

Estimation of the period of permanence of *Cordia americana* seedlings in protected environment

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ABSTRACT: The use of new tools as the technical criterion of interception of the curves of average daily increment and current daily are useful for indicating the optimal period of permanence of the plants in the protected environment. The objective of this study was to determine the length of stay of the *Cordia americana* (Linnaeus) Gottshling & JE Mill seedlings in protected environment based on the morphological parameter's height, base diameter and total dry mass of the seedlings and in the intercept between daily increment curves and increment daily average. The experiment was conducted in a randomized complete block design with four treatments and five replications. The criteria were defined based on the growth curves and intercept between curves of daily increment and average daily increment. The volume of substrate that could be explored by the root system and the density of seedlings per tray influenced the growth, in general larger seedlings were obtained in larger tubes. The period of stay of the seedlings in the nursery varies from 150 to 250 days depending on the treatment used using the dry mass as a quality parameter. The technical criterion used to intercept the curves of daily increment and average daily increment is useful in decision making, with a view to the evaluation of the quality standard of the seedlings.

Estimativa do período de permanência de mudas de *Cordia americana* em ambiente protegido

RESUMO: O emprego de novas ferramentas como o critério técnico de interceptação das curvas de incremento médio diário e corrente diário é útil para indicação do período ótimo de permanência das plantas no ambiente protegido. O objetivo foi determinar o período de permanência das mudas de *Cordia americana* (Linnaeus) Gottshling & J.E. Mill em ambiente protegido baseado nos parâmetros morfológicos altura, diâmetro do colo e massa seca total das mudas e no intercepto entre as curvas de incremento corrente diário e incremento médio diário. O experimento foi conduzido em delineamento experimental de blocos completos casualizados, contendo quatro tratamentos e cinco repetições. Os critérios foram definidos com base nas curvas de crescimento e intercepto entre curvas de incremento corrente diário e incremento médio diário. O volume de substrato explorável pelo sistema radicular e a densidade de mudas por bandeja influenciaram no crescimento, em geral mudas com maiores dimensões foram obtidas nos recipientes maiores. O período de permanência das mudas no viveiro varia de 150 a 250 dias dependendo do tratamento utilizado usando a massa seca como parâmetro de qualidade. O critério técnico utilizado de intercepto entre as curvas de incremento corrente diário e incremento médio diário é útil na tomada de decisão, com vistas à avaliação do padrão de qualidade das mudas.

Introduction

The implantation of forest essences for the recovery of degraded areas and areas of permanent preservation, especially the genus *Cordia*, can be carried out with seedlings produced in a protected environment. The quality of the seedlings is important to increase the survival of the plants in the field, as well as to accelerate the recompositing time (Abreu et al. 2015). Thus, the production of nursery seedlings is one of the most important stages in the process of reforestation implantation (Eloy et al. 2014). Some factors influence seedling quality, such as seed quality, type of container, substrate, management and time spent in the greenhouse. There are few studies that address the seedling residence time in the greenhouse, these studies are with exotic species (Mafia et al. 2005; Reis et al. 2008; Eloy et al. 2014), but with the genus *Cordia* there are no studies dealing with the seedling residence time in the greenhouse.

The volume of the tubes and the spacing between the plants in the protected environment are one of the factors that influence the growth, but when it involves native species, there is a great lack in studies. In general, higher seedling density favors selection of the most vigorous plants, removing low quality individuals (Eloy et al. 2014). Thus, the best arrangement between the seedlings provides uniformity in growth, more homogeneous and allowing greater control over the period of permanence of the individuals in the protected environment (Reis et al. 2008).

The use of new tools as the technical criterion of interception of the curves of average daily increment and current daily, are useful for indicating the optimal period of permanence of the plants in the protected environment (Mafia et al. 2005). However, this methodology can be considered as a new technique to evaluate the quality of the seedlings that directly reflects the performance and survival in the field (Mafia et al. 2005). This procedure was used only to determine the optimal period of permanence of *Eucalyptus* seedlings in the work of Mafia et al. (2005) and Eloy et al. (2014), demonstrating the necessity of these studies with native species. The use of tubes with inappropriate shapes and volumes is directly related to the deformities presented by the root system of plants produced in nurseries. These receptors provide abnormal growth in the distribution of the superficial and lateral roots, causing the imbalance in the absorption of nutrients and water in quantities essential for the molt (Alfenas et al. 2004). This is due to the imbalance between root dry mass and dry shoot mass (Mafia et al. 2005).

