# Forage Yields and Structure of *Moringa oleifera* cv Nicaragua at Different Cutting Frequencies

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## ABSTRACT

The effect of the cutting frequency (45 and 60 days) on the morphological and productive behavior of *Moringa oleifera* Lam vc Nicaragua with irrigation and organic fertilization, on little differentiated fluvisols in Cauto Valley, in 2012. A randomized block design with four repetitions was applied. The cutting frequency affected the morphological variables (P≤ 0.001), but not DM from leaves, stems, and total yields (P≥ 0.05). The cutting times for both frequencies predisposed great variability between the first (February-March) and the third (June-July) cuts. The best plant height values were achieved in 60 days (P≤0.001), in comparison to 45 days, whereas the number and thickness of leaves per shoots varied (P≤ 0.001) at different cutting times based on innate plant features, not on the cutting frequency. Leaf proportion was higher (P≤0.001) in the 45-day frequency, and the DM yields ha$^{-1}$ from leaves and DM ha$^{-1}$ only differed in the first 45-day cut, in comparison to the other averages within the same cutting frequency, and the 60-day cut. The structure and productive behavior of Moringa were influenced by the cutting frequencies and times, whereas the cutting frequency alone just modified the structural variables.

**Key words:** *productivity, forage shrubs, cutting height*

## INTRODUCTION

Nowadays, *Moringa oleifera* is a treelike plant used increasingly as forage (Pérez, Sánchez, Armengol, and Reyes, 2010). It has a lot of nutrients and high biomass production, and it is resistant to high temperatures and the lack of rain (Godino, Arias, and Izquierdo, 2013). These capacities of the plant should be considered for use in animal nutrition, in areas where the effects of climate on forage food production are negative.

In that sense, in the eastern part of Cuba, particularly, the climatic conditions critically predispose grass production in the dry season (November-April). Several varieties of the plant (Criolla and Nicaragua) have been used in that region for seed production (Rosell *et al.* 2014). However, their forage potential or the effect of trimming at different ages on production, have been overlooked. Iglesias and Ortega (2016) noted that the forage produced by this shrub-like tree is ready for consumption between 35 and 45 days, with yield averages of 10 t/ha/cut, but regardless of the cutting frequency effect on the plant structure.

Accordingly, the type of climate and behavior of the climatic variables have a direct influence on the agronomic behavior and growth habit (Verdecia, 2015); therefore, plant structure and productivity by cutting could not always be maintained. This effect has been given little value for the production of shrub-like species by cutting in the east of Cuba.

Accordingly, the aim of this paper was to evaluate the effect of the cutting frequency on the morphological and productive behaviors of *Moringa oleifera* cv Nicaragua.

## MATERIALS AND METHODS

*Location, climate, and soil*

The experiment was made between February and October 2012, at the Station for Pastures and Forages (EEPF), Jorge Dimitrov Center for Agricultural Research (IIA). The station is located 10 ½ km from the city of Bayamo, Cuba, on 20º 18´13´´ north latitude, and 76º 39´ 48´´ west longitude.

The soil at the experimental area is a slightly differentiated fluvisol (new soil classification for Cuba) (Hernández, Pérez, Bosch, Rivero, and Camacho, 2015). The soil is flat, made of soft clay, with good draining conditions; fertility is average.

The local climate classifies as relatively humid tropical (Barranco and Díaz, 1989). The annual precipitations average is 98.8 mm, with minimum monthly values of 0 mm in January and February. Figure 1 shows the differences in white. El maximum value was 236 mm (September), and during

the period evaluated, the accumulated precipitations (1 185.3) accounted for 9.73% of the total in eleven years (1 1896 mm). Fig. 1 shows the monthly rain distribution during the experiment and the historic mean by month.

*Treatment and experimental design*

The treatments consisted of cutting frequencies (45 and 60 days) under a randomized block design with four repetitions.

