because of the complexity of the indicators studied and their interactions, it was decided to weigh them. The method used was that of mean superindexes as a way to determine treatment differences for weighing purposes. In cases where two superindexes were similar, the mean of the respective values was taken. The established system for the indicators was set as shown in Table 2.

TABLE 2

## Weighing of indicators from significant differences expressed by superindexes

| DM | TCP | SCP/TCP % | N-NH3/N4 % | pH | Maximum weighing |
|---|---|---|---|---|---|
| a-3 | a-3 | d-3 | c-3 | c-3 | 15 |
| b-2 | b-2 | c-2 | 2 | b-2 | |
| c-1 | c-1 | b-1 | 1 | a-1 | |
| | | a-0 | | a-1 | |

## RESULTS

## Experiment 1

DM showed a tendency to decrease during the whole measured period, adjusting well to a quadratic regression (Figure 1). TCP was maintained without major fluctuations (Table 3).

The percentage of SPC oscillated but was always above the initial value, with marked increases at the end. The best fit was a grade 4 polynomial equation (Figure 2).

TABLE 3

**Changes in total crude protein (%) in mulberry silages**

| | **Days** | | | | | | | | | | **SD** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **2** | **8** | **14** | **20** | **30** | **60** | **90** | **120** | **180** | |
| TCP | 18.9 | 18.4 | 18.4 | 19.3 | 18.9 | 18.0 | 19.9 | 18.0 | 18.5 | 19.1 | 4.6 |

**Figure 1. DM content in mulberry silages over time**

**Figure 2. Changes in the percentages of soluble protein in mulberry silages**

**Figure 3. Changes in N-NH3/total N [ percent] in mulberry silages**

The percentage of ammonia N from total N showed an increase from 14 days onwards, with maximum values at 180 days. The best fit was a cubic polynomial equation (Figure 3).

The pH dropped rapidly during the first 8 days, but at 30 days started to rise, showed a slight decrease at 60 days and then a constant value until the end. The best fit was a cubic polynomial equation but the $R^2$ values were low (Figure 4).

**Figure 4. Changes in pH in mulberry silages.**

## Experiment 2

The results of the indicators evaluated are shown in Table 4. The best DM contents were found in the wilted silages. The addition of final molasses to 4 and 6 percent of formic acid at 0.2-0.3 percent produced higher DM contents than the control, but nothing at lower doses. Formic acid favoured better total CP conservation, the same as wilting with 4 percent molasses compared to the control. Other treatments were different.

The treatment with the best SCP/TCP ratio was wilting, followed by 2 and 4 percent molasses and the control. The highest values were those of formic acid.

The lowest N-$NH^3$/total N were obtained with wilting and with 6 percent molasses, not different from formic acid at 0.1 percent. Other treatments, with higher values, were no different.

The lowest pH was obtained with 6 and 4 percent of molasses. The later was no different from 2 percent molasses, formic acid at 0.1 and 0.2 percent and the control. The highest values were with 0.3 percent formic acid and wilting.

An analysis of the relative weighing of the results considering the significance index (Table 5), shows that wilted silage reaches 80 percent of the possible points, followed by 6 percent molasses, but with a difference of 13 points between them.

Silages with 0.1 and 0.2 percent of formic acid were of better quality than 0.3 percent formic acid, and this was similar to the control silages.

## DISCUSSION

### Experiment 1

DM losses were high, approximately 25 percent. The explanation for this should be studied from two points of view. First, it is known that during oven drying, silages lose volatile components which underestimate DM values, for this reason, values and, obtained should be taken with caution (Dulphy and Demanquilly (1981). Second, the duration of the trial should be considered. In practice, silages are not stored for more than six months.

Although Vallejo (1995) found similar losses in silages made from tree foliages, losses with mulberry in his experiment were lower, resulting from the high fermentative quality of the silage. For this reason additives enhance DM conservation and, in the case of final molasses, there is an additional supply of solids (De la Fuente, 1990).

TABLE 4

**Effect of additives and wilting in fermentative quality of**

**mulberry silages**

| Treatments | DM | CP | SCP/TCP (%) | pH | NH3/total N (%) |
|---|---|---|---|---|---|
| Control | $31.82^{c}$ | $22.5^{c}$ | $39.9^{c}$ | $5.0^{b}$ | $11.2^{a}$ |
| Wilting | $40.20^{a}$ | $24.7^{b}$ | $12.3^{d}$ | $5.4^{a}$ | $6.2^{c}$ |
| Molasses 2 percent | $33.68^{bc}$ | $21.8^{c}$ | $38.6^{c}$ | $4.9^{b}$ | $12.1^{a}$ |
| 4 percent | $34.76^{b}$ | $24.2^{b}$ | $38.6^{c}$ | $4.8^{bc}$ | $10.5^{a}$ |
| 6 percent | $35.67^{b}$ | $23.0^{bc}$ | $43.7^{b}$ | $4.6^{c}$ | $7.5^{bc}$ |
| Formic acid: 0.1 percent | $32.67^{c}$ | $26.4^{a}$ | $63.8^{a}$ | $5.0^{b}$ | $9.3^{b}$ |
| 0.2 percent | $34.67^{b}$ | $27.3^{a}$ | $61.6^{a}$ | $5.0^{b}$ | $13.0^{a}$ |
| 0.3 percent | $34.60^{b}$ | $26.7^{a}$ | $62.2^{a}$ | $5.3^{a}$ | $14.0^{a}$ |
| ES ± | 1.36 | 2.4 | 0.8 | 0.1 | 2.6 |

| | | | | | |
|---|---|---|---|---|---|
| Sig percent | 0.5 | 0.5 | 0.1 | 0.1 | 0.5 |

TABLE 5

**Weighing of indicators in mulberry silages wilted or with additives**

| Treatments | DM (%) | CP (%) | SCP/TCP (%) | pH | N-$NH^3$/NT % | Total | Weight % |
|---|---|---|---|---|---|---|---|
| Control | 1 | 1 | 2 | 2 | 1 | 7 | 47 |
| Wilting | 3 | 2 | 3 | 1 | 3 | 12 | 80 |
| Molasses | | | | | | | |
| 2 % | 1.5 | 2 | 2 | 2 | 1 | 8.5 | 57 |
| 4 % | 2 | 2 | 2 | 2.5 | 1 | 9.5 | 63 |
| 6 % | 2 | 1.5 | 1 | 3 | 2.5 | 10 | 67 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Formic acid | | | | | | | |
| 0.1 % | 1 | 3 | 0 | 2 | 2 | 8 | 53 |
| 0.2 % | 2 | 3 | 0 | 2 | 1 | 8 | 53 |
| 0.3 % | 2 | 3 | 0 | 1 | 1 | 7 | 47 |

It was clear that under the conditions in which these silages were prepared, there was a permanent degradation. There were no signs of stabilization.

Although TCP values were maintained in all treatments of experiment 1, formic acid preserves quality and being this is one of the main advantages in using it. (Ready and Murphy, 1996).

Mulberry proteins also suffer quality changes, with fermentative and nutritional implications. Forage protein hydrolysis is an inherent process in silage making (Ohshima and McDonald, 1978). The fermentation of mulberry in this experiment, without pretreatments or additives, could not control this process, since pH 4.3, considered the minimum necessary to stop proteases (McDonald, Henderson and Heron, 1991), was never reached. The SCP/TCP increased constantly.

The magnitude of the process was reflected in the fluctuations occurring between 30 and 120 days, which indicate condensation and rearranging of soluble N compounds. In this period almost all the soluble N was in the form of ammonia.

Formic acid addition induced high SCP/TCP ratios. The same effect was found by Carpintero, Henderson and McDonald, (1979), while studying increasing doses of formic and sulphuric acids in temperate grass-legumes mixes, where acidification promoted higher soluble nitrogen. This was seen as the result of a non-enzymatic hydrolysis. However, in the current experiment, high ammonia percentages were not found. This contradiction should be interpreted as the result of the microbe predominating in this silage, since it is mainly responsible for deamination.

In a study conducted by González *et al*., (1997) with micro-silos of mulberry, there was a direct relationship between pH and lactic acid, which allowed adequate ammonia values in relation to total N.

From these results it can be inferred that formic acid at 0.3 percent did not control the undesirable fermentations (Luis *et al*., 1991), agreeing a low quality index. This is not the situation with wilted silages, in which pH increases are due to a less intensive but higher quality fermentation (Narsh, 1979).

This line of thought agrees with the results obtained with final molasses. The addition of soluble carbohydrate facilitates the rise in acidity by promoting more vigorous lactic fermentation

(Ojeda, 1993).

**Experiment 2**

The above action was detected in silages with 6 percent molasses. However, the response to the indicators was an increment in the SCP/TCP ratios compared to other doses, confirming that acidification promoted the presence of soluble N compounds, but substantially improving ammonia percentages. Vallejo (1995) also found decreases in pH and ammonia percentages in mulberry silages with 5 percent molasses. This effect was attributed to a better quality of fermentation with almost double lactic acid concentration when using molasses compared with silages with no additives.

In this study, the most effective treatment was wilting, since it gave the best indicators and ammonia contents. Although Narsh (1979) only found positive aspects of wilted silages, Ojeda *et al*., (1998) found that during sun drying of mulberry, the leaves lose water more quicly and thus proteases should be rapidly inactivated, restricting their action during fermentation.

Research on temperate forages has shown that there is different behaviour in protein hydrolysis depending on forage type, irrespective of whether there was wilting (Messman, Weiss and Koch, 1994).

From the results of this research, it can be concluded that mulberry silages should receive adequate attention not only in relation to initial crude protein content but also to the ways in which nitrogen is transformed. Wilting appears to be the most suitable technology for reducing protein degradation during conservation.

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# Mulberry production with swine lagoon effluent

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## INTRODUCTION

In sustainable animal production systems, the procedures for nutrient management to enhance environmental conditions have always been a well-recognized priority. The advent of concentrated, large animal production units presents the monumental challenge of responsible management of manure nutrients (Adeola, 1999). Swine manure is primarily a mixture of urine and faeces, and it contains undigested dietary components, endogenous end- products and indigenous bacteria from the lower intestinal tract (Sutton *et al*., 1999). On average, 60 to 80 percent of ingested N and P are excreted, while for K it is over 90 percent (Voermans, Verdoes and den Hartog, 1994). Swine waste from anaerobic lagoons contains virtually all of the nutrients needed for plant growth and development. This represents a valuable resource that can replace costly inputs in pasture and crop production (Mueller *et al*., 1994), and with appropriate application rates, potential soil and water pollution is eliminated (Sutton *et al*., 1978). The application of lagoon effluent to land is facilitated with crops that assimilate large amounts of nutrients.

