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Growth of *Cordia trichotoma* seedlings in different sizes of recipients and doses of fertilizer

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This aim of this work was to evaluate the initial growth of *Cordia trichotoma* seedlings, submitted to different sizes of recipients and doses of controlled-release fertilizer (CRF). This experiment was performed in a greenhouse, and evaluation was done in factorial scheme using two volumes of recipients (110 and 180 cm^3) combined with five doses of CRF (0 (controlled); 2.5; 5.0 and 7.5 g L^{-1} de substrate). The experimental design was completely random with four repetitions each evaluated in factorial scheme. Significant interaction was observed between the size of the recipient and the doses of CRF for most analyzed variables. It indicated that, the quantity of fertilizer to be used depends on the size of the recipient, emphasizing that in the conditions in which the seedlings were produced; the minor volume of substrate does not cause restrictions on growth. It is perceived that most evaluated parameters need higher doses than the maximum provided, in at least one of the recipients, demonstrating elevated nutritional requirement of the species during the nursery phase. The recipient of 110 cm^3, combined with the dose of 7.5 g L^{-1} of CRF is recommended because of the economy of substrate, nursery space and practicality of transportation.

Key words: Native species, controlled-release fertilizer, louro-pardo, seedling production.

INTRODUCTION

Studies related to the performance of tropical tree species with ecological and commercial potential are incipient, mainly regarding the inherent characteristics of the processes of seedling production. Among these tree species is *Cordia trichotoma* (Vell.) Arrab. Ex Steud. (louro-pardo), recognized for its timber quality, easy workability and multiplicity of use, which gives it high aggregated commercial value, it has wide natural occurrence in tropical and subtropical forests in Argentina, Bolivia, Brazil, Paraguay and Uruguay (Carvalho, 2003).

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The tree presents high survival rate and growth in planting (Salvadori et al., 2013), and it can be used in reforestation geared towards the reestablishment of altered areas (Carvalho, 2003) and for commercial purposes (Scheeren et al., 2002).

In this sense, considering the potential of *C. trichotoma* in environmental recovery, as well as its economic importance due to wood quality and volume growth, it becomes essential to carry out studies, focusing on initial process of seedling production which will provide high survival and growth after planting.

In the seedlings production of arboreal species in nursery, the growth characteristics of the various species which may be partially controlled through the use of appropriate inputs should take into account. In the production of forest seedlings, the main factors that influence the final quality of seedlings, are based on the kind and the size of recipient (South et al., 2005; José et al., 2005) and the basis fertilization (Jacobs and Landis, 2009; Rossa et al., 2015). The dimensions of the recipient can influence several aspects, because they control the quantity of water and nutrients available for the seedling growth (Lana et al., 2010; Brachtvogel and Malavasi, 2010). If the substrate does not provide sufficient quantities of the mineral elements demanded by the plants, the fertilization in turn has to serve this nutritional demand, allowing the adequate growth and development (Landis, 1990; Rossa et al., 2011).

Among the fertilizers used currently are the ones with controlled- release (CRF), mainly, because of its peculiarity of providing the nutrients slowly to the plants, in a synchronized way, balancing the demand with the availability in the substrate, and maintaining constantly, the levels of the essential elements to the seedlings during the growth period (Landis and Dumroese, 2009; José et al., 2009). Besides, the release rates are adjusted by the manufacturer, according to the thickness and the nature of the material (coating), and the variable duration is 3 to 18 months (Valeri and Corradini, 2005; Landis, 2009; Landis and Dumroese, 2009). However, because of the high cost the FLC, adequacy of doses to production systems becomes necessary to optimize the cost-benefit ratio (Rossa et al., 2013).

Thus, knowledge of substrate volume associated with mineral nutrition used in the production of seedlings in the nursery represents a strategy to achieve seedlings in less time and cost with minimum standard of quality capable of providing adequate growth of *C. trichotoma*. Therefore, the aim of this work is to evaluate the seedling growth of the species, submitted to different sizes of recipient and doses of controlled-release fertilizer.

