Scientific Paper

Effect of planting distance on the yield of *Morus alba* (L.) var. yu-12

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Abstract

In order to evaluate the effect of planting distance on the dry matter yield of *Morus alba*, variety yu-12, a study was conducted for two years at the Pastures and Forages Research Station Indio Hatuey. The planting distances were: 1,30 x 0,20 m; 1,30 x 0,40 m and 1,30 x 0,60 m. The dry matter yield of the edible biomass (DMYEB), and the dry matter yield of the leaves (DMYL) and of the fresh stems (DMYFS) were measured. In the first year there were no significant differences among the planting distances for any of the studied variables, and the annual DMYEB were 10,91; 9,55 and 9,58 t/ha/year for 0,20; 0,40 and 0,60 m of distance between plants, respectively. In the second year significant differences were found for all the variables in favor of the lowest planting distance (0,20 m); the DMYEB increased: 13,44; 10,94 and 10,06 t/ha/year for 0,20; 0,40 and 0,60 m. It is concluded that during the first year of exploitation the DM yield was not influenced by the planting distance between plants; likewise, the DM yields of the edible biomass, leaves and fresh stems were higher during the second year of exploitation with the distance of 1,30 m between rows and 0,20 m between plants, and they increased with regards to the first year, for which the persistence of the crop and its regrowth capacity was remarkable.

Keywords: biomass, mulberry, sexual reproduction

Introduction

Mulberry (*Morus alba*, L.) was introduced in Cuba with forage production purposes, and has been proven to have good qualities for feeding different animal species (Lamela *et al*., 2010).

In the Pastures and Forages Research Station Indio Hatuey there are 21 varieties, among them tigreada, acorazonada, criolla and indonesia, which were introduced from Costa Rica in 1996; along with them the variety called cubana, which had been imported from Ethiopia years ago, was naturalized. Afterwards, in 2000, the Animal Science Institute of Brazil facilitated the obtainment of two selections (IZ-40, IZ-64) and three hybrids (IZ-15/7, IZ-13/6, IZ-56/4); and in 2005 the varieties ichinose, supermorera, cheongol and ppong were introduced, from South Korea, taxonomically belonging to the species *M. alba* (Martín *et al*., 2015).

In 2011, the institution enlarged its germplasm with six varieties: universidad, universidad mejorada, universidad nueva, yu-12 and yu-62, introduced from China; and the var. Murcia, from Spain.

The first introduced varieties were reproduced through asexual methods, mainly propagules from mature branches, and with adequate agronomic management they can produce about 8 t of edible DM/ha/year (Martín *et al*., 2015).

However, in the most recently obtained varieties, it has been proven that the main reproduction method is by botanical seed, and the agronomic factors that enhance the yields have been little studied.

In this regard, several authors observed that the optimum cutting frequency and height, fertilization, planting distance and density in each case determine the yields of the mulberry varieties that are propagated by cuttings (Benavides *et al*., 1994; Boschini and Vargas, 2009).

In this sense, the planting density is a factor that influences the agricultural production of most crops, because increasing or decreasing the space between plants can cause affectations in the yield, due to the competition that is established at interspecific level, which is given by the vital space demanded by each species for its development.

Noda and Martín (2014), when studying the effect of planting density on the tigreada variety, recommended using high mulberry densities to obtain adequate dry matter yields of edible biomass and achieve better land utilization. Thus, they stated that the plant grows well when 37 500 plants/ha are used, in triple rows separated at 0,50 m x 0,40 m between plants.

Based on the above-mentioned arguments, the objective of this study was to evaluate the effect of planting distance on the dry matter yield of *M. alba*, variety yu-12, which is reproduced by seed.

Materials and Methods

The trial was conducted at the EEPF Indio Hatuey, located in the Perico municipality –Matanzas province, Cuba–, during 2013 and 2014. In this period 360,6 mm of rainfall were recorded and the mean temperature was 29,2 ºC.

The soil has flat topography and is classified as lixiviated Ferralitic Red, according to Hernández-Jiménez *et al*. (2015).

For the planting a technical nursery was previously created, in which root trainers were used and two to three seeds of the var. yu-12 were deposited in each one. When the seedlings had reached between 40 and 50 cm of height they were transferred to the ultimate site. Before transplant to the field soil preparation activities were performed, which consisted in plowing, crossing and re-crossing.