The Yucatán peninsula is located in southeast Mexico. Geologically, the northern part of the peninsula may be characterized as a Cenozoic carbonate platform, with extremely permeable carbonate rocks, that consists of an undulating karst plain with gentle slopes from sea level to an elevation of 30 m. The insoluble fraction of limestones produce the soils of Yucatán. They are thin, residual, terra rossa soils, commonly rich in the mineral halloysite. Soils rarely exceed a few centimetres, and most of the terrain consists of bedrock outcrops with thin accumulations of soil in topographic lows. The high surface infiltration and rock permeability, and the low relief of the area combine to produce a regional aquifer with a very low hydrologic gradient (Dohering and Butler, 1974).

The only natural source of fresh water in the Yucatán peninsula is a fragile aquifer system consisting of a fresh water lens floating on saline water, and the great vulnerability of the aquifer is revealed in studies related to water pollution in wells (deeper than 30 m) in the city of Mérida, with faecal coliform bacteria exceeding the maximum permissible levels for treatment to produce a safe water supply (Vázquez & Manjarres, 1993; BGS, FIUADY, CNA, 1995).

Swine production in Yucatan is economically important. Its value was over US$100 million in 1999. The pig population has been growing dramatically since 1975 has increased more than 20 percent annually between 1990 and 1997 (INEGI, 1998). Although swine production has been transformed into a dynamic activity, soil and water pollution can occur whenever large quantities of organic waste materials are concentrated in a single area and soluble materials move downwards into the groundwater. Nitrate concentration in wells near swine farms reaches high levels, of more than 45 mg/l (Pacheco, Cabrera and Gómez, 1997). On the other hand, phosphorus does not yet represent a pollution risk, because of its lower soil mobility than that of nitrate-N (Coffey, 1999) and it is adsorbed in limestone (Pacheco and Cabrera, 1996).

Mulberry demands a lot of nutrients in order to produce large biomass yields with high nutritional value. The maintenance of soil fertility and plant persistence become important if significant amounts of soil nutrients are to be extracted in the biomass under cut-and-carry systems (Sánchez, 2000). There is also a close relationship between fertilizer dosage and quantity/quality of mulberry leaves (Ye, 2000). Therefore, mulberry represents an alternative to applying nutrient-rich swine lagoon effluent and to decreasing the environmental impact of intensive swine production.

## MATERIAL AND METHODS

The study was conducted at the Instituto Tecnológico Agropecuario No. 2, located near Conkal (Yucatán, Mexico). The experimental site is located at 9 m above sea level in a tropical (Aw 0) climate with annual rainfall ranging from 900 to 1 000 mm. Average temperature is 26.5ºC (García, 1981). Soils are calcareous, rocky and shallow and are classified as leptosol rendzic (FAO, 1998), with a medium depth of 15 cm.

Stakes measuring 30-40 cm, with at least four buds, were directly planted. Rooting was induced with indol 3-butyric acid.

The experimental design was a complete randomized block in a split-plot arrangement with four replicates (Table 1). The main plot was density (10 000 and 20 000 plants/ha), and subplots were level and type of nitrogen application; including a control ($T_0$) no nutrient addition; urea (U) at 300 kg of N/ha/year, in four applications (every 91 days); and effluent loading rates (ELR) from an anaerobic lagoon (10 m in diameter by 2.5 m in depth) to apply approximately 150, 300 and 450 kg of N/ha/year in ten applications (every 35 days) with a pump for solids. The experimental plot measured 5 x 5 m and the useful plot 4 x 4 m. Cuts were every 91 days beginning on 15 July, 1998.

TABLE 1

## Description of treatments

| Treatment | Density Plants/ha | Nitrogen level kg/ha/y | Fertilization type |
|---|---|---|---|
| 1 | 10 000 | 0 | None |
| 2 | 10 000 | 300 | Urea (U) |
| 3 | 10 000 | 150 | Swine lagoon effluent (SLE 150) |
| 4 | 10 000 | 300 | Swine lagoon effluent (SLE 300) |
| 5 | 10 000 | 450 | Swine lagoon effluent (SLE 450) |
| 6 | 20 000 | 0 | None |
| 7 | 20 000 | 300 | Urea (U) |
| 8 | 20 000 | 150 | Swine lagoon |

| | | | |
|---|---|---|---|
| | | | effluent (SLE 150) |
| 9 | 20 000 | 300 | Swine lagoon effluent (SLE 300) |
| 10 | 20 000 | 450 | Swine lagoon effluent (SLE 450) |

Forage production and nutritive value were determined. Forage samples were used to evaluate DM production from the whole plant. The proportion of leaves, young stems and mature stems were determined from two plants in every experimental plot. DM, CP and OM were determined by AOAC (1980). NDF was determined following Goering and Van Soest (1970). Sample preparation for Ca, Mg and K was according to Fick *et al*. (1979) and concentration was measured in an atomic absorption spectrophotometer (GBC 901). P concentration was evaluated according to Harris and Popat (1954) in a ultraviolet light spectrophotometer (Spectronic 21). Nitrogen recovery was calculated by subtracting amounts taken up in the control treatment and dividing by the amount of nitrogen applied (Kelling *et al*., 1977). When data effects were significant ($P < 0.05$), means were separated by using the Tukey test option of the ANOVA procedure of SAS for Windows v. 6.11 (1996).

## RESULTS AND DISCUSSION

There was no density x N level interaction ($P > 0.10$) in DM production and its fractions. Therefore, only the principal effects are discussed. Total biomass yield was significantly increased ($P < 0.01$) with density, of 20.3 and 25.7 tonnes DM/ha for low and high density, respectively. This increase represents 26.6 percent more DM yield. These results are in agreement with Benavides, Borrel and Esnaola. (1986) who found that DM yield was increased when plant density per ha was higher. DM yield was significantly different ($P < 0.01$) among applications of urea and ELR compared with the control treatment. However, no significant yield difference was found between urea and ELR. Thus, N in the swine lagoon effluent was as effective as urea for forage production. Regression analysis shower a linear trend ($P < 0.01$) of total forage yield with increasing application rates of lagoon effluent. The linear equation, fitted to the control treatment and the three ELR treatments, was $Y = 17.32 + 0.021 x$, $R2 = 0.356$ where Y = total DM yield (tonnes/ha) and x = effluent N application rate (kg/ha). The 450 kg N/ha ELR produced the greatest DM yield, but it was not statistically different (15.7, 22.9, 26.0 and 26.8 tonnes/ha/year for 0, 150, 300 and 450 kg N/ha/year, respectively.

Swine lagoon effluent has been shown to be an effective nutrient source and can replace commercial fertilizer. Goat manure applied to mulberry in Costa Rica increased DM yield linearly (Benavides *et al*., 1994) and yield was higher when N was applied in the form of manure in comparison with fertilizer (Takahashi and Kronka, 1968). In agreement with this, DM yield in the present work was significantly different ($P < 0.01$) with 300 kg N as urea compared to 300 kg N as ELR (23.4 against 26.1 tonnes/ha/year, respectively).

Leaf: stem proportion (49.2: 50.8) did not change among planting densities and nitrogen level, despite yield differences. Leaf DM yield was significantly different ($P < 0.01$) among densities, 7.4 against 9.9 tonnes/ha/year. Leaf proportion decreased linearly with harvest length (Boschini, 2000).

Mineral concentrations of mulberry leaves are given in Table 2. No effects were observed ($P > 0.05$) on NDF (mean of 23.4), OM (mean of 87.1) and Ca (mean of 4.3 percent). Liu *et al.* (2000) observed higher NDF values in mulberry leaves cutting in spring and autumn, with 38.8 and 41.4 percent, respectively. Kitahara, Shibata and Nishida, (2000) reported lower Ca level (2.98 percent). There was a density x nitrogen level interaction in P concentration in leaves. Mg and K content were significantly affected (P < 0.001) by N fertilization form and level.

TABLE 2

**Mineral concentration on dry basis in mulberry leaves when fertilized with swine lagoon effluent**

| Plants/ha | N level kg/ha/y | N source | Ash % | Ca % | P % | Mg % | K % |
|---|---|---|---|---|---|---|---|
| 10 000 | 0 | | 13.2 | 3.9 | 0.35 | 0.49 | 1.52 |
| 10 000 | 300 | Urea | 13.0 | 4.1 | 0.29 | 0.56 | 1.41 |
| 10 000 | 150 | ELR | 12.9 | 4.4 | 0.29 | 0.61 | 1.24 |
| 10 000 | 300 | ELR | 13.2 | 4.5 | 0.28 | 0.58 | 1.44 |
| 10 000 | 450 | ELR | 13.2 | 4.3 | 0.29 | 0.62 | 1.43 |
| 20 000 | 0 | | 12.5 | 4.4 | 0.29 | 0.49 | 1.47 |
| 20 000 | 300 | Urea | 12.1 | 4.1 | 0.24 | 0.59 | 1.20 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 20 000 | 150 | ELR | 13.2 | 4.5 | 0.30 | 0.59 | 1.35 |
| 20 000 | 300 | ELR | 12.0 | 4.3 | 0.27 | 0.57 | 1.51 |
| 20 000 | 450 | ELR | 12.6 | 4.6 | 0.28 | 0.59 | 1.28 |
| Density | | | 0.0473 | 0.2342 | 0.0110 | 0.4762 | 0.0697 |
| N level | | | 0.3848 | 0.2226 | 0.0071 | 0.0001 | 0.0001 |
| Density x N level | | | 0.3897 | 0.3953 | 0.1134 | 0.4994 | 0.0027 |
| Standard error | | | 0.301 | 0.182 | 0.014 | 0.017 | 0.042 |

ELR = effluent loading rates.

Protein increased (P < 0.001) with ELR, with 125.7, 143.6, 150.6 and 166.6 g/kg of DM for 0, 150, 300 and 450 ELR, respectively. These values are lower than those observed by Liu *et al*. (2000) of 211 and 209 g/kg of DM in mulberry leaves harvested in spring and autumn, respectively, and by Shmidek *et al*. (2000) of 217 to 236 g/kg of DM in various *Morus* varieties. But Singh and Makar (2000) reported that on DM basis, the leaves contained between 150 and 153 g/kg of CP. Moreover, protein content in mulberry leaves differs with fertilizer level (Rodríguez, Arias and Quiñones, 1994), age at regrowth (Scarpelli *et al*., 1969) and basal or apical leaf position (Araya *et al*., 1994).

Table 3 shows nutrient recovery by mulberry plants. These recoveries were affected ($P < 0.01$) by density and N level. Nitrogen uptake by the crop is important when land application is used as a wastewater treatment system because N is removed from the soil. Thereby preventing $NO_3$-N leaching to groundwater (Liu *et al*., 1997).