MATERIALS AND METHODS

The study was conducted in a greenhouse located at (29°43’14,3” S and 53°43’17,5” O) in Universidade Federal de Santa Maria (UFSM), Santa Maria, Brazil. The climate of the region, according to the Köppen classification, is of Cfa fundamental type, humid subtropical, characterized by average temperature of between -3 and 18°C in the coldest month, and higher than 22°C in the hottest month, with an annual average precipitation of 1,769 mm (Alvares et al., 2013).

The seeds used in the work came from diaspores of *Cordia trichotoma*, collected from 14 seed trees located in fragments of the Decidual Seasonal Forest (29º45’30,3” S and 53º34’43,9” O), in the municipality of Santa Maria, Brazil. After the collection, the next stage was extraction and processing, in which the remaining petals were removed to form a seed lot.

The treatments consisted the following: two sizes of recipients, containers of 110 cm^3 (6 splines, internal diameter of 35 mm and height of 13.5 cm) and of 180 cm^3 (8 splines, internal diameter of 52 mm and height of 13 cm); and five doses of controlled-release fertilizer - CRF (Osmocote® of NPK formulation (15-09-12), in the doses of 0 (controlled); 2.5; 5.0 and 7.5 g of CRF L^{-1} of substrate. For seedling production, the commercial substrate peat based on *Sphagnum* and vermiculite, plus 20% of carbonized rice husk (CRH) was used.

The sowing was performed directly in the recipients (containers) with five seeds in each; the containers were arranged in trays, which were taken to the greenhouse. The seedling first emerged on the 60th day after sowing, then, thinning was performed to eliminate the excess seedlings, leaving just one seedling per recipient. On the 210th day after sowing, the seedlings were evaluated using the following morphological variables: height (H), stem diameter (SD), relation H/SD, shoot dry mass (SDM), root dry mass (RDM) and total dry mass (TDM).

The height of the seedling was measured from the stem to the apical bud, using a graduated scale (millimeters). The stem diameter was measured with a digital caliper (precision of 0.001 mm). To evaluate SDM, RDM and TDM, the seedlings were cut and separated in shoot and root part. The root part containing the substrate was washed in running water in sieves with mesh size of 1mm. Samples of both the roots and the shoot part were then placed in Kraft paper bags, identified and submitted for drying in kiln with a temperature of 70°C until they had constant weight. After these, they were weighed on an analytical balance (0.001 g) in order to obtain dry mass.

The experiment was a completely randomized (DCR) design of 2x5 factorial scheme (two sizes of recipients and five doses of controlled-release fertilizer), consisting of 10 treatments. Each treatment was represented by four repetitions of 24 plants.

After the normality of the residues has been confirmed, and the variance homogeneity done with the Shapiro-Wilk and Bartlett tests, respectively, through the Action software (TEAM ESTATCAMP, 2014), variance analysis (ANOVA) was performed. When interactions were significant, they were divided and the averages were compared by the Tukey test and/or the polynomial regression (α 0.05). The statistical analysis of the variables used was made with the following statistical model for the factor analysis:

$$Y_{ijk} = \mu + a_i + d_j + (ad)_{ij} + e_{ijk}.$$

Where Yik = observation of the i factor in the level j, k in the repetition; μ = general average; ai = size of the container; dj = dose of the controlled release fertilizer; (D) ij = effect of interaction and eijk. = Error associated to each observation.