*Experimental procedure*

The experimental units were 9 x 7 m plots separated by 2 m. The planting density was 0.5 m between rows, and 0.25 m between plants. Irrigation (500 mm) was applied, depending on the values suggested by Herrera (2006), along with 20 t/OM/ha from bovines, with 1.38% nitrogen content, and a contribution of 62.9 kg/N/ha. Cutting was applied 10 cm from the base of the stem. The soil was prepared conventionally (plowing, disc harrowing, crossing, harrowing, raking, and leveling), using animal traction to reduce possible contamination of the ecosystem.

Observation of plant growth dynamics took place after the establishment cut, and it was continued according to the pre-set cutting frequencies. Three plants per repetition were selected at random, and their heights were measured from the base of the stem to the apex of the highest leaf, reshoot number and thickness, number of leaves/reshoots, weight of woody stems, weight of young stems, leaf weight, and dry matter (DM) yields of leaves, stems, and total.

DM yields were estimated from the fresh weight of leaves, stems, and the whole plant. To achieve that, the plants were sectioned in leaves and stems, and the green leaf/stem proportion was determined. The proportion was made into a 200 g sample, and then it was placed in a stove at 60°C for 72 h. Later, when constant values were achieved, they were weighed in order to determine DM yields.

*Statistical analysis*

Statistica 10.0, for Windows, was used for statistical analysis. The normality and variance homogeneity tests were based on K-S and Bartlett, respectively. Analysis of variance and the Duncan's test (1955) were made for mean comparisons, using the equation below:

$Y_{ijk} = \mu + R_i + FC_j + e_{ijk}$

Where,

$Y_{ijk}$ = variable response.

$\mu$ = common constant for all the observations

$R_j$ = effect of i-th repetition (j=1, ….,4).

$R_j$ = effect of i-th repetition (j=1, ….,4).

$e_{ijk}$ = normally distributed random error (0, $\sigma^2 e$).

## RESULTS AND DISCUSSION

Evaluation of the normality of data and variance homogeneity of all the variables studied revealed that the values achieved in the K-S and Bartlett tests were P≥0.06 and P≥0.058, respectively. Accordingly, the null hypothesis was assumed in all cases, with 5% significance.

The preset cutting frequencies defined the morphological behavior of cv. Nicaragua at different times. Plant height (Table 1) was affected by the two frequencies, but the 60-day cutting frequency produced higher values at cutting (P≤0.001) than the 45-day frequency. However, when the last cut was made, in September-October, the behavior of height changed. The 45-day cutting frequency showed higher numerical values than the ones achieved for 60 days, but without significance.

In the first three cutting moments (February-March, March-April, and June-July) for the two frequencies studied (45 and 60 days), no significant differences were observed in the number of shoots. Only the second cut for the 45-day frequency was statistically different (P≤0.001) from the third cut for the 60-day frequency. The number of shoots for both ages (45 and 60 days) declined in the last cut, compared to the first three (Table 1).

Meanwhile, shoot thickness had a more variable behavior, caused by the effect of the cutting frequency at different times. A significantly higher value was achieved in the second cutting moment for the 60-day frequency, similar to the previous and following cuts for the same frequency. It was not different (P≤0.05) from the last moment (September-October), for the 45-day frequency. However, it differed (P≤0.001) from the rest of the values achieved at different cutting moments for the 45-day frequency. A significantly low value was achieved in the fourth cutting moment (September-October) (P≤0.001), for the 60-day frequency.

The number of leaves per shoot evolved according to the number of cuts for the 45-day frequency. An inverse behavior was observed for the 60-day frequency, whose significantly high values

were achieved in the first cutting moment for the 60-day frequency, and the last moment for the 45-day frequency. Between cutting moments, the variable studied showed improving (45-day) and depressing (60-day) transitions.

The stem-leaf proportion, and the cutting frequency and moments may have been influenced by this behavior (Table 2).

The greatest leaf proportion (P≤0.001) was achieved for the 45-day frequency, in the third cutting moment (June-July), and it differed (P≤0.001) from the rest of the percentages for both frequencies at different cutting times.