Thus, the present study had the objective of determining the length of stay of *Cordia americana* (Linnaeus) Gottshling & JE Mill in a protected environment based on the morphological parameter's height, base diameter and total dry mass

of the seedlings and the intercept between the curves daily increment and average daily increment.

Materials and Methods

The study was carried out with the *Cordia americana* (Linnaeus) Gottshling & JE Mill from September 2014 to February 2015, in a protected environment with Pampeana type greenhouse, with a low-density polyethylene cover, 150 mm thickness. The experiment was conducted in the forest nursery of the Federal University of Santa Maria, Campus of Frederico Westphalen, under geographic coordinates 27°23'46"S and 53°25'38" W at 480 m altitude.

The climate of the region according to the classification of Köppen is Humid Subtropical (Cfb) (Alvares et al. 2013), with rainfall regime balanced, however, to the reduction of precipitation in the winter season, annual average between 1,700 and 1,900 mm and average temperature between 20 and 23° C (Rossato, 2014).

The production of the seedlings was made from seeds from the company MP® seeds. At the sowing, performed on September 26, 2014, 4 seeds were placed per tube filled with commercial substrate (Tecnomax®). All treatments received base fertilization with five kg of slow release fertilizer with formula 15-09-12 per m³ of substrate. At 40 days after sowing, a thinning of the seedlings was done, leaving only the best and most central.

The experiment was conducted in a randomized block design with four treatments and five replications. Each block consisted of the following treatments: i) 170 cm³ tube with 100% (T1) and; ii) 50% (T2) occupancy; iii) 90 cm³ tube with 100% (T3) and; iv) 50% (T4) in the tray. Each experimental unit consisted of 35 and 28 plants, respectively, for 100% (high density) and 50% (average density) tray occupancy, with the 10 central plants being evaluated and the others as the border composing, when two seedlings per treatment and repetition were sampled. From the 60 days after sowing, five evaluations were performed, with intervals of 20 days. The high density corresponded to 434 and 237 plants per m² and the average density of 217 and 118 plants per m², for large and medium tube, respectively. During the experiment, daily watering was carried out in an automated way, reaching the field capacity of the substrate.

The following morphological characteristics were evaluated: shoot height (H), base diameter (BD) and total dry mass (TDM). The H was determined from the substrate level up to the tip of the last sheet, using a ruler graduated in millimeters, and the BD was measured at the substrate level with the aid of a digital caliper, with millimeter precision.

The determination of the TDM was made from the weighing of the plant, with subsequent drying of the materials in a greenhouse with forced ventilation at

65°C until constant weight, being weighed with the help of an electronic scale, with precision of four decimal places.

For each parameter evaluated, we adjusted the logistic model proposed by Leite and Oliveira (2002), defined by:

$$Y = \alpha(1 + \beta e^{-\gamma T}) + \varepsilon$$

In which: Y = evaluated variable; T = period in days; α , β and γ = coefficients of the model; ε = error.

From this model, it is possible to calculate the

daily increment and daily average increment defined by Leite and Oliveira (2002) and calculated by the derivative $\frac{dY}{dT} = \gamma Y(\alpha - Y)/\alpha$ and used in determining the technical rotation, in that Y , T , α and γ retain the meaning quoted above.

The coefficients of the logistic model (Table 1) were estimated by regression using the 5% level of significance, using SAS Learning Edition 8.0 software (2003).

Table 1: Morphological parameters, treatments and coefficients of the logistic model (α , β and γ) and determination (R^2 aj) used to define the relationship between height, base diameter and total dry mass of the American Cordia seedlings (Y s) in function of age (T).