One month after planting, sugarcane filter cake was applied at a rate of 1,2 kg/plant. The establishment period was 12 months; at all times the area remained free from weeds.

A completely randomized design was used in which three planting distances were studied: 1,30 x 0,20 m; 1,30 x 0,40 m and 1,30 x 0,60 m, which corresponded with densities of 38 450; 19 225 and 12 811 plants/ha, respectively. This originated three treatments replicated four times, for a total of 12 plots of 10 x 6 m each, with a net area of 8 x 4 m. The evaluation period was two years. In each year four cuttings were performed in the rainy season (RS) and 4 in the dry season (DS), with intense cutting frequencies of 40 and 50 days during the RS and the DS, respectively.

The cuttings were made with machete, at a height of 50 cm above the soil basis, according to the recommendations made by Noda (2006). First, the plants of the edge effect were cut and then, the five plants per plot, which were randomly selected for sampling purposes.

Based on the selected plants, the following aspects were determined: total weight, leaf weight and ligneous stem weight, and by difference the weight of the fresh stems was calculated. From the proportions of leaves and fresh stems, the edible biomass was obtained.

From each biomass component a portion of 250-300 g was taken for determining the dry matter content (AOAC, 1990).

In order to determine the agronomic performance, the yield variables were taken into consideration: dry matter yield of the total biomass (DMYTB), dry matter yield of edible biomass (DMYEB), dry matter yield of leaves (DMYL) and dry matter yield of fresh stems (DMYFS).

For the data processing a simple classification ANOVA was used after verifying that the assumptions fulfilled the variance homogeneity and normal distribution; for such purpose the statistical Infostat, version 1.1 was used. The means were compared by Duncan's test (1955) for a significance level of $p \leq 0,05$.

Results and Discussion

Figure 1 shows the effect of planting distance on the dry matter yield of the edible biomass, leaves and fresh stems, in each season, for the first year of exploitation of the crop. There were no significant differences among the planting distances for any of the studied variables.

These results differ from the report by Noda and Martín (2014), when evaluating three planting frames in mulberry variety tigreada; in this study, since the first year of exploitation of the crop, the highest dry matter yields of edible biomass and its components (leaves and stems) were found as the distance between plants was reduced.

It should be emphasized that these authors used the propagation method by cuttings, because it is the most widely used one for the variety tigreada; while in this study seedlings from nursery which had been planted from seeds, were used. Thus, it is inferred that the response obtained for the first year of exploitation could have been in correspondence with the root system that is developed in each case, although it is necessary to do further research in this regard.

It is known that the plants that develop adventitious roots are those obtained from asexual methods (cuttings, layerings, grafts, etc.), which absorb water and the necessary nutrients from the availability present in the topsoil, for which competition for nutrients is established since early ages, because the roots of more than one plant can occupy the same area. This is contrary to what can occur in the plants with pivoting roots, which have the advantage of extracting the nutrients from the deeper soil layers (Valla, 2007). Nevertheless, these statements should be tested based on physiological studies that prove them.

In another line of thought, it should be emphasized that the dry matter yield of edible biomass was 3,96;

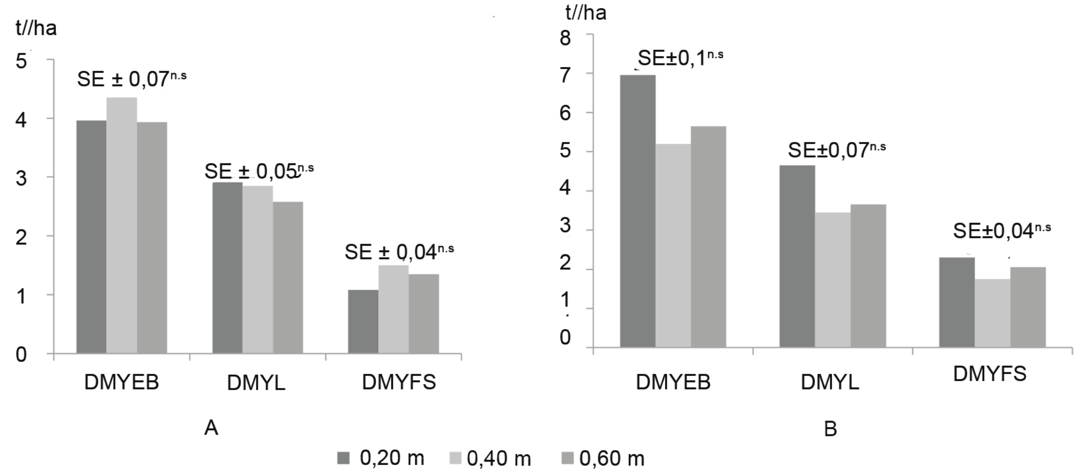

Figure 1. Effect of planting distance on the dry matter yield of the variety yu-12 in the first year of exploitation. A) dry season, B) rainy season.