TABLE 3

**Total nutrient uptake and recovery in mulberry as affected by N source and rate of swine lagoon effluent application**

| Density plants/ha | N level kg/ha/year | N source | N kg | Ca kg | P kg | Mg Kg | K kg |
|---|---|---|---|---|---|---|---|
| 10 000 | 0 | | 140.0 | 270.5 | 25.7 | 34.4 | 109.2 |
| 10 000 | 300 | Urea | 259.8 | 458.0 | 32.7 | 62.1 | 165.4 |
| 10 000 | 150 | ELR | 212.0 | 411.6 | 28.3 | 57.6 | 113.1 |
| 10 000 | 300 | ELR | 267.5 | 501.1 | 31.8 | 64.3 | 186.4 |
| 10 000 | 450 | ELR | 303.2 | 478.1 | 33.4 | 69.0 | 183.5 |
| 20 000 | 0 | | 165.5 | 361.3 | 24.1 | 40.4 | 113.6 |
| 20 000 | 300 | Urea | 286.6 | 517.0 | 31.1 | 74.2 | 176.9 |
| 20 000 | 150 | ELR | 300.8 | 562.2 | 38.6 | 74.2 | 206.3 |
| 20 000 | 300 | ELR | 337.4 | 618.5 | 39.6 | 80.8 | 195.3 |
| 20 000 | 450 | ELR | 402.5 | 695.9 | 43.3 | 88.2 | 225.1 |
| Density | | | 0.0033 | 0.0011 | 0.0401 | 0.0044 | 0.0154 |
| N level | | | 0.0001 | 0.0004 | 0.0133 | 0.0001 | 0.0007 |
| Density x N level | | | 0.6380 | 0.6558 | 0.2727 | 0.8977 | 0.1531 |

| | | | | | |
|---|---|---|---|---|---|
| Standard error | 30.385 | 54.967 | 3.649 | 7.144 | 19.504 |

ELR = effluent loading rates.

For all swine lagoon effluent treatments, the total amount of applied N recovered by the mulberry plant was higher than the N recovered by urea, but the percentage of N recovered decreased with increasing N application rates, with 90.2, 57.3 and 40.4 percent in ELR 150, 300 and 450 kg N/ha/year, respectively. N recovery was 40.4 percent with urea.

Mulberry removed large quantities of the nutrients applied in the effluent. Removal per hectare increased with higher loading rates, resulting from both higher DM yields and higher concentrations in dry matter. The application of effluent to deliver the equivalent to approximately 450 of N/ha/year, did not cause agronomic problems and represents an alternative to diminish ambient concerns about swine production.

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## Annex 1. Mulberry, an exceptional forage available almost worldwide

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## SUMMARY

Mulberry (*Morus* sp.), the traditional feed for the silkworm, has been selected and improved for leaf yield and quality in many environments and is spread throughout the world. Mulberry leaves are highly palatable and digestible (70-90 percent) for herbivorous animals and can also be fed to monogastrics. Protein content in the leaves and young stems, with a good essential amino acid profile, varies from 15 to 28 percent depending on the variety. Mineral content is high and no antinutritional factors or toxic compounds have been identified. The establishment of this perennial forage is through stakes or seed, and it is harvested by leaf picking or cutting whole branches or stems. Yields depend on variety, location (monthly temperature, solar radiation and rainfall), plant density, fertilizer application and harvesting techniques but, in terms of digestible nutrients, mulberry produces more than most traditional forages. The leaves can be used as supplements replacing concentrates for dairy cattle; as the main feed for goats, sheep and rabbits; and as an ingredient in monogastric diets.

## INTRODUCTION

Mulberry (Morus spp.) leaves have long been the traditional feed for the silkworm (*Bombyx mori*). There is evidence that sericulture started about 5 000 years ago (Yongkang Huo, South China Agricultural University, personal communication) and hence the domestication of mulberry. Mulberry has been selected and improved for leaf quality and yield over the centuries. Through silk production projects, mulberry has been taken to countries all over the world, and it has now spread from the temperate areas of northwest and central Asia, Europe and North America through the tropics of Asia, Africa and Latin America to the southern hemisphere (southern Africa and South America). There are mulberry varieties for many environments, from sea level to altitudes of 4 000m (FAO, 1990), and from the humid tropics to semi-arid lands, such as in the Near East with 250 mm of annual rainfall and the southwestern United States (Tipton, 1994). Mulberry is also produced under irrigation. Although the majority of silk production projects have had limited duration because of silk processing constraints and limited market opportunities, mulberry trees have remained in most places where they have been introduced.

The main use of mulberry globally is as feed for the silkworm but, depending on the location, it is also appreciated for its fruit (consumed fresh, in juice or as preserves), as a delicious vegetable (young leaves and stems), for its medicinal properties in infusions (mulberry leaf tea), for landscaping and as animal feed. In Peru the multiple uses of mulberry have been recognized (Zepeda, 1991). There are several countries where mulberry is utilized traditionally as a feed in mixed forage diets for ruminants, such as in certain areas of India, China and Afghanistan. In Italy there have been several studies on the use of mulberry for dairy cows and other domestic animals (Vezzani, 1938; Maymone, Tiberio and

Triulzi, 1959; Bonciarelli and Santilocchi, 1980; FAO, 1993) and in France a research project was undertaken to introduce mulberry in livestock production (Armand, 1995). But it was only in the 1980s that specific interest in the intensive cultivation and use of mulberry as animal feed started in Latin America. It is surprising that a plant that has been improved for leaf quality and yield to feed the silk worm, which has high nutritional feed requirements, has received such limited attention from livestock producers, technicians and researchers.

Like several significant breakthroughs in science and technology, the discovery of the value of mulberry as a high-quality feed in Latin America happened serendipitously. A Costa Rican farmer of Chinese origin, whose silk project had failed, fed mulberry leaves to his goats and was impressed by the palatability of the leaves and by the performance of his animals. He communicated his observations to scientists at the Tropical Agriculture Research and Training Center

(CATIE), who were receptive to the farmer's news and forward thinking enough to include mulberry in their tree fodder evaluations and later in agronomic and animal performance trials (J. Benavides, personal communication). In Africa, the International Centre for Research in Agroforestry (ICRAF) in Kenya and the Livestock Production Research Institute in the United Republic of Tanzania have also conducted successful agronomic and animal trials by themselves, apparently without being aware of the interest elsewhere.

## Genetic resources

Mulberry belongs to the Moraceae family (subtype angiosperms; class dicotyledons; subclass urticales) and there are several species: *Morus alba, M. nigra, M. indica, M. laevigata, M. bombycis*, etc. which have been used directly, or through crossings and induced mutations, for the development of varieties to support silkworm production. The diploid *M. alba* (2n=2x=28) is the species most widely spread, but polyploid varieties, which originated in various research stations in Asia, show greater leaf yields and quality. In general, polyploid varieties have thicker and larger leaves of a darker green colour, and produce more leaves. There is a large variation in leaf production and in leaf quality (e.g. protein content) among the many species and in the varieties and cultivars grown at different locations under a wide range of soil and environmental conditions, indicating the huge potential for identifying suitable germoplasm for most sites. Many of the references on mulberry in the literature do not specify which species or varieties were used. Names are often given based on leaf features. In many cases, locally grown varieties (native or criolla) seem to perform adequately, since they are probably well adapted to local conditions.

TABLE 1

## Chemical composition (percentaje of dry matter) of mulberry

| Variety | CP | CF | NDF | ADF | EE | Ash | Ca | P | Reference |
|---|---|---|---|---|---|---|---|---|---|
| *Leaf* | | | | | | | | | |
| Hebba[l] | 15.9 | 12.6 | | | 7.1 | 15.9 | 2.42 | 0.24 | Narayana & Setty, 1977 |
| Izatnagar[1] | 15.0 | 15.3 | | | 7.4 | 14.3 | 2.41 | 0.24 | Jayal & Kehar, 1962 |
| Palampur[1] | 15.0 | 11.8 | | | 5.1 | 15.5 | | | Singh *et al*., 1984 |
| Parbhani[1] | 22.1 | 5.9 | | | 3.9 | 13.4 | 3.3 | 1.43 | Deshmukh *et al*., 1993 |
| Kanva-2 | 16.7 | 11.3 | 32.3 | | 3.0 | 17.3 | 1.80 | 0.14 | Trigueros |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | & Villalta, 1997 |
| Mpwapwa[1] | 18.6 | | 24.6 | 20.8 | | 14.3 | | | Shayo, 1997 |
| Dominican | 20.0 | | | 23.1 | 4.0 | 4.5 | 2.70 | | ITA#2, 1998 |
| Criolla | 19.8 | | | | | | 1.90 | 0.28 | Espinoza *et al*., 1999 |
| Tigreada | 21.1 | | | | | | 2.74 | 0.38 | |
| Indonesia | 20.1 | | | | | | 2.87 | 0.33 | |
| *Leaf & young stem* | | | | | | | | | |
| Tigreada | 27.6 | 13.2 | | | | 10.4 | | 0.20 | González *et al*., 1998 |
| Indonesia | 24.3 | 15.3 | | | | 11.2 | | 0.29 | González |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | *et al*., 1998 |
| Criolla | 27.6 | 16.9 | | | | 11.8 | | 0.26 | González *et al*., 1998 |
| Acorazonada | 25.2 | 14.1 | | | | 13.4 | | 0.15 | González *et al*., 1998 |
| Koruso 21[2] | 11.0 | 10.0 | 22.0 | 20.6 | 5.9 | 13.9 | 3.13 | 0.37 | Casoli *et al*., 1986 |
| Koruso 21[3] | 8.0 | 11.8 | 24.7 | 24.5 | 5.3 | 19.3 | 4.76 | 0.37 | Casoli *et al*., 1986 |
| *Young stem* | | | | | | | | | |
| Criolla | 11.3 | | | | | | 1.33 | 0.29 | Espinoza *et al*., 1999 |
| Tigreada | 11.7 | | | | | | 1.38 | 0.33 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tigreada | 11.7 | | | | | | [illegible] | [illegible] | |
| Indonesia | 11.9 | | | | | | 1.53 | 0.43 | |
| Dominican | 4.7 | | | 48.2 | 1.7 | 1.3 | 1.61 | | ITA No.2, 1998 |
| Stem | | | | | | | | | |
| Dominican | 3.8 | | | 50.2 | 1.0 | 1.8 | 1.10 | | ITA No.2, 1998 |
| Mallur | 11.5 | 34.0 | | | 2.7 | 9.32 | 1.56 | 0.20 | Subba Rao *et al*., 1971 |
| Bark | | | | | | | | | |
| Mpwapwa | 7.8 | | 46.8 | 36.9 | | 6.1 | | | Shayo, 1997 |
| Whole plant | | | | | | | | | |
| Dominican | 11.3 | | | 34.4 | 1.6 | 1.9 | 2.10 | | ITA No.2, 1998 |

[1] Names of places where local varieties were used.

[2] September 1982.

[3] November 1983.

