

Establishment and Management of Mulberry for Intensive Forage Production

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Introduction

Mulberry, originated from temperate zones in Asia, extended throughout the world (Benavides *et al*, 1994). In tropical Central and South America, it adapted in an excellent way (Rodriguez *et al*, 1994). It is a perennial tree or shrub easily propagated, with fast growth and with vigorous shooting. It develops a strong vertical and profuse horizontal root system (Paolieri, 1970). These features improve physical soil conditions and allow better water conservation. As forage, mulberry has shown excellent organoleptic and intake for livestock (Benavides *et al*, 1994; Ortiz, 1992; Castro, 1989).

Protein content varies from 14 to 22% on dry matter (DM) basis (Piccioni, 1970) and *in vitro* digestibility between 70 and 80% (Ortiz, 1992).

Under tropical conditions, where conditions favour plant growth, mulberry culture has been practised under various densities and cutting frequencies which results in large yield differences. In Guatemala, Blanco (1992) obtained 19 ton of DM/ha in 4 cuts every 9 weeks, with 30cm between plants and a cutting height of 75cm. In Costa Rica, Benavides *et al* (1994) used densities of almost 23,000 plants per ha, with DM yields from 21 to 28 ton/ha. Rodríguez *et al* (1994) worked in Guatemala with planting distances of 60 and 80cm between plants and

harvesting frequencies of 6, 9 and 12 weeks, with DM yields of 1 to 4.6ton/ha/harvest. These results suggest that yield increases with density (Benavides *et al*, 1986).

In Japan two planting densities are used, 10 and 20 thousand plants/ha for the traditional and intensive production systems, respectively (IFA, 1992).

This paper shows the experimental results of the effects of planting densities, cutting heights and frequencies of harvest on dry matter production in a high altitude tropical environment.

Environmental Conditions and Establishment

The study was conducted at the Dairy Cattle Experimental Station “Alfredo Volio Mata” of the University de Costa Rica, located at 1,542m above sea level, with 2,050mm of annual rainfall (May to November). Mean temperature is 19.5°C and relative humidity 84%. The soil is volcanic, classified as Typic Distrandepts (Vásquez, 1982), with medium depth, good drainage and medium fertility (Ca, 7.7; Mg, 3.0; and K 1.54 cmol/l; P, 10.0; Cu, 28.8; Fe, 234; Mn, 6.3; and Zn, 2.6 mg/l). The pH is 5.9. The zone is considered a Low Mountain Humid Forest (Tosi, 1970, cited by Vásquez, 1982).

The mulberry plantation was established with young stakes of 1-2cm in diameter, 40cm in length and with at least three buds at 5-8cm in depth at three planting densities: 60, 90 and 120cm between rows and plants, which is equivalent to 27,777, 12,345 and 6,944 plants/ha. It was fertilised with a 10-30-10 fertiliser at the rate of 120 kg of P₂O₅/ha/año. In July and October ammonium nitrate was applied in two equal doses to complete 150 kg de N/ha/year. After one year half of the plots were cut at 30cm and the other at 60cm in height. From that time, cut were maid every 56d (6 cuts); 84d (4 cuts) and 112d (3 cuts) for 336d.

Weeding was done after each harvest, leaving cut plants between rows. Ammonium nitrate was applied when shoot reached 3-5cm (approximately 2 weeks post-harvest) at the rate of 300 kg N/ha/year (Rodríguez *et al*, 1994).

Leaf and stem samples were dried at 60°C for 48h, and after grinding DM determinations were made at 105°C.

Forage Production

Table 1 presents DM yields by density, height and cutting frequency ($P = 0.01$). Density strongly influenced yields. Yield dropped 37% (10.2 ton/ha) from planting densities 60 to 90cm and 13% (2.2 ton/ha) from 90 to 120cm. Leaf:stem proportion did not change among planting densities despite yield differences. There was more DM produced at the 60cm cutting height ($P < 0.01$) due to more leaves.

Total and stem DM yields increased linearly ($P < 0.01$) with the length between harvests, but leaf yield only increased from 56 to 84d. Leaf proportion decreased linearly with harvest length. Up to 100d there were more leaves than stems. Leaf production is little affected by cutting frequency. The interaction planting density by cutting height was significant for the whole biomass and highly significant for leaf yield. Density by frequency interaction was not significant for whole plant, leaf and leaf:stem ratio, but highly significant for stem yield.

Height by frequency interaction was significant ($P \leq 0.01$) for all DM yields but not for leaf:stem ratio, despite the wide range (0.96 to 1.68) observed. At 30cm of cutting height DM increase with cutting length, but at 60cm height, DM yields do not raise further 84d. Similar effects are seen with leaf and stem yields.

Table 1. Annual dry matter production (ton/ha) of mulberry depending on planting density, cutting height and frequency.