Statistical analysis

For the analysis, the SISVAR statistical package was used (FERREIRA, 2011). Pearson correlation was performed to

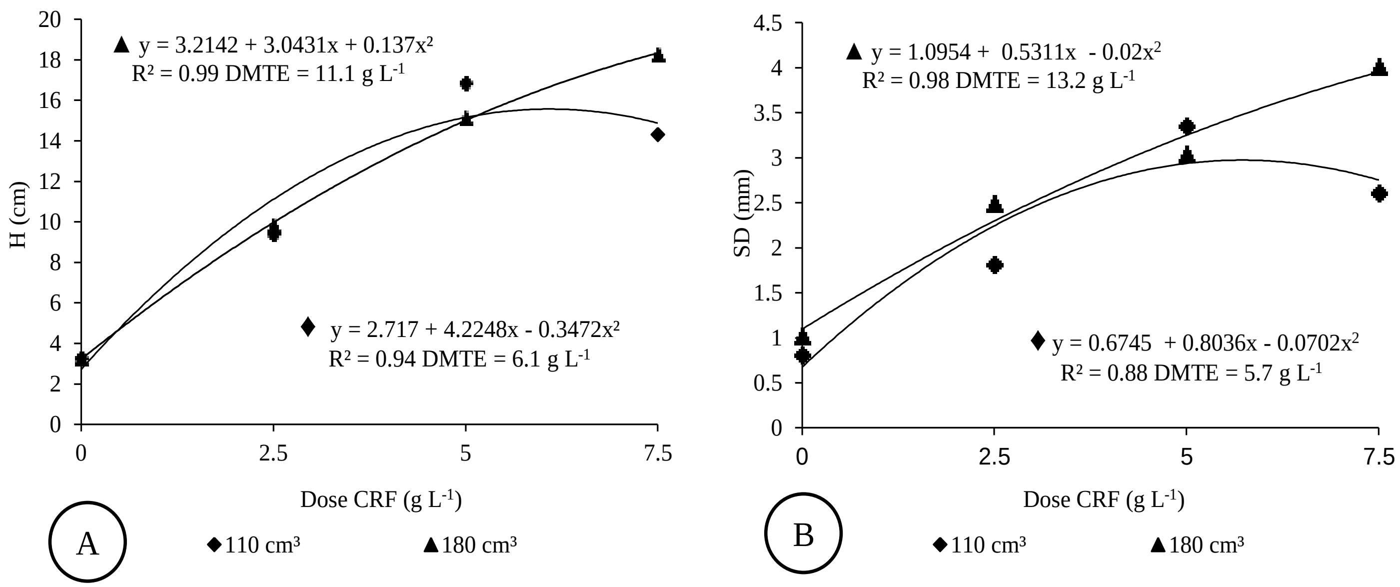

Figure 1. A: Height (H) and B: Stem diameter (SD) of seedlings of *Cordia trichotoma* as a function of different sizes of recipients and doses of controlled-release fertilizer (CRF) on the 210th day after sowing. DMTE - Dose of maximum technical efficiency.

complement the interaction among traits.

RESULTS AND DISCUSSION

By two hundred and ten days after sowing, it was observed that the height (H) of the *Cordia trichotoma* seedlings was influenced (p<0, 05) by the size of the recipient and the dosage of controlled-release fertilizer (CRF) used. (Figure 1A).

When the doses of maximum technical efficiency (DMTE) was calculated, it was observed that the height of the recipient in 110 cm^3 with 6.1 g L^{-1} of CRF was 15.6 cm, while the height of the recipient in 180 cm^3 with 7.5 g L^{-1} of CRF was 18.3 cm, which was the maximum height observed. This shows that the H variable responds positively when submitted to higher doses of fertilization (Figure 1A). Similar results were obtained by Rossa et al. (2013) in seedlings of *Schinus terebinthifolius* Raddi (aroeira-vermelha), with recipient of the same capacity. This result can be justified by the fact that the volume capacity of the recipient is greater and thus allows appropriate development of the root system before theapplication of the substrate and fertilizer to the seedlings (Lopes et al., 2005; Abreu et al., 2015).

The seedlings produced in the recipients of 110 cm^3, demonstrated a greater growth in stem diameter (SD) when 5.7 g L^{-1} of CRF (DMTE) was used (Figure 1B). This suggests that with this dosage, the seedlings will have greater survivability in the field, since according to Brisset et al. (1991); SD is an appropriate parameter, to evaluate the quality of the seedlings, due to the fact that it positively correlates with the root growth.