4,35 and 3,93 t/ha in the DS and 6,95; 5,2 and 5,65 t/ha in the RS, for the planting distances between plants of 0,20; 0,40 and 0,60 m, respectively. Thus, the annual yields were 10,91; 9,55 and 9,58 t/ha/year; higher than those obtained by Martín (2004). In his study, this author used cutting frequencies of 60 days in the RS and 90 days in the DS and obtained annual yields of 8 t/ha, for which the productive potential of yu-12 behaved better than the one reported for the variety tigreada in Cuba.

According to Cifuentes and Kee-Wok (1998), the variety is one of the factors that determine the mulberry yield, due to the specific characteristics shown by each one. For example, the ones with short internodes and big leaves will provide higher biomass availability per plant. Yu-12 is one of the mulberry varieties with these characteristics; yet, although it was remarkable in plain view, it was not the objective of this study to evaluate the morphology and botany of the variety.

On the other hand, the quantity of cuttings in each season could have been a positive factor in obtaining the yields, which were higher than the ones reported by Martín (2004); however, it must be taken into consideration that this could negatively influence the persistence of the crop in time.

Figure 2 shows the dry matter yield of the edible biomass, leaves and fresh stems, for each season, during the second year of exploitation of the crop. Significant differences were found for all the studied variables in favor of the lowest planting frame (0,20 m), and the DMYEB was 5,04 and 8,04 t/ha in the DS and RS, respectively.

These results coincide with the ones obtained by Benavides *et al.* (1986), Rodríguez *et al.* (1994) and Boschini *et al.* (1999). In those cases different planting distances from the ones evaluated in this study were used; nevertheless, the highest yields were obtained when decreasing the separation between plants. Thus, in this experiment it was confirmed that planting distance influences the mulberry yield.

As the spacing between plants increased, the yield per hectare decreased. With the 0,40-m distance the yields were moderate (3,06 t/ha in the DS and 5,1 t/ha in the RS). When 0,60 m was used the DMYEB decreased, with values of 2,01 and 3,35 t/ha in each evaluated period.

Regarding the DMYL and DMYFS, it was also observed that at higher spacing between plants the yield per hectare decreased. However, when estimating the biomass production per plant, in leaves as well as stems, a trend to increase their mass was observed when using higher distances between plants. The yield was 0,74 and 0,80 kg/plant/year of leaves and stems in the 0,20-m distance; 0,91 and 0,98 kg/plant/year in 0,40 m; and 1,02 and 1,10 kg/plant/year of leaves and stems, respectively, in 0,60 m. This performance was also found by Boschini *et al.* (1999) in another mulberry variety, with higher planting distances.

On the other hand, Criollo and García (2009) stated that with the increase of planting density the biomass per plant generally decreases, although it increases per surface unit.

The results during the second year of exploitation of the crop in favor of the lowest planting distance can