## Composition and nutritive value

The results of chemical composition of mulberry fractions from various authors are given in Table 1. Crude protein content in leaves varies from as low as 15 percent to 28 percent depending on the variety, age of the leaves and growing conditions. In general, crude protein values can be considered similar to most legume forages. Fibre fractions are low in mulberry leaves compared with other foliages. Shayo (1997) reported lignin (acid detergent lignin) contents of 8.1 percent and 7.1 percent for leaves and bark, respectively. A striking feature of mulberry leaves is the mineral content, with ash values up to 25 percent. Typical calcium contents are around 1.8 to 2.4 percent and phosphorus 0.14 to 0.24 percent. Espinoza, Benavides and Ferreire, (1999) found potassium values of 1.90-2.87 percent in leaves and 1.33-1.53 percent in young stems, and magnesium contents of 0.47-0.63 percent for leaves and 0.26-0.35 percent for young stems.

Table 2 shows the digestibility of mulberry. As can be seen, leaf digestibilities *in vivo* (goats) and *in vitro* are very high (>80 percent) and total digestibility is equivalent to that of most tropical forages. The degradation characteristics of mulberry, determined by the nylon bag technique, are presented in Table 3. Leaves would be completely degraded if they remained in the rumen for enough time (Maymone, Tiberio and Triulzi, 1959).

TABLE 2

**Digestibility of mulberry**

| Method | Fraction | Digestibility (%) | Reference |
|---|---|---|---|
| *In vivo* (*goats*) | Leaf | 78.4-80.8 | Jegou *et al*., 1994 |
| *In vitro* | Leaf | 89.2 | Araya, 1990, cited by Rodríguez *et al*., 1994 |
| | Leaf | 80.2 | Schenk, 1974, cited by Rodríguez *et al*., 1994 |
| | Leaf | 89-95 | Rodríguez *et al*., 1994 |
| | Stem | 37-44 | Rodríguez *et al*., 1994 |
| | Total | 58-79 | Rodríguez *et al*., 1994 |
| | Leaf | 82.1 | Shayo, 1997 |
| | Bark | 60.3 | Shayo, 1997 |

The average amino acid composition and N content of 119 mulberry varieties grown experimentally in Japan (Machii,

1989) are shown in Table 4. Tryptophane was not included in the analysis. As can be seen from the data, essential amino acids are over 46 percent of total amino acids. It can be calculated from the table that the average nitrogen (N) is 16.6 percent of the total molecular weight of the mulberry amino acids (plus ammonia), and thus the converting factor from N to mulberry protein is 6.02. The 204.3 mg of amino acids per g of protein is equivalent to 3.47 percent N, which is 80 percent of total N in mulberry leaves. Once tryptophane is subtracted, the difference, a non-protein fraction, is likely to be composed of nucleic acids and other unidentified N compounds.

The most important protein in mulberry leaves, as in most leaves, is ribulose-1.5-bisphosphate carboxylase (RuBisCO) whose active site is responsible for carbon fixation (Kellogg and Juliano, 1997). Nitrogen in RuBisCO can be 43 percent of the total nitrogen in mulberry (Yamashita and Ohsawa, 1990).

TABLE 3

## *In sacco* degradation of mulberry

| Fraction | Parameter | | | | Reference |
|---|---|---|---|---|---|
| | a | b | a + b | c | |
| Leaf | 35.7 | 64.0 | 99.7 | 0.0621 | ITA No.2, 1998 |
| Whole plant | 30.4 | 46.2 | 76.6 | 0.0667 | ITA No.2, 1998 |
| Leaf & young stem | 27.8 | 48.95 | 76.8 | 0.0300 | González *et al*., 1998 |

TABLE 4

## Amino acids and N content of mulberry varieties (Machii, 1989) and soybean meal

| Compound | Soybean meal | Mulberry |
|---|---|---|

| Compound | Soybean meal | | Mulberry | | |
|---|---|---|---|---|---|
| | **content (mg/g DM)** | **%1** | **Content (mg/g DM)** | **SD** | **%1** |
| Non essential amino acids | n.a.[2] | | 108.93 | | 53.3 |
| Essential amino acids (EAA): | | | | | |
| Lysine | 32.92 | 6.7 | 12.33 | 2.58 | 6.0 |
| Methionine | 7.30 | 1.5 | 2.99 | 0.61 | 1.5 |
| Threonine | 20.34 | 4.1 | 10.52 | 1.75 | 5.2 |
| Valine | 26.29 | 5.3 | 12.83 | 2.17 | 6.3 |
| Isoleucine | 26.85 | 5.4 | 10.04 | 1.88 | 4.9 |
| Leucine | 39.55 | 8.0 | 19.45 | 3.10 | 3.1 |
| Tyrosine | 14.38 | 2.9 | 7.40 | 1.39 | 3.6 |
| Phenylalanine | 25.51 | 5.2 | 12.26 | 2.06 | 6.0 |
| Histidine | 12.92 | 2.6 | 4.61 | 0.82 | 2.3 |

| | | | | | |
|---|---|---|---|---|---|
| Trytophane | 6.97 | 1.4 | na[2] | - | - |
| Total EAA | 213.03 | 43.1 | 92.43[3] | - | 45.3 |
| Ammonia (NH3) | na[2] | | 2.89 | 0.54 | 1.4 |
| Total (AA + NH3) | 494.38 | 100 | 204.25 | | 100 |
| Nitrogen (percent) | 7.91 | | 4.36 | 9.63 | |

[1] Percentage of the amino acid in the total sum of amino acids (plus ammonia).

[2] Not available. [3] Without Tryptophane

**Source:** [4] Machii, 1989; [5] NRC, 1984.

***Palatability***. One of the main features of mulberry as forage is its high palatability. Small ruminants avidly consume the fresh leaves and the young stems first, even if they have never been exposed to it before. Then, if the branches are offered unchopped, they may tear them off and eat the bark.

Cattle consume the whole biomass if it is finely chopped.

There is a report (Jegou, Waelput and Brunschwig, 1994) of ad libitum DM intake of 4.18 percent of liveweight (average of three lactating goats), which is much higher than in other tree fodders. Jayal and Kehar (1962) reported DM intakes of mulberry leaves of 3.44 percent of body weight in sheep under experimental conditions. Animals initially prefer mulberry over other forages when they are offered simultaneously, and will even dig through a pile of various forages to look for it (Antonio Rota, FAO Barbados, personal communication). In a comparative study, Prasad and Reddy (1991) reported higher daily dry matter intakes of mulberry leaves in sheep than in goats (3.55 against 2.74 kg DM/100 kg body weight).

## Agronomy

***Establishment.*** The most common planting method worldwide is by stem cuttings, but in certain places seed is preferred. As is the case with other tropical perennial forages for cut-and-carry systems, planting by seed assures deeper roots with a greater capacity to find water and nutrients that eventually results in higher biomass production and greater longevity. Seeds might be the most acceptable way of transporting, quarantine and store selected materials. The advantages of stem reproduction (cloning) are certainty of production characteristics, practicality in obtaining material and ease of planting. Male plants might be preferred when introducing foreign germoplasm to new locations since this prevents involuntary expansion (Morgan P. Doran, University of California, Davis, United States, personal communication). As in most perennial forages, the time and the establishment cost (mainly for land preparation, planting and weed control) are critical for the successful introduction of mulberry.

***Cultivation***. Mulberry is cultivated for fruit as isolated trees or in orchards; for small-scale silkworm rearing along boundaries or along food crops in mixed farming systems; for large silk projects or for intensive forage production in pure stands; and also for forage in association with N-fixing legumes (FAO, 1993; González and Mejía, 1994). Mulberry is also found mixed with other trees in natural forests or plantations.

***Fertilization***. All the required nutrients for mulberry growth must come from the soil, since mulberry does not fix atmospheric nitrogen. In pure stands, mineral and organic fertilizers (animal and vegetable manures) must be used to replenish the nutrients removed with the foliage in order to maintain a sustainable production. The association with legumes with effective N-fixing rhizobium can reduce N inputs and may be the most desirable combination for some farms, but even when recycling nutrients in animal manures, extra chemical fertilizers are required for maximum yields (J.E. Benavides, personal communication). Responses of mulberry to N fertilizers have been clearly demonstrated, both in inorganic and organic forms, with better responses to the latter (Table 5). According to Kamimura *et al*. (1997), the nitrogen level in soils is the major factor for mulberry growth.

***Harvest and preservation***. For silkworm feeding, individual leaf picking, shoot harvesting and whole branch cutting are practised, depending on the feed requirements of the silkworm larvae stages and harvesting costs (FAO, 1988). For silkworms, leaves are offered fresh some other forms of feeding are being developed. For ruminant feeding, the preferred method has been branch cutting by hand, although mechanical harvesting could be employed in the future for direct feeding of fresh material on a large scale, for processing or for drying. Forage conservation by ensiling has been successfully achieved (Vallejo, 1995; González, 1996, cited by Benavides, 1999) and there have been some preliminary studies on leaf drying (Ojeda *et al*., 1998). Leaf blades dry within hours under full sun but more time is required for petioles and stems. Some conditioning (e.g. passing through rollers) may help to reduce water content and minimize the deterioration of leaf quality by over exposure. Diploid varieties dry more quickly since they tend to have more stomata per unit of leaf area (Govindan, Narayanaswamy, 1988).

TABLE 5

**Effect of goat manure or ammonium nitrate application on total DM yields during three consecutive years**

| **Year** | **Level of manure (tonnes DM/ha/year)** | | | | **$NH_4NO_3$** |
|---|---|---|---|---|---|
| | 0 | 240[1] | 360[1] | 480[1] | 480[1] |
| 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 the same letter horizontally do not differ (P >0.001).

***Yields.*** The production of leaf and total DM per hectare of mulberry depends on the variety, the location, plant density, fertilizer applications and harvesting techniques. Table 6 gives the yields of mulberry in various locations. Total biomass yield and leaf proportion vary with species and varieties. Climate (moisture and solar radiation) and soil fertility are determining factors on productivity (Espinoza, Benavides and Ferreire, 1999). Increasing planting density increases leaf yields (Gong, Ren and Wang, 1995).

Fresh leaf yields of 40 tonnes/ha/year (approximately 10 tonnes of dry matter) have been reported in India (Mehla, Patel and Tripathi, 1987) and in Costa Rica (Espinoza, Benavides and Ferreire, 1999). Maximum dry matter yields of edible material (leaves and young stems) and total biomass were 15.5 and 45.2 tonnes/ha/year, respectively. Total leaf DM yields of less than 10 tonnes could be expected under less intensive production.