In the recipient of 180 cm^3 the dosage of 7.5 g L^{-1} presented result higher than that of other doses, (Figure 1B). The SD of the seedlings with the recipient of 180 cm^3 indicates that this variable responds to the addition of fertilization, demonstrating the same tendency observed in the H variable, when this recipient was used. This fact displays the evidences of the high nutritional demand of *Cordia trichotoma* in the nursery, which responds positively to significant doses of CRF, increasing its growth.

For the relation between H and SD, the seedlings of *C. trichotoma* presented significant difference ($p<0.05$) only in recipient size, and the greatest average (5.59 $cm.mm^{-1}$) was obtained in the recipient of 110 cm^3. The lower value (4.33mcm.mm^{-1}) of the relation between the H and SD of the seedlings produced in the container of 180 cm^3, occurred due to the greater increase in SD, this was observed when compared with the seedlings of the 110 cm^3 recipient. It is worthy to note that the seedlings did not present etiolation, or unbalanced growth, according to the description of José et al. (2005). This demonstrates that there was balanced allocation of assimilates for air growth.

According to Carneiro (1995), the relationship between H and SD demonstrates that the height of the seedlings has to be compatible with the stem diameter; and the lower the relation, the greater the capacity of the seedlings to survive and to establish themselves in the field, considering that the ideal values for this relation in seedling of *Pinus taeda* have to be between 5.4 and 8.1. However, according to Birchler et al. (1998), this value can be as high as 10, which is what is considered in seedlings with adequate quality, high growth rate and survival after planting

We infer that for *C. trichotoma* seedlings, values between 5 and 6 cm mm^{-1} can be used with reference to the H/DC relation, representing balanced growth in height and stem diameter, which might provide faster establishment post planting. The analysis of the values of dry mass (SDM, RDM and TDM), indicated interaction between the factors doses and recipient for RDM and TDM; for SDM only the factor dose of fertilizer presented significant difference (p <0.05), and the responses of growth were quadratic, estimated by DMTE in 7.0 g L^{-1} (Figure 2A).

According to Navroski (2013), the SDM is considered the structure of the seedling responsible for performing photosynthesis and allocate carbon for the different parts of the plant. With this, we can infer that seedlings with greater value of SDM will be able to adapt to the conditions of planting, because they present greater reserves of photo-assimilation, which are essential to the supply of the vital necessities to the plants (Bellote and Silva, 2000).

The root dry mass (RDM) of the seedlings produced in the recipient of 110 cm³ presented a tendency to increase with a dose of 5.4 g L^{-1} and decrease with a dose of 7.5 g L^{-1}.

Those produced in the recipients of 180 cm³, when used the dose of 7.5 g L^{-1}, presented an average production of dry mass superior to recipient of lower volume, however the same was not sufficient to express its maximum technical efficiency (DMTE = 8.3 g L^{-1}) (Figure 2B). We believe that the use of 110 cm³ container provides greater cost benefit, given that at a dose of 5.4 g L-1 of CRF it results in approximately 3.5 g of RDM per plant, while the plastic tube with 180 cm³ requires larger volume of substrate and reaches about 7.2 g L^{-1} RDM of CRF.

Because seedlings with greater root biomass tend to grow more and survive better in field than the plants with smaller root biomass (Haase, 2008). When the accumulation of total dry mass (TDM) was analyzed, it was observed that the DMTE of the recipient with greater capacity, was (8.2 g L^{-1}), and this is higher than the DMTE of the 110 cm³ recipient which was 5.9 g L^{-1} (Figure 2C).

In the absence of fertilization (Controlled) and with 2.5 g L^{-1}, independent of the recipient used, it was observed that the contribution of RDM and TDM was lower when compared to the other dosages (Figure 2B and C). This behavior is associated with the limitation of growth and development due to the insufficient supply of nutrients that can result in metabolic alterations in the plant (Taiz and Zeiger, 2013).

