SCIENTIFIC PAPER

# *Response of* Moringa oleifera *Lam to fertilization strategies on lixiviated Ferralitic Red soil*

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**ABSTRACT:** In order to know the effect of organic-mineral fertilization on the productive performance of drumstick tree, on a euthric lixiviated Ferralitic Red soil, the following treatments were evaluated: $T_0$ = absolute control; $T_1$ = 0,6 t $ha^{-1}$ of fertilizer 9:9:12 (54 kg N, 54 kg $P_2O_5$ and 72 kg $K_2O$) at planting and 130 kg $ha^{-1}$ of urea (61 kg N) per forage cutting; $T_2$ = mixture of 0,3 t $ha^{-1}$ of the formula 9:9:12 (27 kg N, 27 kg $P_2O_5$ and 36 kg $K_2O$) with 4 t $ha^{-1}$ of cattle manure at planting and mixture of 65 kg of urea (30 kg N) with 2 t $ha^{-1}$ of cattle manure per cutting; and $T_3$ = 8 t $ha^{-1}$ of cattle manure at planting and 4 t $ha^{-1}$ of cattle manure per cutting. The design was randomized blocks with five replications. The results of the five cuttings indicated response to the three fertilization variants; the organic-mineral combination ($T_2$) stood out, producing the highest yield of total dry matter (20,11 t $ha^{-1}$), followed by the mineral variant (14,29 t $ha^{-1}$) and the organic one (13,46 t $ha^{-1}$ $año^{-1}$). The control only yielded 10,57 t $ha^{-1}$. The annual dry matter yield of leaves had a similar performance, with the best value in $T_2$ (11,34 t $ha^{-1}$). It is concluded that under similar edaphoclimatic conditions variants of organic-mineral fertilization can be used to improve the forage yield and quality of this plant.

*Keywords*: fertilizer application, biomass, manure, leaves

## INTRODUCTION

*Moringa oleifera* (drumstick tree) is a tree species recently evaluated in Cuba for animal feeding, because its foliage constitutes a source rich in true protein with low presence of antinutritional factors (Cohen-Zinder *et al*., 2016). The production of sufficient biomass quantities with adequate nutritional quality for the supplementation of fibrous diets based on grasses depends on management factors such as planting density, cutting frequency and intensity and fertilization.

In this sense, the high total biomass yields (27-99 t/ha/year) with cuttings every 45 days have been associated to the application of high rates of nitrogen fertilizers (Mendieta-Araica *et al*., 2013) and/or to the maintenance of high populations, of up to a million plants per hectare (Foild *et al*., 1999); which hinders the cultivation labors and has negative incidence on the nutrient availability in the soil, especially when there is not sufficient nitrogen fertilizer to replenish the quantities that are annually extracted. For such reason, it is convenient to prolong the harvest periods, taking into consideration that the plants need to recover from the cutting-induced stress and replenish the necessary reserves for regrowth; but without drastically compromising the quality of the harvested forage. Under the edaphoclimatic conditions of Cuba, it has been proven that with cutting intervals every 80-85 days plant recovery is possible (González, 2013).

On the other hand, the limited access to mineral fertilizers imposes the adoption of fertilization techniques which combine organic and inorganic sources. It is known that the organic materials act on the soil fertility, through the nutrient supply and the regulation of mineralization/immobilization; likewise, they are source of energy for the antimicrobial activity and precursor of the soil organic matter. The main challenge is in combining organic sources of different quality with inorganic fertilizers that optimize the availability of nutrients for the plant (Crespo, 2014); for which a trial was conducted in order to study the effect of different fertilization alternatives on the biomass production of drumstick tree.

## MATERIALS AND METHODS

Planting took place in August, 2013, at the Research Station Miguel Sistachs Naya, of the Institute of Animal Science (San José de las Lajas, Mayabeque province, Cuba); which is located between 22º 53' N and 82º 02' W and at 80 m.a.s.l., on an euthric lixiviated Ferralitic Red soil (Hernández *et al*., 1999). A conventional soil preparation was performed, consisting in plowing –through a Belarus tractor of 60 Hp, with ADIS 3 disc plow– and crossing with alternate passes of medium harrow; the plots were marked with a rotovator. Planting took place in 1 x 10 m plots, with which a final population of 20 000 plants $ha^{-1}$ of *M. oleifera*, from Nicaragua, was achieved. The first cutting was made 100 days after planting, in November. Then, cuttings were performed every 85 days (four in total). No irrigation was used.