The lowest values of leaf proportion were achieved in the fourth cut (September-October) for the same frequency, and it was normal when the second cut took place for the same frequency, and the first cut of the 60-day frequency, whereas stem production was significantly higher (P≤0.001) for the 60-day frequency in the second and third cuts (April-July).

The 45-day frequency showed low proportions for this organ, the lowest occurred in the third cut (June-July). This value differed from the ones reported at the different moments and averages for the 60-day frequency.

The yields of DM ha$^{-1}$ from leaves (Table 3) varied with time. Only the averages of the third cut (June-July) differed significantly (P≤0.001), in comparison to the average from the first cut (February-March), for the 45-day frequency.

Dry matter from stems increased remarkably in the third cut, for the 60-day frequency, and it was significantly different (P≤0.001) from the 45-day frequency in the second and third cuts (March-July). No significant differences (P≥0.05) were observed (Table 3) for the cutting age (45 and 60 days) averages in the other cutting times. Regarding total DM yields, the highest averages were achieved for the evaluation frequencies in the third cut. They only differed (P≥0.05) from the first cut averages for the 45-day frequency.

The morphological variables were altered for P≤0.001 by the cutting frequency; however, yields (leaves, stem, and total) did not show any significant differences (P≥0.05) (Table 4).

The cutting frequencies and the coinciding time of the year determined fluctuations of plant height (Table 1). According to Godino, Arias, and Izquierdo (2013), in order for the plant to achieve proper development, the highest temperatures

should be between 25 and 35 ºC. In the Cauto Valley, temperatures have the same range, though relative humidity is above, but keeps close to 80% (ONEI, 2015). Godino, Arias, and Izquierdo (2013) noted that sustained relative humidity above 85% affected growth and development, which shows the ecotype adaptability to the climatic conditions of Cauto Valley. Water availability was not a limitation until the second quarter of the evaluation period (Fig. 1). It has been identified as the main climatic variable that can determine the productive behavior of Moringa.

Alfaro and Martínez (2008) recorded superior heights than this study (1.20-1.50 m) in 45 days, in Guatemala, which may have been influenced by the climatic conditions of the experimental area, in which there were periods (February-March and March-April) of scarce rainfall (≥100 mm). In their experiment, the plants were irrigated strategically to guarantee their stability, rather than their hydric needs.

Obando and Ortega (2016) observed that plant height and other morphological variables were affected by the planting density (1 x 0.5; 1 x 0.75; and 1 x 1 m) used in their study, which determined the expression of the productive potential. In this study, the density established (0.5 x 0.25 m) did not affect the variable, since planting was performed with stakes. Rosell *et al.* (2014) determined that in the shooting and developing processes, seed thickness is the determining variable, instead of planting density, at least in early ages.

In periods when shoots are supposed to re-emerge, depending on certain moments of the year and the cutting frequencies, the number of cuts also plays a role. That way, in the Cuban eastern conditions, variability is determined by the combination of these two factors (Table 1), mainly due to the exhaustion caused by the preset frequencies due to accumulation of reserves during the rainy season (May-October), with longer exposure to light and stability in radiation levels (Cáceres, 1985). Part of this study coincided with the last period evaluated for both cutting frequencies when the lowest number of shoots were observed (P≤0.001) for the 45 and 60-day cutting ages. Although this period contributes most to the accumulation of soluble compounds due to photosynthesis, that response is linked to the number of cuts, which did not favor the accumulation of re-

serves and supposedly led to poor root development.

In a similar study Petit, Casanova, and Solorio (2010) pointed out that the main differences in the number of re-shoots of *Moringa oleifera, Leucaena leucephala,* and *Guazuma ulmifolia* in monocropping during the rainy season were related to differences in root development of the two above-mentioned species, compared to Moringa. It was always significantly lower in relation to the number of shoots in the study, which were also lower to the ones in Table 1.

However, there was a correspondence between the number and thickness, as there were fewer, but stronger, fully-grown re-shoots, particularly for the 60-day frequency, when the plant had more time to accumulate organic compounds before being trimmed.