Some authors verified that the reduction in the volume of the recipient resulted in decrease of dry mass production of seedlings, as it was reported for *E*. *grandis* (GOMES et al., 2003), *S*. *terebinthifolius* (José et al., 2005) and *P*. *rigida* (Gasparin et al., 2015). Nevertheless in the study, we verified that in recipient of smaller size, the seedlings of *C*. *trichotoma* showed satisfactory results when lower doses of CRF were applied, while in recipient of greater volume the seedlings required higher quantity of the same fertilizer. Thus, seedlings of *C*. *trichotoma* when produced in recipient of lower volume (110 cm³), presented greater efficiency in the use of nutrients.

From the analysis, it can be observed that most of the studied variables presented significant correlation (Table 1). According to Filho et al. (2010) the intensity of the correlation is represented by a numerical value ranging from -1 to 1. Callegari-Jacques (2003), classifies the correlation rate in relation to intensity, where; $r = 0$ (there is no correlation), $0 < r < 0.3$ = (weak); $0.3 \le r < 0.6$= (regular); $0.6 \le r < 0.9$= (strong); $0.9 \le r < 1$ = (stronger) and $r = 1$ = (perfect). The H variable is strongly correlated to the SD variable, demonstrating the balance existing in growth, in which the increasing of H corresponds to the increment of SD. The H also correlates strongly with SDM, RDM and TDM (Table 1). On the other hand, the relation H and SD was the parameter that was weakly correlated with the other variables under evaluation (Table 1).

The RDM positively correlates with the H and the SD (Table 1), demonstrating that the seedlings which have a well-developed root system can develop better in field. According to Almeida et al., (2005) this is possible due to the greater area of water and nutrients absorption and the greater capacity of sustainability of seedlings. As most of the variables are strongly correlated and bearing in mind that the dry mass represents the net photosynthesis, seedlings of *C. trichotoma* produced in container of 110 cm³ demonstrated better quality, however it becomes relevant care with the maintenance in post planting, especially, with the control of invasive herbaceous species capable of competing with the seedlings for water and nutrients.

In this study, when the seedlings were planted in recipient with greater dimension (180 cm³), the DMTE of most of the evaluated parameters were above the maximum tested dose, while in seedlings planted in recipient of 110 cm³, all the evaluated parameters achieved the DMTE. Thus, it can be concluded that the nutritional demand of *C. trichotoma* seedlings depends on the size of the recipient used, thus, smaller recipients have lower nutritional demand