A randomized block design with five replications was used and the treatments were:

T0 = control.

T1 = 0,6 t $ha^{-1}$ of fertilizer formula 9-9-12 (54 kg N, 54 kg $P_2O_5$ and 72 kg $K_2O$) at planting and 130 kg $ha^{-1}$ of urea per cutting, for a total N dose of 300 kg $ha^{-1}$ $year^{-1}$.

T2 = mixture of 0,3 t $ha^{-1}$ of formula (27 kg N, 27 kg $P_2O_5$ and 36 kg $K_2O$) with 4 t of cattle manure $ha^{-1}$ at planting and mixture of 65 kg of urea with 2 t of cattle manure $ha^{-1}$ per cutting, for a total N dose of 300 kg $ha^{-1}$ $year^{-1}$.

T3 = 8 t $ha^{-1}$ of cattle manure at planting and 4 t $ha^{-1}$ of cattle manure per cutting, for a total N dose of 180 kg $ha^{-1}$ $year^{-1}$.

To estimate the total nitrogen dose, a content of 1,5 % of N was considered in the cattle manure dried in stove; of the applied N quantity 50 % was utilized by the plant in the first year as assimilable N (Crespo, 2014).

In each cutting the green weight of all the harvested material was determined, at a height of 30 cm over the soil level, in each plot. The fractions leaves and stems of five plants per plot were separated and weighed, and dried at 60 ºC until reaching constant weight, in a free air circulation stove; then the dry weight of the leaves and stems was measured. With these indicators the dry matter yield of the whole plant and the leaves was estimated.

Figure 1 shows the monthly performance of rainfall and ambient temperature during the experimental period (August, 2013-October, 2014). The temperature remained over the historical mean throughout the period, and the highest differences occurred in February, August, September and October, 2014. The accumulated rainfall was similar to the historical mean (1 860 *vs*. 1 942 mm) and the same monthly distribution was maintained, although the intense drought that occurred in January, April and May should be emphasized.

The chemical analysis of the soil at the beginning of the experiment showed high P content (6,65 mg 100 $g^{-1}$), high Ca content (6,55 $cmol_c$ $kg^{-1}$) and low Mg (1,73 $cmol_c$ $kg^{-1}$) and OM (2,91 %) content. The soil pH was slightly acid (pH KCl = 5,35).

The Shapiro Wilks (1965) and Levene's tests (1960) were conducted to verify the normality and homogeneity assumptions of the residues, respectively. Duncan's test (1955) was used for mean