Morphological Parameters	Treatments	Equation Coefficients			R^2 aj
		$Y = \alpha (1 + \beta e^{-\gamma T})^{-1} + \varepsilon$			
		α	B	γ	
Height (cm)	T1	20.0267	81.6547	0.0560	0.98
	T2	15.8413	73.7700	0.0562	0.99
	T3	17.1552	53.0926	0.0484	0.99
	T4	14.1007	29.3713	0.0431	0.98
Base diameter (mm)	T1	5.6029	14.2145	0.0381	0.99
	T2	5.6213	25.6681	0.0454	0.99
	T3	5.3346	20.7570	0.0354	0.98
	T4	5.5283	10,8425	0,0270	0,98
Total dry mass (g)	T1	3.3955	291.8	0.0513	0.94
	T2	3.0965	198.3	0.0475	0.95
	T3	7.5032	135.2	0.0261	0.94
	T4	2.8378	79.4	0.0345	0.92

Where: T1 = large tube + high density; T2 = large tube + medium density; T3 = medium tube + high density and T4 = medium tube + medium density.

Results and discussion

The height of the seedlings was influenced by the volume of the tubes ($P < 0.05$) and the arrangement of the plants in the trays, based on the regression analysis. Considering the growth curves of all treatments (Figure 1A), these differ from the 60 days after emergence. At 140 days, T1 (170 cm³ tube with 100% occupancy) treatment seedlings presented higher mean height compared to the other treatments (Figure 1A). T1 is the combination of the largest volume of substrate available for exploration and less useful space between the seedlings. The smaller living space between the seedlings provides

greater competition for solar radiation, favoring vertical growth (Eloy et al. 2014).

The density of the seedlings had no significant effect on the base diameter (Figure 1B), which was influenced only by the volume of available substrate. The growth curve for the base diameter shows the two points of inflection, but not finding the asymptote, the theoretical diameter of the asymptote can be considered as the α of the adjusted model. The total dry mass (Figure 1C) presented a significant difference for the different treatments but was more affected by the volume of the tube. The total dry mass is indicative of the amount of nutrients absorbed by the seedlings and, ultimately, their vigor (Eloy et al. 2014).