Nevertheless, the number of leaves did not coincide with the moments of higher quantities of re-shoots (P≤0.001) (Table 1). According to Magaña (2012), this response was related to climate, rather than the cutting age, an assumption that coincides with the findings of this study. In each period, plant growth underwent similar climatic conditions, though not the same, with effects on their phenotypical expression. The behavior of mean shoot thickness underwent a variability stimulated by the effect of the cutting frequency on their quantities (Table 1).

The literature review showed no references between the trimming effect on the behavior of shoots and their thickness, except for the effect of grazing. Hrabar, Hattas, and Du Toit (2009) in a simulated trimming of *Colophospermum mopane,* by elephants, observed a compensation between a decrease in the size of re-shoots and an increase in their number, which was mainly related to water availability in the soil. In this study, water availability was not a limitation, but age was. It marked differences in the process of accumulation of organic compounds for re-shoot growth, though there seems to be a compensatory response based on the existing climatic conditions in the area for re-shooting after defoliation or trimming, depending on the case.

The leaf/stem proportion was more affected by the cutting moment than by the cutting frequency used (Table 2). A variable behavior was observed, and there were more stems than leaves, though accumulation should not pose concerns in terms of animal feeding, since the stems are chemically qualified (Rosell *et al.,* 2014) for animal food, making a more efficient and integrated use of plants.

Cordoví, Ray, Tamele, Nhantumbo, and Chimbalambala (2013) reported yields of dry matter higher than this study (Table 3) in all the cutting moments. Assuming from this behavior that the intrinsic mechanisms used by plants to regulate and express their phenotype determined by the ecosystem, the above researchers utilized different shrub-like species to evaluate different specific responses to this ecosystem. In their research, they used a broad range of climatic variables and edaphic combinations to stimulate the plants, which determined a different productive response from this study.

The height values (Table 4) were better than the values reported by Fonseca, Molinet, Santiesteban, and Torres (2015), when the cutting age and height were combined in some morphological variables of *M. oleifera* on fluvisols. Fonseca *et al.* (2015) said that the main limitation of the productive potential was the shortage of water the plants endured during the experimental phase. It did not kill the plants, but did hinder productivity and led to poor root development, since the establishment cut coincided with growing.

In that sense, the behavior of shoot number and thickness (Table 4) were within the expectations. At early ages, the plants mobilize reserves to generate leaves and, through photosynthesis, they produce soluble carbohydrates to form other organs and botanical fractions. Therefore, the 45-day frequency produced a greater number of shoots. This behavior coincided with Ybalmea, Sánchez, Febles, and Mora (2000), who found that the number of shoots was reduced as age increased. According to the authors, more developed shoots possibly demand more nutrients, which in combination with the shade effect on the youngest shoots, cause their death. It may have been the reason, but it is also part of the physiological growth response of the plant.

Based on the previous conditions, the total DM yields showed no statistically significant differences. Loyola, Pérez, Triana, Valido, and Yeró (2014), after evaluating the productivity of +3-year-old Moringa for hedges, achieved 2.5 t/DM/ha/cut$^{-1}$, below the reports in Table 3 for the 45-day frequency. However, these results were

better than for the 60-day frequency; therefore, it may be inferred that rather than the cutting frequency, DM production is more dependent on the cutting management.

This criterion coincided with the results of Cordoví *et al.* (2013), when they characterized several shrub-like graminaceae in semi-arid conditions in the south of Mozambique, without irrigation. The cutting frequency was made at blossoming; and then it was continued at the beginning of senescence.

## CONCLUSIONS

In the 45-day and 60-day frequencies the plants showed acceptable growth, which corresponded with the plant´s development stage. Besides, the cutting moments induced variable morphological behaviors in the plants, which may define the persistence of the species and its recovery time.

## RECOMMENDATIONS

The best cutting frequency for *M. oleifera* is after 60 days.