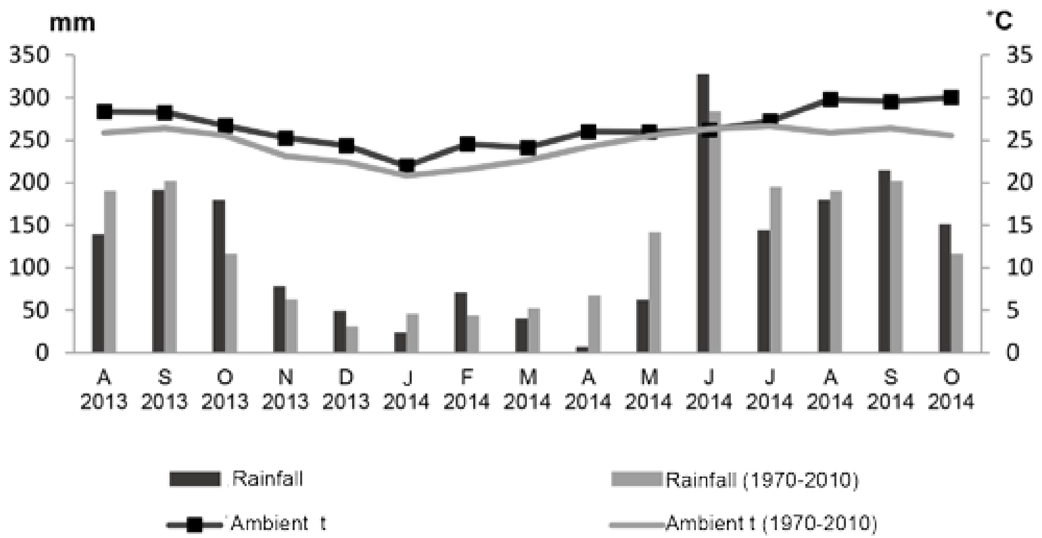


Figure 1. Monthly performance of rainfall and ambient temperature during the experimental period. Comparison with the historical mean 1970-2010.

comparison. The analysis was carried out with the statistical pack Infostat version 2008, elaborated by Di Rienzo *et al.* (2008).

## RESULTS AND DISCUSSION

In general, all the fertilization treatments favored the biomass production of the whole plant in the cuttings of November, February, May and October (table 1), which showed the deficiency of assimilable nitrogen in the soil. The dry matter yield in the first cutting in the four treatments was lower than the one reported by Lok and Suárez (2014): between 5,51 and 6,61 t ha$^{-1}$, in a study in which the forage was harvested 60 days after planting, but with populations between 600 000 and 920 000 plants ha$^{-1}$, higher than the ones in this experiment (20 000 plants ha$^{-1}$).

The absence of irrigation during the establishment period could have also been the cause of such performance. In this regard, Larwanou *et al.* (2014) stated that the irrigation regime is more strongly correlated with the growth and development indicators of this species than fertilization, during the early stages of the establishment.

The yield in the treatments with fertilization, in the first cutting suggests the need of studying the application of higher N doses; in this sense, Lok and Suárez (2014) obtained dry matter yields of up to 6 t ha$^{-1}$ when applying 100 kg N ha$^{-1}$ at planting, under similar conditions.

In the cuttings of July and October, the organic-mineral combination produced the highest dry matter yield, and it suggests that both sources show additive effect on the nutrient availability in the soil. The dry matter yield in these two cuttings exceeded the one found by Padilla *et al.* (2014), which, under similar edaphoclimatic conditions, did not exceed 3 t ha$^{-1}$ per cutting, which was due to the application of shorter harvest intervals (from 45 to 60 days) and to the absence of fertilization. On the other hand, no differences were observed among the fertilization treatments in the cuttings of February and May when periods of intense drought occurred, which affected the assimilation of nutrients by the plants.

In general terms, with the organic-mineral fertilization the highest leaf yields were obtained in all the cuttings (table 2), which were maintained in the range from 0,5 to 3 t ha$^{-1}$; this coincides with the report by Mendieta-Araica *et al.* (2013) when applying doses of 261 kg N ha$^{-1}$ year$^{-1}$. Nevertheless, the response to this treatment during the cuttings of February and May was higher than the one obtained by those authors in the harvests of the dry season, which could have been caused by the management with intensive cuttings (every 45 days) throughout the year. On the other hand, it has been

Table 1. Effect of fertilization on the dry matter yield (t ha$^{-1}$) in each cutting.

| Treatment | November | February | May | July | October |
|---|---|---|---|---|---|
| Control | 1,49$^{c}$ | 0,64$^{b}$ | 0,43$^{b}$ | 3,97$^{b}$ | 4,04$^{c}$ |
| Mineral | 3,46$^{b}$ | 0,94$^{a}$ | 1,53$^{a}$ | 2,95$^{c}$ | 5,42$^{b}$ |
| Órganic-mineral | 3,78$^{a}$ | 0,94$^{a}$ | 1,81$^{a}$ | 7,2$^{a}$ | 6,39$^{a}$ |
| Organic | 3,43$^{b}$ | 1,05$^{a}$ | 1,63$^{a}$ | 3,69$^{b}$ | 3,66$^{d}$ |
| SE ± | 0,08 | 0,08 | 0,09 | 0,10 | 0,10 |

Means with different letters indicate significant differences at $p < 0,05$ (Duncan, 1955).