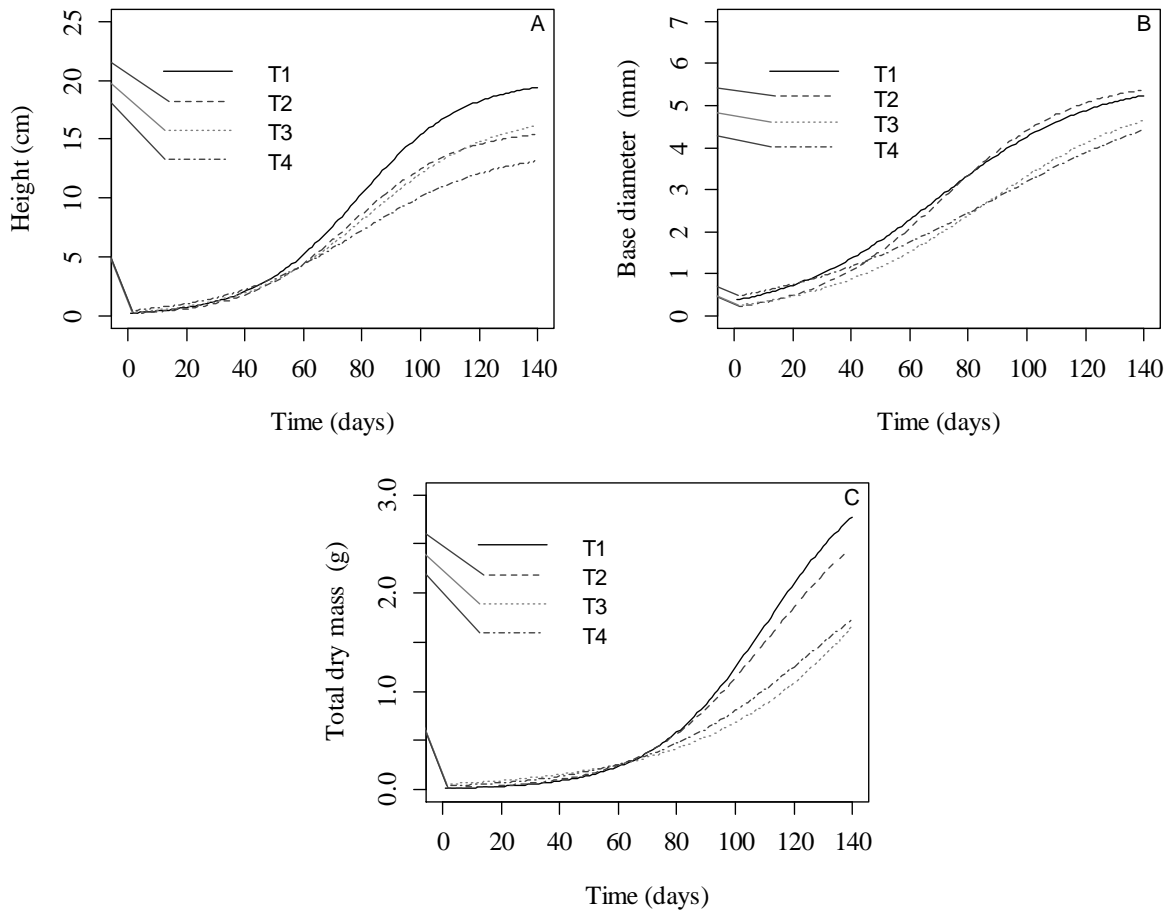


Figure 1: Mean height (A), mean base diameter (B) and mean total dry mass (C) as a function of the age of the American Cordia seedlings of the four treatments tested. In what: T1 = 170 cm³ tube + high density; T2 = 170 cm³ tube + medium density; T3 = 90 cm³ tube + high density and T4 = 90 cm³ tube + medium density.

In order to recommend the shelf life of the plants in a protected environment, it was considered as technical criterion the intercept between daily increment curve and average daily increment curve for the variables evaluated (Eloy et al. 2014). Based on plant height as seedlings should be transplanted to the field 107 days after plant emergence for treatment T1, and 104, 113 and 108 days for treatments T2, T3 and T4, respectively (Figure 2).

In a similar study, Mafia et al. (2005) studying eucalyptus clones (*Eucalyptus grandis* W. Hill ex Maiden x *Eucalyptus urophylla* Blake), found periods of 82 and 110 days after plant emergence, to produce plants of good quality. The shortest period is related to the species studied, because the genus *Eucalyptus* grow faster when compared to the genus *Cordia*. On the other hand, Eloy et al. (2014) working with *Eucalyptus grandis* found periods of 138 to 163 days after emergence, for expedition of seedlings with good quality. These higher values found by Eloy et al. (2014) may be

associated with the volume of substrate explored (50 and 90 cm³) and the non-application of the base fertilization, the authors also do not mention other applications. For the present work, 5 kg of slow release fertilizer was applied to each m³ of substrate.

The point at which the curves of daily increment and average daily increment intercept are defined as the optimal age for the expedition of the protected environment seedlings (Campos and Leite, 2006). When only the highest efficiency of plant growth, related to the average daily increment, is considered, the technical rotation of the crop is defined. However, it does not correspond to economic rotation, which uses other factors, such as production costs and current interest rates (Campos and Leite, 2006). Thus, the period of the intercept of the increment curves represents the maximum efficiency of the individual's growth, after that period the quality standard of the seedlings is impaired because the seedlings tend to stabilize the growth (Mafia et al. 2005).