TABLE 6

**Examples of mulberry yields**

| Location | Variety | Fraction | Yield (tonnes/ha/year) | | Reference |
|---|---|---|---|---|---|
| | | | Fresh | DM | |
| Karnataka, India | M-5 | Leaf | 40 | | Mehla *et al*., 1987 |
| | | Stem | 52 | | |
| Mpwapwa, | Local | Leaf | | 8.5 | Shayo, |

| | | | | | |
|---|---|---|---|---|---|
| Tanzania | | | | | 1997 |
| | | Stem | | 14.1 | |
| | | Bark | | 2.7 | |
| San José, Costa Rica | Tigreada | Leaf and young stem | | 11.0 | Espinoza *et al.*, 1999 |
| | Indonesia | Leaf and young stem | | 8.7 | |
| Puntarenas, Costa Rica | Tigreada | Leaf and young stem | | 13.4 | |
| | Indonesia | Leaf and young stem | | 12.5 | |
| Matanzas, | Tigreada | Total | 30 | | González |

| | | | | | |
|---|---|---|---|---|---|
| Cuba | | biomass | | | *et al*., 1998 |
| | Acorazonada | Total biomass | 33 | | |
| | Indonesia | Total biomass | 26 | | |
| | Local | Total biomass | 30 | | |
| Cuyutla, Guatemala | Local | Total biomass | 37 | | Rodríguez *et al*., 1994 |
| | | Leaves | 16 | | |
| Zhenjiang, Jiangsu, China | Shin Ichinose | Leaves | 32 | | Gong *et al*., 1995 |
| | | Branches | 28 | | |
| | | Stems | 8 | | |
| Kalimpong, | Local | Leaves | 22 | | Tikader *et* |

| | | | | | |
|---|---|---|---|---|---|
| W. Bengal, India | | | | | *al*., 1993 |
| | BC 259 | Leaves | 20 | | |
| | TR 10 | Leaves | 19 | | |
| | C 763 | Leaves | 19 | | |

## ANIMAL PERFORMANCE WITH MULBERRY

### Ruminants

Although the feeding value of mulberry for dairy cattle has been recognized for some time in Italy (Vezzani, 1938; Maymone, Tiberio and Triulzi, 1959) and it has been traditionally used in Himalayan countries, research on mulberry for ruminants has been rather limited. Jayal and Kehar (1962), given on the high digestibility values of *M. indica* leaves, suggested that they could be used as supplements for lower-quality forages. Mulberry was used to replace grain-based concentrates in lactating cows with excellent results (Table 7). Yields did not significantly decrease when 75 percent of the concentrate was replaced with mulberry. Milk production increased with the levels of mulberry offered to goats on a King grass diet (Rojas and Benavides, 1994) as shown in Figure 1. At CATIE, Turrialba, Costa Rica, a module of two dairy goats (Saanen x Toggenburg), fed exclusively with forage from 775 $m^2$ of mulberry (17 000 plants/ha), in association with *Erythrina berteroana* (5 128 trees/ha) just as green manure, and from 425 $m^2$ of King grass, produced an average of four litres per day, equivalent to over 12 000 litres per ha/year (Oviedo, Benavides and Vallejo, 1994).

TABLE 7

**Substitution of concentrates by mulberry in lactating Holstein cows grazing Kikuyu grass** (*Pennisetum* *clandestinum*)

| **Parameter** | **Concentrate: Mulberry** | | |
|---|---|---|---|
| | **100:0** | **60:40** | **25:75** |
| Milk yield (kg/d) | 14.2 | 13.2 | 13.8 |
| Intake (kg MS/d): | | | |
| Concentrate | 6.4 | 4.2 | 1.9 |
| Mulberry | 0 | 2.8 | 5.5 |
| Kikuyo grass | 9.3 | 7.8 | 6.2 |
| Total | 15.7 | 14.8 | 13.6 |

**Source**: Esquivel et al., 1996.

Also in Costa Rica, liveweight gains of bulls belonging to the Romosinuano breed (a criollo type) fed Elephant grass, increased to over 900 g/day when mulberry was offered as a supplement at 1.7 percent of their body weight on a DM basis (González, 1996, cited by Benavides, 1999). Table 8 presents the results of an experiment in Guatemala with growing Zebu x Brown Swiss steers being fed increasing levels of mulberry as a supplement to a sorghum silage diet (Velázquez *et al*., 1994).

**Figure 1. Milk yield and forage intake in goats fed increasing levels of mulberry on a King grass diet (Rojas & Benavides, 1994)**

**Source:** Rojas and Benavides, 1994.

Although the growing rates with the highest mulberry level are not impressive (195 g/day), most likely because of the poor quality of the silage, this trial shows the high nutritive value of the supplement. Total intake and weight changes improved with the amount of mulberry offered reflecting its higher nutritive value compared to the basal diet. Daily gains of female calves (0-4 months) were not affected when mulberry leaves were offered ad libitum and the commercial concentrate reduced to 25 percent of the amount traditionally used (González and Mejía, 1994). In lambs, gains reached 100 g/day when King grass was supplemented with 1.5 percent dry matter of mulberry (Benavides, 1986).

## Monogastrics

The silkworm has a relatively simple digestive system. In some ways it is comparable to that of monogastric animals, so that, in theory, mulberry leaves could also be used at least as one of the ingredients in monogastric diets. In a trial with growing pigs in which a commercial concentrate was replaced by up to 20 percent of mulberry leaf (Trigueros and Villalta, 1997), the best level of substitution was 15 percent. It increased daily gains from 680 g/day ith only concentrates, to 740 g/day and also gave the best economic results. In rabbits, the reduction of concentrate offered daily from 110 to 17.5 g with ad libitum fresh mulberry only reduced gains from 24 to 18 g/day, but decreased to more than half the cost of the meat produced (Lara y Lara, Sanginés and Dzib, *et al*., 1998). The combination of mulberry and *Trichantera gigantea* leaves, as the protein source, and blocks made of molasses, cassava root meal and rice bran, as the energy source, gave better reproduction and growth performance than a diet of commercial concentrates and grass (Le Thu Ha *et al*., 1996). Singh, Goel and Negi (1984) supplemented Angora rabbits, receiving pelleted diets, with mulberry leaves ad libitum and obtained intakes of mulberry equivalent to 29-38 percent of the total intake. This level significantly reduces feed cost. Deshmukh, Pathak and Takalikar (1993) fed mulberry leaves as the sole ration for adult rabbits. These authors found daily intakes of 68.5 g for dry matter, 11.2 g for crude protein and 175 kcal for digestible energy (equivalent to 2.55 Mcal of digestible energy per kg). The digestibility values were 74 percent for crude protein, 59 percent for crude fiber and 64 percent for dry matter. The authors concluded that mulberry leaves provided enough nutrients for maintenance. Narayana and Setty (1977) found better egg yolk colour and increased egg size and production with the inclusion (up to 6 percent) of shade-dried *M. indica* leaf meal in the mash of laying hens.

TABLE 8

**Effect of mulberry supplementation level on intake and weight changes of Zebu x Brown Swiss steers fed on sorghum silage**

| **Parameter** | **Mulberry level (% BW[1])** | | | |
|---|---|---|---|---|
| | **0** | **0.5** | **1.0** | **1.5** |
| DM intake (percent BW/day | | | | |
| Total | 2.26 | 2.39 | 2.64 | 2.88 |
| Sorghum silage | 2.26 | 1.91 | 1.68 | 1.51 |

| | | | | |
|---|---|---|---|---|
| Daily gains (g/d) | - 128 | - 29 | 164 | 195 |

[1] BW = Body weight.
**Source**: Velázquez, et al., 1994.

Other small herbivores, such as guinea pigs, iguanas and snails, could also be fed mulberry leaves. In fact, wild green iguanas (*Iguana iguana*) came to feed on recently established mulberry fields in Costa Rica (J.E. Benavides, personal communication).

## LIVESTOCK PRODUCTION SYSTEMS

The traditional way of using mulberry as animal feed in silkproducing areas is by providing ruminants with the residue left by the silkworm. A model of sericulture and milk production has been proposed by Mehla, Patel and Tripathi (1987), in which dairy cows receive mulberry residue and concentrates. The generation of edible protein and employment are much greater than with food grains. This refuse material is added to fish ponds for herbivorous carps in the Chinese dyke-pond system, which is one of the most intensive agricultural low-input systems in the world, and generates food and outputs for a large number of people (Korn, 1996). In these silk areas, as well as where mulberry grows wild, cut-and-carry systems are practised and it is the most obvious way of utilizing mulberry for livestock, either from pure stands or from associations with legumes (Benavides, Esquivel and Lozano, 1995). Mulberry foliage can constitute the supplement to low-quality forage (grass) based diets or as the main component of the ration.

A natural association of mulberry and livestock occurs in regions such as the Near East and Central Asia where mulberry trees are kept for fruit production. Fallen leaves in the autumn are consumed by domestic animals. Since fruit ripens in late spring or early summer, it may be possible to harvest leaves for forage one or more times before the winter.

The only suggestion of utilizing mulberry for direct grazing came from FAO (1993), proposing a complementary association with clover (*Trifolium subterraneum*) for sheep and cattle grazing in Tuscany (Italy). Mulberry benefits from the N fixation by the clover and contributes with high-quality forage during the summer. The association produces more forage over a longer period than the individual pure stands.

## CONCLUSION

The net result of the long selection and improvement of mulberry has been that it is comparable or better than many other forage plants in terms of nutritional value and yield of digestible nutrients per unit of area, especially in tropical environments. Yield, quality and availability worldwide make mulberry a very important option for intensifying livestock systems, especially in those places where enough nutrients can be applied to obtain maximum response in biomass production. The high mineral content of mulberry foliage should be specifically taken into account in nutrient recycling and fertilizing schemes to prevent loss of soil fertility.

Considering its high quality and palatability, mulberry should be relatively more valuable as a feed, the smaller are the animals. Under equal circumstances, stock with higher nutrient requirements (per kg of liveweight) should be given preference when feeding mulberry.

The greatest immediate impact of mulberry in animal production would be in tropical areas if introduced as a supplement for lactating cows and as feed for growing calves. It could be grown near stables where simple harvesting and manuring practices could be implemented.

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# Annex 2. Utilization of mulberry in animal production systems

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## 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; Cubillos, Vonhout and Jiménez, 1975) and by land and capital limitations predominant in most small farms (Ávila, Navarro and Lagemann, 1982).

Apart from the socio-economic aspects, the later is related to the type of agricultural technology historically practised in Central America from the times of Spanish colonization. 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 Society, 1992; Skerman and Riveros, 1992). This indicates that the natural vegetation looked very different then compared to how it does now.

Spanish colonial settlement implied the introduction of land use technologies imported from temperate areas, such as the plough and grasses to feed farm animals (Meza and Bonilla, 1990; Tosi Jr and Voertman, 1977). These technologies, still in use, have contributed significantly to the loss of natural soil cover and biodiversity. This has also prevented the rational utilization of forests aiming at questionable productivity in the medium and long term. In relation to traditional livestock keeping, "... it is little encouragement, for the grass pasture experts, to realize 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, Cameron and Riveros, 1991). The establishment of agricultural areas in virgin land has been part of a process, that 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 1950s, more than 50 percent of forests have been substituted by migratory agriculture or by grasslands (Collins, 1990; UNESCO, 1979; National Geographic Society, 1992) which, in most cases, are in scattered plots belonging to small farms, or have low carrying capacity on large farms (Collins, 1990). In Central America, without large amount of inputs and labour, the productivity of grasslands cannot be maintained. This is partly due to invasion of autochthonous woody plants as to what - "... while man insists in keeping grassland, natures fights for establishing forests" (Skerman and Riveros, 1992).