Conclusions

The application of controlled-release fertilizer (CRF) in

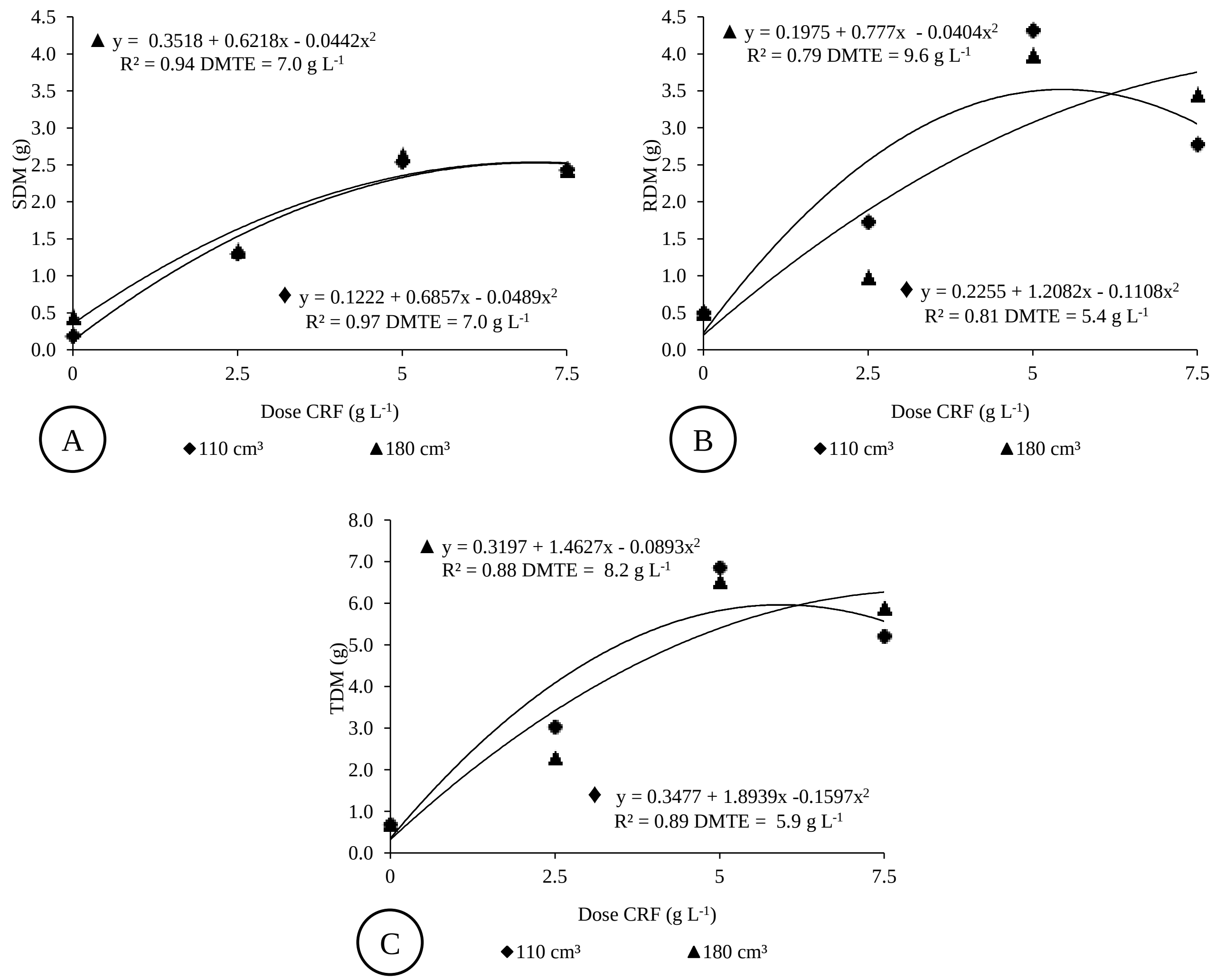

Figure 2. A: Shoot dry mass (SDM), B: Root dry mass (RDM) and C: Total dry mass (TDM) of seedlings of *Cordia trichotoma* in function of the use of different sizes of recipients and doses of controlled-release fertilizer on the 210th day after sowing. DMTE - Dose of maximum technical efficiency.

Table 1. Coefficient of Pearson correlation among the variables height (H), stem diameter (SD), relation H/SD, shoot dry mass (SDM), root dry mass (RDM), total dry mass (TDM) in seedlings of Cordia trichotoma in function of the use of different sizes of recipients and doses of controlled-release fertilizer on the 210th day after sowing.

Variables	H	SD	H/SD	SDM	RDM	TDM
H		0.97*	0.09^{ns}	0.97*	0.91*	0.94*
SD			-0.11^{ns}	0.90*	0.83*	0.86*
H/SD				0.24^{ns}	0.15^{ns}	0.19^{ns}
SDM					0.96*	0.98*
RDM						0.99*
TDM						

*Coefficients of Pearson correlation significant at 5% of probability of error; ^{ns} coefficients of Pearson correlation not significant at 5% of probability of error

the production of *C. trichotoma* seedlings had positive effect on the growth of plants. Thus, for the production of seedlings in nursery, the following is recommended: recipient of 110 cm³, combined with the dose of 7.5 g L^{-1} of CRF (15-09-12 NPK).

Other factors to be considered are: the economy of substrate, nursery space, practicality of production, transportation and the quality of seedlings. It is also recommended that other studies be carried out, which will test doses of CRF higher than the ones tested in this study; in order to elucidate the best dose required for the species.

Conflict of interests

The authors have not declared any conflict of interests.

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