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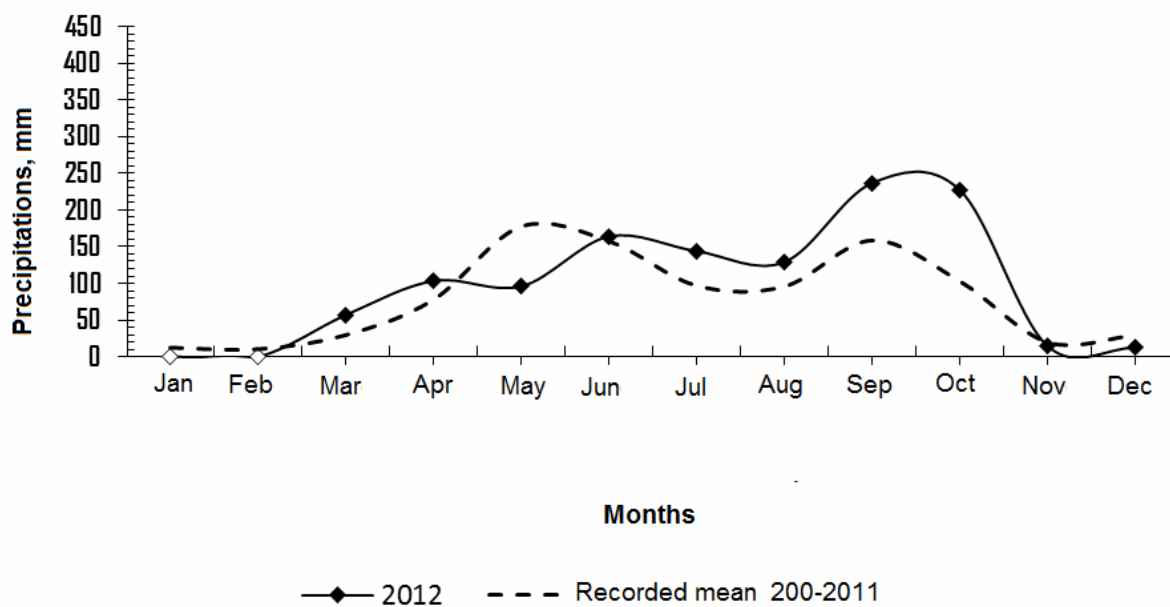
*Source: the authors*

**Fig. 1. Behavior of precipitations in 2012 compared to the recorded monthly mean**

**Table 1. Behavior of plant height and shooting at different cutting moments for the frequencies evaluated**

| Frequencies (days) | February-March (1st cut) | March-April (2nd cut) | June-July (3rd cut) | September-October (4th cut) | SE± |
|---|---|---|---|---|---|
| | | | Cutting moments | | |
| | | [1]Plant height (cm) | | | |
| 45 | 75.6$^c$ | 91.93$^c$ | 80.26$^c$ | 96.6$^{bc}$ | 1.2 |
| 60 | 121.7$^{ab}$ | 149$^a$ | 136.6$^a$ | 78.7$^c$ | 1.02 |
| | | [2]Number of re-shoots (U) | | | |
| 45 | 3.1$^{ab}$ | 4$^a$ | 3.4$^{ab}$ | 1.5$^c$ | 0.2 |
| 60 | 3.3$^{ab}$ | 3.3$^{ab}$ | 2.5$^b$ | 1.8$^c$ | |
| | | [2]Number of leaves per shoot (U) | | | |
| 45 | 8.5$^b$ | 8$^b$ | 9.5$^{ab}$ | 10.6$^a$ | 1.2 |
| 60 | 10.3$^a$ | 9.8$^{ab}$ | 9.7$^{ab}$ | 7.8$^c$ | |
| | | [2]Thickness of shoots (cm) | | | |
| 45 | 0.88$^b$ | 0.76$^c$ | 0.71$^c$ | 1.05$^{ab}$ | 0.12 |
| 60 | 1.06$^{ab}$ | 1.2a | 0.99$^{ab}$ | 0.57$^d$ | |

a, b, c: unequal letters for each frequency at different cutting moments are statistically different, according to Duncan (1955)[1], for (P≤0.001).

a, b, c: unequal letters for each frequency at different cutting moments are statistically different, according to Duncan (1955)[2], for (P≤0.001).