The question then arises would have happened in the American tropics if, instead of introducing the plough and 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? Research on forage trees and shrubs, in particular that on mulberry, aims to give a partial response to this question.

The above considerations, added to small- and medium-size farmers' lack of access to appropriate production technologies; high population growth; and other aspects related to the socio-economic situation of Central America, indicate the necessity for novel solutions that will allow substantial changes to be made in current production practices. In this changing process, the development of technologies more suited to the ecological and socio-economic conditions of the region 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 has been practised among producers in Central America for decades. This empirical knowledge about forage properties of various species is of great value for science. In several studies to characterize production systems, producers report a large number of species for browsing and for cut-and-carry systems with animals in confinement (Ammour and Benavides, 1987; Arias, 1987). The more systematic recognition of these resources is the aim of the research on forage trees carried out in Central America, part of which is reported in this article.

Studies on the subject have been oriented towards valuation of trees and shrubsas a source of forage 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 above traditional forages from the point of view of its nutritional value, its yield or its agronomic versatility. To qualify, these requirements are: i) nutritional content and intake that will allow animal performance improvements; ii) resistance to repeated pruning/harvesting; and iii) high biomass yields per unit area. Apart from these features, it is advisable to select native species to take advantage of their adaptation to the environment, and species that can easily be 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 coast of Costa Rica and in the Petén of Guatemala; in semi-arid areas near 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 1 000 m in the high plateaus of Guatemala and Costa Rica (Hernández and Benavides, 1993; Araya *et al*., 1993; Mendizábal *et al*., 1993; Godier *et al*., 1991).

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

The information provided by producers has also allowed simple and easy to implement agronomic management practices to become known. Examples are the woody forages identified in the western Plateau of Guatemala where, in most cases, propagation is carried out by vegetative means (stem cuttings) with which a faster biomass can be obtained compared with sexual seed (Ruiz, 1992).

The forage from most of these woody forages shows CP 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 with 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*. Their leaves, with more than 30 percent CP and 75 percent IVOMD, are edible. Also outstanding in nutritive value are two species of the Moraceae family, mulberry (*Morus* spp.) and Amate (*Ficus* spp.) 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* spp.), White Tora (*Verbesina turbacensis*) and Purple Tora (*V. myriocephala*). All of these have CP higher than 20 percent and IVOMD higher than 70 percent (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 percent with lactating goats (Benavides, 1993). In other work, acceptability has been sought in forage 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 and Benavides, 1993; Reyes and Medina, 1993).

Both Poró and Black Wood (*Gliricidia sepium*), are legumes characterized by high CP content, but with lower IVOMD

(Benavides, 1991). In these cases, research has shown that energy supplementation significantly improves animal performance (Benavides and Pezo, 1986) and that starch sources give a better response than simple sugars (Samur, 1984).

With 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 commercial concentrates. With these species, intakes higher than 5 percent of body weight are reported. With mulberry foliage, increasing weight gains have been observed when raising its proportion in the diet (Rojas, Fuentes and Benavides, 1994; López *et al*., 1993).

Of the known technologies, vegetative propagation is the most used, since it shortens the establishment period, is easy to carry out and widely known by producers. Germination percentage exceeds 95 percent, when stem cuttings of mulberry and Amapola are used in humid tropical conditions (Araya and Benavides, 1992; Benavides, 1993; López *et al*., 1993a,b). With the Yellow Sauco, nursery planting of stakes and further transplanting seem to be the most suitable propagation method (Araya and Benavides, 1992). In some species it 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 about 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 utilized. Results of an experiment under humid tropical conditions, using King grass (*Pennisetum purpureum* x *P. typhoides*) with Poró with no nutrient replenishment and all biomass removed showed that grass yields are not reduced by the presence of the tree, since tree pruning reduces competition for light. It was also found that digestible nutrient yields per area were triple compared with the grass alone. Nevertheless, in the short term for the grass and in the medium term for Poró, productivity declines because of lack of nutrient replenishment (Benavides, Rodríguez and Borel, 1989).

The other way is to utilize associated Poró foliage as green manure for the grass. In the humid tropics, grass yields improved when increasing amounts of Poró foliage were applied. At the same time, the sole presence of the tree, even without pruning, stimulated grass growth compared with grass in a monoculture without trees (Libreros *et al*., 1994a,b).

Traditionally in livestock husbandry, there is an unidirectional relationship between animals and plants, the first benefiting by obtaining the feed, but without contributing to its generation. In confined systems, it is possible to establish a two-way relationship, since most manure can be used as fertilizer. In this way a more balanced system can be established and the plants will benefit from the animal excreta. This particularly applies to those woody species and the best forage features. With their high biomass yields and without being able to fix nitrogen, they require high levels of fertilizer applications. In order to find a rational ecological solution, goat manure has been applied to Amapola and mulberry plantations. The yields have been 18 and 30 tonnes of dry matter per ha, respectively. With mulberry, yields increase over years (Benavides *et al*., 1993).

Of great importance, in sites with bimodal rainfall pattern, are tree-pruning techniques that allow abundant biomass production during the dry season. 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 stopping flowering, results in increasingly higher biomass yield during the dry period (Hernández, 1988). Similar results were obtained by other authors working with Amapola and Jocote (*Spondias purpurea*) (Rojas, Vallejo and Benavides, 1992).

To date, most of the technologies have been implemented in small farms and in goat production systems oriented towards family consumption. In these situations, in addition to the technological aspects, it is essential to know the economic viability of the alternatives developed, both at the station and on the 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, indicates that the application of forage tree technologies on the farm is profitable and contributes to improving 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) as a supplement is more profitable than the use of concentrates, despite higher yields with the latter (Gutiérrez, 1985). Total cost of DM, from planting to feeding in some forage species nutritionally comparable with commercial concentrates, is lower (Rojas, 1992). This in part explains 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 family subsistence units, high profitability has been found when family labour is not considered, even with animal reproductive problems present (Martínez & Froemberg, 1992).

## Environmental impact of introduced technologies

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

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. Over three years, in a site with a steep slope and serious erosion problems, two types of Amapola plantation were established (Amapola in high density, in contour lines associated with low grass and Amapola in more separate contour lines associated with maize) and were compared with a traditional maize crop (bare soil). Soil loss was much less in the Amapola plantations (Faustino, 1992).

## MULBERRY

### Background

Mulberry is a shrub or a tree traditionally used for feeding the silkworm in various countries. It belongs to the Urticales order, Moraceae family and genus *Morus*. The better known species, *M. alba* and *M. nigra*, seem to have originated in the Himalaya's foothills (FAO, 1990). In Mulberry has excellent nutritional value as forage. Benavides (1991) reported CP values higher than 20 percent and IVOMD above 80 percent.

The literature gives the following climatic ranges for mulberry cultivation: temperature between 18 and 30°C; rainfall between 600 and 2 500 mm; photoperiod between 9 and 13 hours/day; and relative humidity between 65 and 80 percent (FAO, 1988). Currently its cultivation is reported from sea level to 4 000 m, and it is reproduced by seed, stakes and grafting (FAO, 1990).

In Spain, mulberry was recommended for planting in association with other crops such as maize, potatoes, vegetables, alfalfa and fruit-trees, controlling spacing and pruning to avoid light competition. Some authors recommend planting at 80 cm between plants and rows (González, 1951). In other publications, densities of 30 000 plants per ha for low pruning (below 70 cm); 7-12 000 plants for medium pruning (70-170 cm); and between 2 250 and 6 000 plants for high pruning (above 170 cm) are mentioned (FAO, 1988).

The available yield information is almost exclusively on leaves, since they are used to feed the silkworm. In France, fresh leaf 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 trunk diameter (Secretain and 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 tonnes of human faeces and

300 kg of ammonium sulphate, fresh leaf production can reach 13 tonnes/ha/year (FAO, 1988). In Paraguay, leaf yields of 20 000 kg/ha have been obtained in four year plantation harvesting at 30 cm from the surface (Narimatsu and Kiyoshi, 1975).

With widely spaced plants in Turrialba (Costa Rica) a yield of 2.32 kg of DM per plant was calculated per year, cutting at a height of 50 cm. Cutting at 1 m, the yield decreased to 2.16 kg. However, leaf production was 1 kg for both cutting heights. With cuts every 60, 120 and 180 days, total DM production was 1.64, 2.17 and 2.86 kg/plant/year, respectively. However, leaf production declined from 1.11 to 0.84 kg between 60 and 180 days (Benavides, Borel and Esnaola, 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 since the plant has characteristics that are is found in very few others: high levels of CP and high levels of digestible energy. Mulberry is also notable for its good mineral content and particularly for 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 Inemfluensis*) | 22.3 | 8.9 | 54.9 |
| Commercial concentrate | 91.5 | 17.7 | 85.0 |

**Source**: Espinosa, 1996.

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

TABLE 2

## Site and nitrogen fertilization effects on leaf DM content in three Mulberry (*M. alba*) varieties in Costa Rica

| 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 | $29.1^{b}$ |

| | | | | |
|---|---|---|---|---|
| | | | | [illegible] |
| Mean[2] | $29.1^{b}$ | $31.2^{a}$ | $28.3^{c}$ | |

[1] ammonium nitrate

[2] values with the same letter are not statistically different. $P < 0.05$.

**Source**: Espinosa, 1996.

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

TABLE 3

**Site and nitrogen fertilization effects on woody stem DM content in three mulberry (*M. alba*) varieties in Costa**

**Rica**

| 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 the same letter are not statistically different. $P < 0.05$.

TABLE 4

**DM content of mulberry (*M. alba*) by soil manure application**

| **Fraction % 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 are not statistically different. $P < 0.001$.
**Source**: Benavides, Lachaux and Fuentes, 1994.

Mulberry leaves have high levels of CP and IVOMD when compared with other ruminant feeds. Data from Central America indicate CP values between 15-25 percent and IVOMD between 75 and 90 percent, which indicate a quality with comparable or superior to commercial concentrates (Table 5). Non-lignified stems also have a good nutritional quality, with CP values of 7-14 percent and IVOMD of 56 and 70 percent (Benavides, Lachaux and Fuentes, 1994; Espinoza, 1996; Rojas, Benavides and Fuentes, 1994)

As was the case for DM, CP and IVDMD are similar among varieties and are not much affected by fertilization or by cutting frequency (Tables 6, 7, 8, 9, 10 and 11) although an effect was observed on the CP content of leaves and young stems when ammonium nitrate was added instead of goat manure at iso-nitrogenous levels (Table 9).

TABLE 5

**Site and nitrogen fertilization effect on crude protein in three mulberry (*M. alba*) varieties in Costa Rica**

| **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 | $20.4^{a}$ |

| | | | | |
|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | 20.4[a] |
| 540 | 20.0 | 21.6 | 20.6 | 20.7[a] |
| Average | 19.8[a] | 21.1[a] | 20.1[a] | |

Source: Espinoza, 1996.