Spacing (cm)	Cutting		Fraction			Leaf: Stem Ratio
	Height (cm)	Frequency (days)	Whole Plant	Stems	Leaves	
60	30	56	18.3	7.1	11.2	1,60
60	30	84	25.1	11.4	13.7	1,20
60	30	112	40.6	21.6	19.0	0,88
60	60	56	24.4	9.2	15.3	1,75
60	60	84	35.8	16.3	19.5	1,19
60	60	112	30.9	15.8	15.1	0,94
90	30	56	10.2	4.0	6.2	1,63
90	30	84	16.5	7.8	8.6	1,11
90	30	112	26.8	14.5	12.3	0,85
90	60	56	11.2	4.5	7.3	1,64
90	60	84	21.5	9.3	12.2	1,32
90	60	112	20.8	10.3	10.4	1,04
120	30	56	10.0	4.2	5.9	1,40
120	30	84	15.5	7.5	8.0	1,08
120	30	112	19.2	10.4	8.8	0,86
120	60	56	10.1	39.7	60.8	1,63
120	60	84	15.8	7.2	8.6	1,22
120	60	112	20.9	10.9	10.0	0,96
Means						
60			27.5	12.3	15.1	1.36
90			16.3	7.5	9.0	1.35
120			14.1	6.6	7.5	1.27
	30		18.4	8.7	9.8	1.26
	60		20.1	8.9	11.3	1.38
		56	14.0	5.5	8.7	1.61
		84	21.7	9.9	11.8	1.19
		112	26.5	13.9	12.6	0.93

The three-way interaction, height, frequency and density were significant for the three variables measured. Leaf:stem ratio was not affected by this interaction.

Discussion

Forage mulberry plantations were studied for the humid tropics in Costa Rica (Benavides *et al*, 1994) and for the dry tropics in Guatemala (Rodríguez *et al*, 1994).

The present study was conducted in a high environment (1,542m) with excellent solar radiation throughout the year. Annual DM yields differ a lot depending on density, cutting frequency and height in order to be considered during establishment and management. Planting distance was responsible for 39.48% of total variation in DM yields; cutting height only 0.80 % and frequency 30.64%.

Individual plant DM yields were 0.99, 1.31 and 2.03kg/year for planting distances of 120, 90 and 60cm, respectively. In China, traditional density is 10,000 plants/a (IFA, 1992, Tieng *et al*, 1988) and 25,000 for intensive cultivation. Lin *et al* (1996) studied spacing effect (1.5 x 0.6, 1.8 x 0.60, 1.5 x 0.75, 2.25 x 0.60, 1.80 x 0.75 y 1.8 x 0.9m) on leaf production, and found similar results as the ones of 4 times-per year harvest of the present experiment. Higher shooting per plant does not compensate for higher shooting per ha at higher densities. In general terms, larger spacing reduces light competition (González, 1951) and high-density plantations respond to this competition. The long term effects on the root system and leaf yield are unknown.

Cutting height had a little effect on yield, increasing by 1.7 ton DM/ha/year from 30 to 60cm. Both of these heights are considered low for Chinese practices (Tieng *et al*, 1988). This

increment was due to the leaf fraction. In Turrialba (Costa Rica) annual plant yields were 2.32kg cutting at 50cm and 2.12kg at 100cm in low-density plantations (Benavides *et al*, 1986). Some reports recommend low cutting heights (< 70cm) for 30,000 plants/ha; medium height (70-170cm) for 12,000 plants/ha and high cutting (> 170cm) for densities below 6,000 plants/ha (Tieng *et al*, 1988). Greater leaf production at the height of 60cm suggests to study leaf and stem yields at various cutting heights, under conditions of high light competition in dense plantations.

Frequency of defoliation had a marked effect on yield. Greater yields were observed at longer cutting frequencies. This is related to the re-growth delay period and to plant nutrient reserves. The results clearly show that annual production is lower at frequent intervals. Similar responses were obtained by Rodríguez *et al* (1994) when studying frequencies of harvesting of 6, 9 and 12 weeks in two different periods in Guatemala. In the second year the yield was triple but the frequency effect was maintained. When studying plant growth post-harvest, it was observed that stem buds do not re-grow immediately. It takes 4-10 d for the shoot to reach 1cm. Afterwards, the re-growth continues with 2-3 buds in side branches. The density of re-growth seems proportional to the number of cuts. These observations indicate that plant structure and morphology change depending on cutting frequency reflected on leaf and stem proportion. After each harvest there was a little flux of sap in each branch cut. The results of this experiment show that plant stress (Taiz *et al*, 1991), produced by cutting frequency, has in the short term a negative effect on annual biomass yield.

In the Asian countries, only leaves are harvested every 2-3 months, and they carry out an annual pruning. In the more intensive systems, leaf harvest is often combined with a high pruning in the spring with a leaf harvest and low pruning in the winter (Tieng *et al*, 1988).

Implications and Recommendations

Annual biomass yield increased with planting density. This increase implied lower individual plant yield, indicating competition for basic ground space (root growth and nutrition) and aerial space (gaseous exchange and photosynthesis).

Cutting height had only some influence on biomass production. This could be considered in mechanical culture and harvesting.

Biomass, stem and leaf yield increased with longing cutting intervals. With frequent cuts forage had a larger leaf proportion. Leaf:stem ratio reached 1 at about 100d of harvesting interval. After this time, the forage becomes too lignified losing nutritive value.

This study found the largest biomass production (35ton) at 60cm spacing and 112d cutting frequency. Similar spacing is recommended for an 84d interval, with only slightly less leaf (-0.5 ton) and stem (-5ton) production, with cutting height of 60cm and leaf:stem ratio of 1.19. With a cutting height of 30cm, 112d frequency and 60cm spacing, the yield reached 40ton/ha/year, with a leaf:stem ratio of 0.88. Forage with more leaves saves on labour and transport cost per unit of feed, and animals can show a greater intake.

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