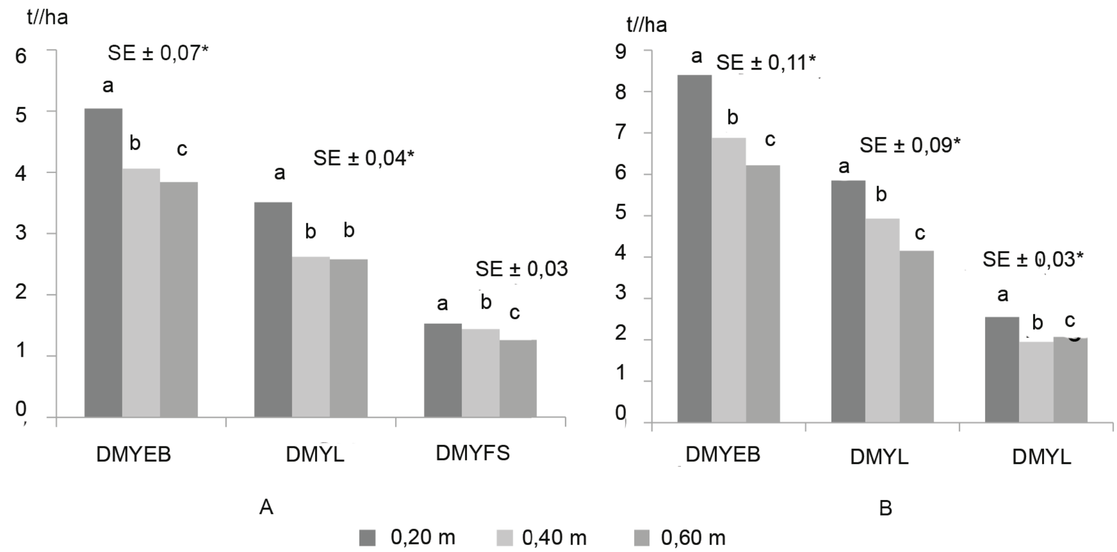

Figure 2. Effect of planting distance on the dry matter yield of the variety yu-12 in the second year of exploitation. A) dry season, B) rainy season.

be due to the interspecific competition for the vital space and nutrients (Páez, 1991), because in this periods the plants have developed their entire root system.

Several authors have emphasized the importance of using high densities to obtain high yields, not only in trees and shrubs, but also in herbaceous plants such as soybean, rice, onion and pepper (Lipinski *et al*., 2002; Gutiérrez *et al*., 2004; Acevedo *et al*., 2011). For such reason, it can be inferred that mulberry has a similar performance to that of other species.

It is important to state that the yields of edible biomass increased in the second year with regards to the first, and 13,44; 10,94 and 10,06 t/ha/year were obtained for the distances of 0,20; 0,40 and 0,60 m, for which all seems to indicate that mulberry is persistent and shows high regrowth capacity when being exploited with intense cutting frequencies (40 and 50 days in the DS and RS, respectively), coinciding with the report by Boschni *et al.* (1999).

According to Francisco (2003), in most trees defoliation influences the CO_2 assimilation processes. When the plant is pruned, the carbohydrate reserves facilitate a vigorous regrowth; but when these reserves are not sufficient or there is not recovery time, the emitted foliage is small, incapable of assimilating sufficient carbon to restore them.

In addition, Nikinmaa *et al*. (2014) stated that pruning reduces the photosynthetic foliage, but the remnant foliage can be better exposed to solar radiation and increase the efficiency of energy conversion; for which a tree with low leaf area density can intercept a higher number of photons per leaf area unit than a tree with high density. For such reason, when using a wide cutting frequency the leaves are more spatially distributed and make a better utilization of sunlight, which has repercussions on the yield increase.

Another aspect, mentioned by several authors (Hernández *et al*., 2000; Francisco, 2003), is that there is interaction between pruning frequency and planting density. In this study the cutting frequency was fixed, but it is considered that it could have been an important factor to obtain these yields, because in the trees planted at high densities, the closing of their canopies should occur earlier than in the ones sown at low densities. In this case, it is stated that to maximize the biomass production in dense plantations shorter cutting intervals are required than in sparser plantations (Horne *et al*., 1986).

In general, in the study it was observed that when decreasing the distance between plants, that is, when increasing the density per hectare, acceptable edible biomass yields can be obtained for feeding monogastrics and ruminants; this also allows to make an intensive land use. The persistence and regrowth capacity of mulberry when pruned with intense frequency was also proven; however, it is necessary to determine the crop persistence in time, under similar conditions.

It is concluded that during the first year of exploitation of the crop the dry matter yield of the variety yu-12 was not influenced by planting distance between plants. In addition, the dry matter yields of edible biomass, leaves and fresh stems were higher during the second year of exploitation, with the planting distance of 1,30 m between rows and 0,20 m between plants. On the other hand, the yield increased in the second year, for which the persistence and regrowth capacity of the plants was remarkable.

It is advisable to use short distances between plants and intense cutting frequencies in mulberry during the first two years of exploitation of the crop, as well as to study the performance of the plant in time when subject to similar conditions as the ones in this study.

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