TABLE 6

**Site and nitrogen fertilization effect on crude protein of young stem in three mulberry (*M. alba*) varieties in Costa Rica**

| **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] |

| | | | | |
|---|---|---|---|---|
| | | | | 10.9 |
| 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 | 11.3[b] | 12.6[a] | 11.7[b] | 11.9[a] |
| Mean | 11.3[b] | 12.4[a] | 11.7[b] | |

**Source**: Espinoza, 1996.

TABLE 7

## Site and nitrogen fertilization effect of leaf IVDMD in three Mulberry (*M. alba*) varieties in Costa Rica

| **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 | 71.5[b] |
| 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 | 75.0[a] | 73.5[a] | 74.7[a] | |

Source: Espinoza, 1996.

TABLE 8

## Site and nitrogen fertilization effect on IVDMD of young stems in three Mulberry (*M. alba*) varieties in Costa Rica

| Site | Variety, % IVDMD | | | Mean |
|---|---|---|---|---|
| | Criolla | Indonesia | Tigriada | |
| Puriscal | 69.5 | 70.5 | 63.9 | 68.0[a] |
| Coronado | 70.3 | 68.6 | 69.9 | 69.6[a] |
| Paquera | 65.9 | 64.7 | 59.4 | 63.3[b] |
| 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 | 68.6[a] | 67.9[a] | 64.4[b] | |

Source: Espinoza, 1996.

TABLE 9

**Manure application effect on crude protein content of Mulberry leaf and young stem**

| Fraction | Manure level1 | | | | NH4NO31 |
|---|---|---|---|---|---|
| | 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 the same letter horizontally are not statistically different. P <0.01.

Source: Benavides, Lachaux and Fuentes, 1994.

TABLE 10

## Manure application effect on DM digestibility of Mulberry leaf and young stem

| Fraction | Manure level1 | | | | NH4NO31 |
|---|---|---|---|---|---|
| | 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 the same letter horizontally are not statistically different. P <0.01.

Source: Benavides, Lachaux and Fuentes, 1994.

TABLE 11

## Annual cutting frequency effect on digestibility and crude protein content of Mulberry biomass

| Fraction | percent CP | | percent 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 the same letter horizontally are not statistically different. P <0.01.
**Source:** Benavides, Lachaux and Fuentes, 1994.

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 percent, respectively) are reduced compared to higher locations with more clouds and lower temperatures ((24.8 and 74.9 percent, 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 because of larger photosynthetic activity (Van Soest, 1994). Coronado has lower temperatures and more cloudiness and rainfall, which could mean limited growth and lignification. But high soil fertility and 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 hand, the clay soils, lower pH and low potassium contents can explain the low biomass yields in Puriscal.

Goats fed exclusively on mulberry and Amapola leaves confined to metabolic cages, apart from high DM intake values showed, high levels of *in vivo* DM and CP digestibilities of mulberry leaves (Table 12). The values reached 90 percent for leaf CP digestibility (Jegou, Waelput and Brunschwig, 1994).

TABLE 12

**DM and crude protein *in vivo* digestibilities of mulberry and Amapola (*Malvaviscus arboreus*) with goats in metabolic cages**

| Forage species | Parameters | | |
|---|---|---|---|
| | Intake, % LW | IVDMD, % | IVCPD, % |

| | | | |
|---|---|---|---|
| Mulberry | 4.18 | 79.3 | 89.5 |
| Amapola | 4.35 | 64.2 | 54.2 |

**Source:** Jegon, Waelput and Brunschwig, 1994.

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 percent, respectively (Espinoza, 1996). In other trials (Table 15), no appreciable differences were found in the mineral content of leaves and young stems when increasing amounts of legume leaves were added to the soil (Oviedo, 1995).

In a report on the proximate analysis of Kanvas-2 variety of mulberry (Table 16), levels of protein (29.6 percent), ash (7.53 percent) and nitrogen-free extract (50.0 percent) were considered high. At the same time, low levels of crude fibre were reported (10.1 percent). In these trials, the type and quantity of leaf amino acids were determined. Twenty-four amino acids in significant concentrations were detected, plus six 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 compound feeds.

TABLE 13

**Fertilization effect on the mineral content of mulberry (*M. alba*) leaf in Costa Rica**

| Variety | Minerals, % of DM | | | | |
|---|---|---|---|---|---|
| | 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 |

**Source**: Espinoza, 1996.

TABLE 14

## Fertilization effect on mineral content of mulberry (*M. alba*) young stems in Costa Rica

| Variety | Minerals, % of DM | | | | |
|---|---|---|---|---|---|
| | 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 |

**Source**: Espinoza, 1996.

TABLE 15

**Mulberry leaf mineral content as affected by level of Poro foliage added to the soil**

| **Mineral** | **Control** | **Proportion of Poro foliage** | **Mean** |
|---|---|---|---|

| | Without trees | in the soil | | | |
|---|---|---|---|---|---|
| | | 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 |

Source: Oviedo, 1995

TABLE 16

**Leaf composition of mulberry variety Kanvas-1, in El Salvador, Central America**

| Leaf | Fractions, % of DM |
|---|---|

| position | 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 |

**Source:** Coto, 1996.

TABLE 17

**Amino acid concentration in the leaves of Mulberry variety Kanva-1 in El Salvador, Central America**

| Amino acid | g/100 g of | Amino acid | g/100 g of | Amino acid | mg/100 g of |
|---|---|---|---|---|---|

| | DM | | DM | | DM |
|---|---|---|---|---|---|
| Alanine | 1.2 | Methionine | 0.4 | Glutathione | 350 mg |
| Arginine | 1.1 | Phenyl-alanine | 1.1 | 5Hydroxypipecolic acid | 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 |
| Isoleucine | 1.4 | Valine | 1.4 | Hydroxanthine | Trace |
| Leucine | 1.8 | Amino-benzoic acid | 8 mg | Trigoneline | Trace |
| Lysine | 1.8 | Choline | 112 | Uridylic acid | Trace |

| | | | | | |
|---|---|---|---|---|---|
| | | | mg | | |

Source: Coto, 1996.

## Animal Response

Evaluations carried out with ruminants (cattle, goats and sheep) show high intake 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 supplements (13.2 and 13.6 kg/animal/day, respectively) at equal DM intake levels (1.0 percent of LW) and superior to grazing only (11.3 kg/animal/day). Mulberry inclusion did not affect fat, protein and total solids content in milk (Table 19), but improved net benefits when compared with the concentrate (US$ 3.29 against 2.84, respectively).

TABLE 18

**Milk yield and DM intake of Jersey x Criollo cows grazing Star grass (*Cynodon nlemfuensis*) and supplemented with mulberry or concentrate**

| 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 |

**Source**: Oviedo, 1995.

TABLE 19

**Milk chemical composition from grazing cows supplemented with Mulberry or concentrates**

| 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 |

**Source:** Oviedo, 1995.

Esquivel *et al*. (1996), when replacing 0, 40 and 75 percent 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*) nor appreciable effects on milk quality (Table 20). Also in these trials, considering only feeding costs, net income per animal was 11.5 percent 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 the milk yield of Holstein cows grazing Kikuyo grass (*Pennisetum clandestinum*)**

| **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 |

**Source:** Esquivel *et al*., 1996.

With cattle, attractive liveweight gains have been obtained when using mulberry foliage as a 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 statistical differences were detected ($P < 0.05$) among supplements (Table 21). The combination 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**

| **Parameter** | **Only** | **Concentrate +** | **Mulberry** |
|---|---|---|---|

| | concentrate | 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 | - |

**Source**: Oviedo, 1995.

With young Romosinuano bulls in total confinement and fed a basal diet of Elephant grass (*Pennisetum purpureum*), gains of 40, 690, 940 and 950 g/animal/day were observed with whole mulberry DM intakes of 0, 0.90, 1.71 and 2.11 percent 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 the gain levels, respectively. The study lasted 70 days and animals were between 13 and 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**

| **DM intake, % LW[1]** | **Mulberry DM 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 the same letter horizontally are not statistically different ($P < 0.05$) with the Tukey test.
**Source:** González *et al*., 1996.

With crossbred dairy goats of 40 kg liveweight, Rojas, Benavides and Fuentes (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 percent of LW on a DM basis (Table 23). There were slight increases in the fat, protein and total solids content (Table 24). In this study, high DM intakes and the additive effect of mulberry supplementation were observed. King grass was clearly substituted by mulberry (Table 25).

TABLE 23

**Effect of mulberry supplementation on milk yield**

**(kg/animal/day) of dairy goats**

| 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 are not statistically different, P <0.0001.

**Source**: Rojas and Benavides, 1994.

TABLE 24

**Effect of mulberry supplementation on fat, protein and**

## total solid contents of goats fed King grass

| Fraction | Intake of mulberry DM, % LW | | | | Mean[1] |
|---|---|---|---|---|---|
| | **1.0** | **1.8** | **2.6** | **3.4** | |
| 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, $P<0.007$.
**Source**: Rojas, Benavides and Fuentes, 1994.

TABLE 25

## Effect of mulberry supplementation on DM intake of confined dairy goats

| Forage | DM 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 are not statistically different, P <0.0006.

**Source:** Rojas, Benavides and Fuentes 1994.

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 a supplement at 0, 0.5, 1.0 and 1.5 percent of LW on a 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

| 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, percent LW | 3.54 | 3.72 | 3.99 | 4.34 | ** |
| DM intake, g/kg/PV$^{0.75}$ | 73.5 | 75.1 | 84.5 | 92.2 | ** |

**Source:** Benavides, 1996.

In a three-year evaluation (Table 27), in an agroforestry model with goats fed exclusively (at 3 percent LW on a DM basis) with King grass and mulberry, a lactation yield of 900 kg per 300 days was reported (Oviedo, Benavides and Vallejo, 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 m$^2$, fertilized 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**

| 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 |

**Source:** Oviedo, Benavides and Vallejo, 1994.

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 forage conserved by ensiling during the rainy season in order to be used 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. Because of 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 percent of CP in the final product) while maintaining between 66 and 71 percent IVDMD (Vallejo, 1995; González *et al*., 1996). These parameters are far superior to silages made with tropical forages. Vallejo (1994), using 40 kg 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 losses 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 rapidly declined (Table 31).

TABLE 28

**Zootechnical parameters of confined goats in the agroforestry model in Turrialba, Costa Rica**

| Parameter | Average | Year[1] | Year[2] | Year[3] |
|---|---|---|---|---|
| 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] Three 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.
**Source**: Oviedo, Benavides and Vallejo, 1994.

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

TABLE 29

**Financial analysis (in US$) of the goat agroforestry module at Turrialba, Costa Rica**

| Description | Years | | |
|---|---|---|---|
| | 1991/92 | 1992/93 | 1993* |
| A. Costs | | | |
| A.1 Investments | | | |
| Mulberry x Poró plantation | 4.61 | 4.61 | 2.88 |

| | | | |
|---|---|---|---|
| Grass x Poró 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.
**Source**: Oviedo, Benavides and Vallejo, 1994.