**Table 2 Cutting age and moment interaction on leaf/stem proportion (L/S)**

| Cutting Frequencies (days) | February-March (1st cut) | | March-April (2nd cut) | | June-July (3rd cut) | | September-October (4th cut) | |
|---|---|---|---|---|---|---|---|---|
| | Cutting moments | | | | | | | |
| | Organs (%) | | | | | | | |
| | [1]Leaves | [2]Stems | Leaves | Stems | Leaves | Stems | Leaves | Stems |
| 45 | 69.8$^b$ | 30.1$^c$ | 62.6$^{bc}$ | 37.3$^{bc}$ | 77.07$^a$ | 22.9$^d$ | 59.8$^c$ | 40.1$^b$ |
| 60 | 61.6$^{bc}$ | 38.3$^{bc}$ | 51.9$^c$ | 48.02$^a$ | 51.3$^c$ | 48.6$^a$ | 66.3$^b$ | 33.6$^c$ |
| SE[1] | 0.3 | | | | | | | |
| SE[2] | 0.12 | | | | | | | |

a, b, c: unequal letters for each frequency at different cutting moments are statistically different among themselves, according to Duncan (1955)[1], for (P≤0.001).

a, b, c: unequal letters for each frequency at different cutting moments are statistically different among themselves, according to Duncan (1955)[2], for (P≤0.001).

**Table 3 Effect of cutting age-cutting moment interaction on structural yields and total DM (t/ha$^{-1}$)**

| Frequencies (days) | Cutting moments | | | | SE |
|---|---|---|---|---|---|
| | February-March (1$^{st}$ cut) | March-April (2$^{nd}$ cut) | June-July (3$^{rd}$ cut) | September-October (4$^{th}$ cut) | |
| | Yields of DM from leaves | | | | |
| 45 | 1.1$^{b}$ | 1.7$^{ab}$ | 2.1$^{a}$ | 1.7$^{ab}$ | 1.2 |
| 60 | 1.7$^{ab}$ | 1.5$^{ab}$ | 1.8$^{ab}$ | 1.5$^{ab}$ | |
| | Yields of DM from stems | | | | |
| 45 | 1.4$^{ab}$ | 1.7$^{b}$ | 1.7$^{b}$ | 2.1$^{ab}$ | 1.3 |
| 60 | 2.1$^{b}$ | 2$^{ab}$ | 2.8$^{a}$ | 1.7$^{b}$ | |
| | Yields of total DM | | | | |
| 45 | 1.3$^{b}$ | 1.7$^{ab}$ | 2.3$^{a}$ | 1.9$^{ab}$ | 1.2 |
| 60 | 2$^{ab}$ | 2$^{ab}$ | 2.1$^{a}$ | 1.8$^{ab}$ | |

a, b: unequal letters for each frequency at different cutting moments are statistically different, according to Duncan (1955), for (P≤0.001).

**Table 4 Effect of cutting frequency on the morphological variables and yields (Results of ANOVA)**

| Variables | Cutting Frequencies (days) | | SE | Sig. |
|---|---|---|---|---|
| | 45 | 60 | | |
| Height (cm) | 87.17 | 122.60 | 0.5 | 0.001 |
| Number of shoots | 3.26 | 2.91 | 0.2 | 0.001 |
| Shoot thickness (cm) | 0.85 | 1.01 | 0.1 | 0.001 |
| Leaves per shoot | 9.11 | 10.33 | 0.9 | 0.001 |
| Leaf % | 62.68 | 58.53 | 0.2 | 0.001 |
| Stem % | 37.3 | 41.4 | 0.6 | 0.001 |
| Leaf yields (t DM ha$^{-1}$) | 4.2 | 3.90 | 0.2 | 0.77 |
| Stem yields (t DM ha$^{-1}$) | 3.30 | 3.56 | 0.6 | 0.76 |
| Yields of dry matter matter (t ha$^{-1}$) | 3.8 | 3.71 | 0.3 | 0.92 |