Table 2. Effect of fertilization on the leaf yield (t ha$^{-1}$) in each cutting.

| Treatment | November | February | May | July | October |
|---|---|---|---|---|---|
| Control | 0,88$^{b}$ | 0,34$^{b}$ | 0,27$^{c}$ | 1,68$^{cb}$ | 1,65$^{c}$ |
| Mineral | 2,33$^{a}$ | 0,6$^{ab}$ | 1,28$^{b}$ | 1,57$^{c}$ | 2,04$^{b}$ |
| Organic-mineral | 2,51$^{a}$ | 0,65$^{a}$ | 1,55$^{a}$ | 3,35$^{a}$ | 3,29$^{a}$ |
| Organic | 2,39$^{a}$ | 0,59$^{ab}$ | 1,24$^{b}$ | 1,97$^{b}$ | 1,99$^{b}$ |
| SE ± | 0,09 | 0,09 | 0,06 | 0,09 | 0,10 |

Means with different letters indicate differences among treatments at $p < 0,05$ ( Duncan, 1955).

proven that it is possible to obtain up to 3 t ha$^{-1}$ in each of the cuttings of the dry season and 6 t ha$^{-1}$ in the rainy season, when applying a total dose of 521 kg N ha$^{-1}$ with cuttings every 45 days (Mendieta-Araica *et al*., 2013), although it should be taken into consideration that this occurs when a population of 125 000 plants ha$^{-1}$ can be maintained.

Table 3 shows the annual dry matter yield of the whole plant and of the leaves in each treatment.

With the organic-mineral combination, it was possible to produce 9,54 t ha$^{-1}$ of dry matter of the whole plant and 6,52 t ha$^{-1}$ of leaves more than in the control without fertilization, which suggests that both sources showed beneficial additive effects. This response is the expected one because the effects of the organic amendments last longer than those of mineral fertilization, because they supply carbon, nitrogen and energy for the growth and reproduction of soil microorganisms (Larney and Angers, 2012). In this regard, Guo *et al*. (2016) stated that the application of variants of organic-mineral fertilization increases the microbial biomass, as well as the activity and availability of carbon and nutrients in the soil.

The leaf production was similar to the one obtained by Mendieta-Araica *et al*. (2013) when they applied an annual dose of 261 kg N ha$^{-1}$; this suggests that it is possible to maintain adequate volumes of leaf biomass under low population conditions, if the harvest periods are prolonged and organic and mineral nutritional sources are combined.

Nevertheless, the fertilization strategy used is feasible to be improved, because it has been shown that it is possible to reach an annual production of 27 t ha$^{-1}$ of dry mass of whole plant and 19,2 t ha$^{-1}$ year$^{1}$ of leaves, with the application of 521 kg N ha$^{-1}$ year$^{1}$ and cuttings every 45 days (Mendieta-Araica *et al*. 2013). According to this result it is necessary that the formulations of the variants of organic-mineral fertilization contain optimum doses of the nutrients to achieve better stability in the soil fertility and in the forage production (Heinrichs *et al*., 2012).

It is concluded that the joint application of 0,3 t ha$^{-1}$ of full formula with 4 t of cattle manure ha$^{-1}$ at planting and the mixture of 65 kg of urea with 2 t of cattle manure ha$^{-1}$ after each cutting increased the production of leaf biomass and whole plant biomass, under the edaphoclimatic conditions in which the trial was conducted.

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Table 3. Annual dry matter yield of the whole plant and of the leaves.

| Treatments | Yield (t ha$^{-1}$) | Yield leaves (t ha$^{-1}$) |
|---|---|---|
| Control | 10,57$^{c}$ | 4,82$^{c}$ |
| Mineral | 14,29$^{b}$ | 7,81$^{b}$ |
| Organic-mineral | 20,11$^{a}$ | 11,34$^{a}$ |
| Organic | 13,46$^{b}$ | 8,19$^{cb}$ |
| SE ± | 0,41*** | 0,41*** |

Means with different letters indicate significant differences at $p < 0,05$ ( Duncan, 1955). ***$p < 0,001$.

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