TABLE 30

## Chemical characterisation of silage made from shrubs and trees

| 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 |

**Source:** Vallejo, 1994.

TABLE 31

## Fermentation indicators of ensiled foliage of three woody forages

| 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 |
| percent 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 |
| percent Acetic acid | 1 | 5.71 | 1.49 | 1.11 |
| | 2 | 1.97 | 1.25 | 1.57 |
| | 3 | 0.85 | 0.16 | 1.10 |
| percent Butyric acid | 1 | 6.84 | 0.24 | 0.03 |
| | 2 | 0.56 | 0.24 | 0.01 |
| | 3 | 0.32 | 0.02 | 0.00 |

| | | | | |
|---|---|---|---|---|
| percent Lactic acid | 1 | 5.14 | 4.64 | 0.71 |
| | 2 | 9.00 | 4.26 | 1.84 |
| | 3 | 6.22 | 1.38 | 0.63 |

TABLE 32

## Fermentation indicators of Mulberry silage used as supplement for Romo-sinuano cattle

| Indicator | Silo 1 | Silo 2 | Average |
|---|---|---|---|
| pH | 4.45 | 5.25 | 4.85 |
| $NH_3$, percent of total N | 7.70 | 4.16 | 5.93 |
| Acetic acid, percent | 3.95 | 1.82 | 2.89 |
| Propionic acid, percent | 0.27 | 0.08 | 0.18 |
| Butyric acid, percent | 0.02 | 0.03 | 0.03 |

| | | | |
|---|---|---|---|
| Lactic acid, percent | 12.93 | 17.15 | 15.04 |

**Source**: González *et al*., 1996.

Using this mulberry silage to supplement young bulls fed a basal diet of Elephant grass, liveweight gains of 600 g/day were obtained (Table 33) with silage intake of 1.1 percent 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, such as its high pH and compaction, which might have reduced consumption. This forage without an additive does not reach the desirable pH levels to assure stability. González (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 percent of LW on DM basis) was found and there was 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 fed a basal diet of Elephant grass**

| **DM intake** | **Mulberry dry matter offered, % LW** | | | |
|---|---|---|---|---|
| | **0** | **0.8** | **1.7** | **2.5** |
| Ensiled mulberry, % | $0^{c}$ | $0.66^{b}$ | $1.05^{a}$ | $1.11^{a}$ |

| | | | | |
|---|---|---|---|---|
| LW[1] | | | | |
| Total DM, % 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 the same letter horizontally are not statistically different, (P <0.05), using the Tukey test.
**Source**: Vallejo, 1994

TABLE 34

**Intake, milk yield and characteristics of goats fed silage of three woody forages as sole diet**

| Species | | | Milk chemical composition | | | |
|---|---|---|---|---|---|---|
| | | | Protein% | Fat | Total | Titratable |

| | DM intake, % LW | Milk, kg/day[1] | | % | solids % | 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 are not statistically different ($P<0.05$)

## AGRONOMY

Mulberry has high biomass production, as shown in several experiments where the effects on yield and quality of cutting frequency, level and type of fertilization and location have been studied. Because of its high production capacity, mulberry extracts a lot of nutrients from the soil. This is why, a combination of organic and inorganic fertilizers has been emphasized.

One of the obvious worries about the agronomy of mulberry is the 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 the 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**

| Species | Horizontal stake | | | Vertical stake | | |
|---|---|---|---|---|---|---|
| | % | Number | Length | % | Number | Length |

| | germ. | of shoots | of shoots (cm) | germ. | of shoots | 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 | $53.8^{b}$ | $1.1^{b}$ | $4.4^{b}$ | $60.4^{c}$ | $1.5^{c}$ | $6.8^{b}$ |

**Source:** Esquivel, 1993

In an evaluation of cutting height (0.5 and 1.0 m) of isolated two year-old plants (Table 36), differences in DM and CP production were not found, although there was a significant effect on the proportion of leaf (Benavides, Borel and Esnaola, 1986). In this same study (Table 37), greater yields were observed with longer cutting frequencies (60, 120 and 180 days). However, this increase was due to more stem production, with leaf production not being affected.

TABLE 36

## Dry matter yields (kg/plant/year) of mulberry at two cutting heights

| 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 | ** |

**Source:** Benavides, Borel and Esnaola, 1986.

TABLE 37

## Dry matter yields (kg/plant) of mulberry under different cutting frequencies

| 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] | ** |

**Source**: Benavides, Borel and Esnaola, 1986.

Under humid tropical conditions in Costa Rica, a mulberry plantation with 25 000 plants/ha produced 35 tonnes DM/year for three years using goat manure as fertiliser (Benavides, Lachaux and Fuentes, 1994). A 20% higher production with goat manure was observed 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 percent a year, reaching 38 tonnes of DM/ha by the third year. Greater total biomass yields were obtained (Table 39) with a four month cutting frequency compared with three months, although leaf yield was not different (Benavides, Lachaux and Fuentes, 1994).

TABLE 38

**Yearly total mulberry biomass (tonnes of DM/ha) when applying goat manure as fertilizer and cutting every four months**

| Year | Level of manure[1] | $NH_4$-$NO_3$ |
|---|---|---|

| | Level of manure | | | | |
|---|---|---|---|---|---|
| | **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 the same letter horizontally are not statistically different, $P < 0.001$.

TABLE 39

## Dry Matter yields of mulberry (tonnes/ha/year) and cutting frequency

| **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 are not statistically different, P <0.001.
**Source:** Benavides, Lachaux and Fuentes, 1994.

In another study, again under humid tropical conditions, Oviedo (1995) found mulberry biomass yields of 8.0, 9.4 and 10.6 tonnes of DM/ha when using Poró 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 and Benavides (1996) reported important differences among varieties in total DM yields, having one variety with almost half 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 under conditions in that area.

TABLE 40

# Site and nitrogen fertilizer effect on DM production of three Mulberry varieties in Costa Rica

| Parameter | Variety, tonnes 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 kg N/ha | 13.7 | 22.8 | 28.3 | $21.6^{a}$ |
| 540 kg N/ha | 17.4 | 26.3 | 28.7 | |
| Average | $14.1^{c}$ | [illegible]$^{b}$ | $25.4^{a}$ | $24.1^{a}$ |

| | | | | |
|---|---|---|---|---|
| Average | 14.1$^{c}$ | 22.3$^{b}$ | 25.4$^{a}$ | |

[1] Values with the same letter horizontally are not statistically different (P <0.05) with the Duncan test.

[2] Ammonium nitrate. *Maximum production*: 45.2 tonnes/ha/year (Indonesia at Paquera with 360 kg N/ha/year). *Minimum production*: 6.5 tonnes/ha/year (Criolla at Puriscal with 180 kg N/ha/year).

**Source:** Espinoza, 1996.

TABLE 41

**Site and nitrogen fertilizer effect on edible DM percentage of three Mulberry varieties in Costa Rica**

| **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 the same letter horizontally are not statistically different, $P < 0.05$ (Duncan, 1955).
**Source:** Espinoza, 1996.

TABLE 42

## Site and nitrogen fertilizer effect on leaf:stem relation in three Mulberry varieties in Costa Rica

| 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] |

| | | | | |
|---|---|---|---|---|
| | | | | [illegible] |
| 540 | 1.00 | 0.57 | 0.75 | 0.77$^{b}$ |
| Average[1] | 1.00$^{a}$ | 0.57$^{c}$ | 0.81$^{b}$ | |

[1] Values with the same letter horizontally are not statistically different, P <0.05 (Duncan, 1955).
**Source**: Espinoza, 1996.

TABLE 43

**Site and nitrogen fertilizer effect on growth rates (tonnes DM/ha/year) of three Mulberry varieties in Costa Rica**

| **Parameters** | **Variety** | | | **Average** |
|---|---|---|---|---|
| | **Criolla** | **Tigriada** | **Indonesia** | |
| Site | | | | |
| Puriscal[1] | 92.5 | 130.0 | 158.3 | 126.9$^{b}$ |

| | | | | |
|---|---|---|---|---|
| Puriscal | | | | 126.9 |
| 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 kg N/ha | 114.2 | 190.0 | 235.8 | 180.0$^{a}$ |
| 540 kg N/ha | 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 are not statistically different, 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. Its high levels of CP and digestibility are far superior to those of most commonly used tropical forages and are comparable to concentrates.

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

With adequate fertilization, yields increase with time as shown in the studies reviewed. Because of its effect on soil physics and the presence of other nutrients, animal manure is superior to ammonium nitrate in terms of yield per unit area. Although mulberry extracts a lot of nutrients from the soil, it is very efficient in their utilization 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, fertilization and rainfall.

## RECOMMENDATIONS

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

### Pruning

Information exists on the effect of cutting height on DM yields but, in some cases, it is contradictory and preliminary (Benavides, 1986; Blanco, 1992). Because of the effect that cutting height seems to have on leaf:stem proportion, it is important to validate this research in new studies and under different conditions.

In plantations destined 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 specifically 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 for feeding the silkworm, and there is no information for its application in plantations to produce forage for ruminants.

One of the main problems of tropical livestock husbandry is feeding during the dry period. With regard to this, it is recommended 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 the lack of mechanical harvesting and manure spreading techniques. These are not a problem for small producers.

## Planting

The planting period is more important in the dry tropics than in areas with well-distributed rainfall. This has received little attention, yet 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 study needs to be continued to discover its effect on production persistence. Obviously, spacing will depend on whether mulberry is planted as a monoculture or in association.

According to field observations, it is possible that mulberry stakes could be placed horizontally, saving planting material and labour.

The development of planting systems on 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 the yield of traditional crops.

## Fertilization

Without doubt the most important constraint for mulberry production is its high dependency on soil nutrients. For this reason fertilization has received special attention in CATIE’s work. However, much remains to be done, in particular by using other organic fertilizers and associations with other nitrogen fixing plants. Although high yields can be expected with chemical fertilizers, their use may 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 trees might be considered because of their capacity for soil retention and nutrient recycling.

## Evaluations of species and varieties

Several species or varieties of mulberry are being planted in different locations and countries. However, comparative studies on the advantages and disadvantages of each, depending on climate and soil type, have not been made.

Breeding and selection of species and varieties are one of the most important disciplines for mulberry, in particular because of its high forage potential and the existence of a great deal of germplasm.

## Forage conservation

Reiterating that it is in the dry areas with bimodal rainfall where mulberry can have the most relevant role, it is advisable to continue studies on ensiling techniques, in particular the means of reducing pH. Mixtures of mulberry and tropical grasses should also be evaluated in order to stabilize the silo and obtain a better quality product for 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 research on mulberry also includes an economic analysis as an important factor to define recommendations for mulberry use.

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