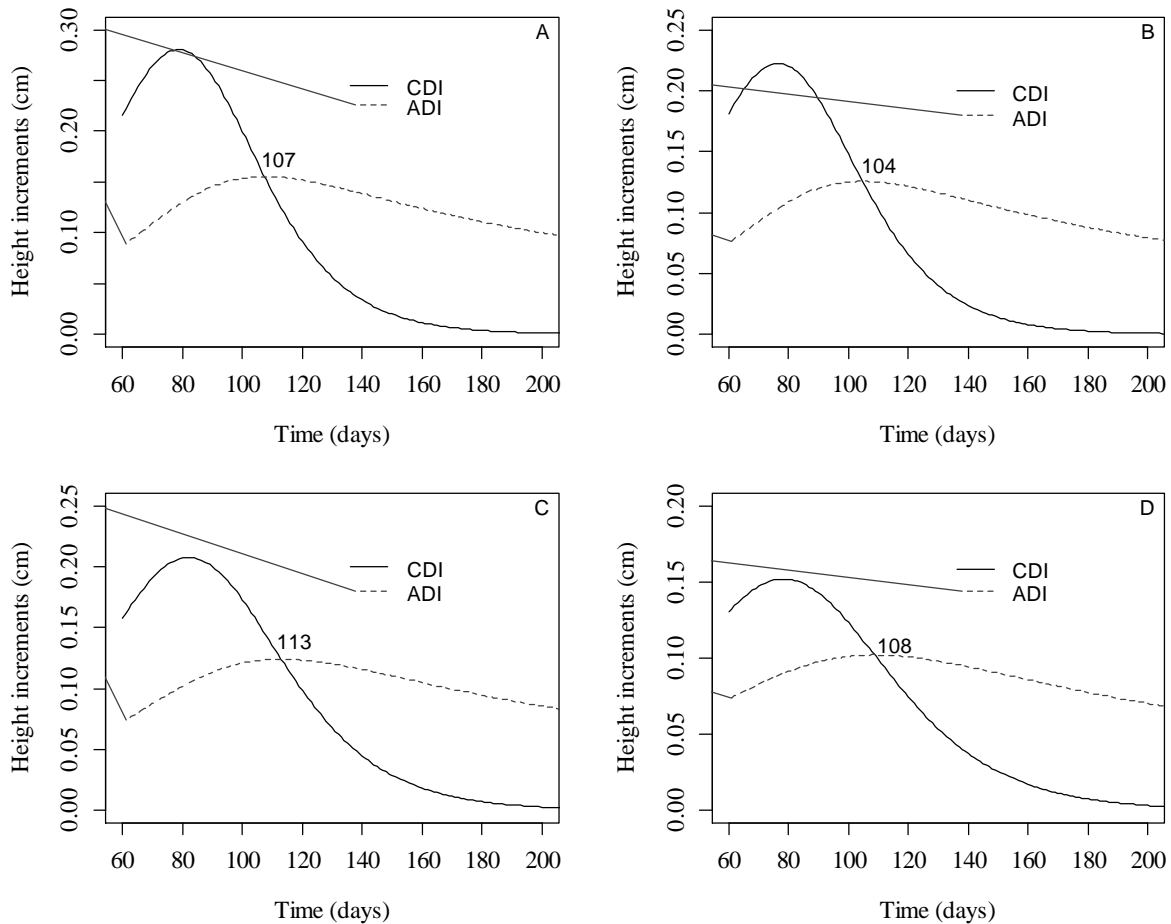


Figure 2: Current daily increments (CDI) and average daily increments (ADI) for height according to the age of the *Cordia americana* seedlings, according to the treatments: T1 = seedlings developing in large tubes (170 cm³) arranged in density high (237 tubes m⁻²) (A); T2 = in large tubes and medium density (118 tubes m⁻²) (B); T3 = medium tube (90 cm³) and high density (434 tubes m⁻²) (C) and T4 = medium tube + medium density (217 tubes m⁻²) (D).

Thereby, base diameter in the treatment T1 was found the age of 95 days after the emergence of the plants as the most suitable for the expedition of the seedlings of the nursery. For the T2, T3 and T4 treatments the defined age was 99, 119 and 116 days, respectively (Figure 3), showing that the larger tubes anticipate the moment of the expedition of the seedlings in 15 to 20 days when compared to the time of dispatch of seedlings produced in medium tubes, adopting the base diameter as reference.

The results demonstrated, when compared with the literature, show a certain similarity. Reis et al. (2008) determining the length of stay of *Eucalyptus grandis* seedlings, found values between 100 and 115 days, after the emergence of the plants, as the best indicated for the expedition with a good quality standard. However, the length of stay of the seedlings in the nursery may be longer, considering the height and diameter of the seedling base of *Tabebuia impetiginosa*, Cunha (2005), found a period of 180 days of stay in the nursery, a difference

caused by difference between the characteristics of each species.

Considering the total dry mass, in the T1 treatment, the age of 148 days after the emergence of the plants as the most suitable for the expedition of the nursery seedlings was observed, and for T2, T3 and T4 treatments the defined age was 149, 254 and 173 days, respectively (Figure 4).

For Alfenas et al. (2004), seedlings that have a higher standard of quality, present better conditions of growth and competition in the field. These characteristics can be affected by the time of permanence in the nursery, since from the moment the ideal period of rotation in the nursery is exceeded. The root system of the seedlings tends to present folding, imposed by the restriction of the explorable substrate space, in addition to suffer reduction of leaf area and present fragility to certain diseases. Is more suitable variable to evaluate the seedlings permanence time should be used for seedling dry mass.

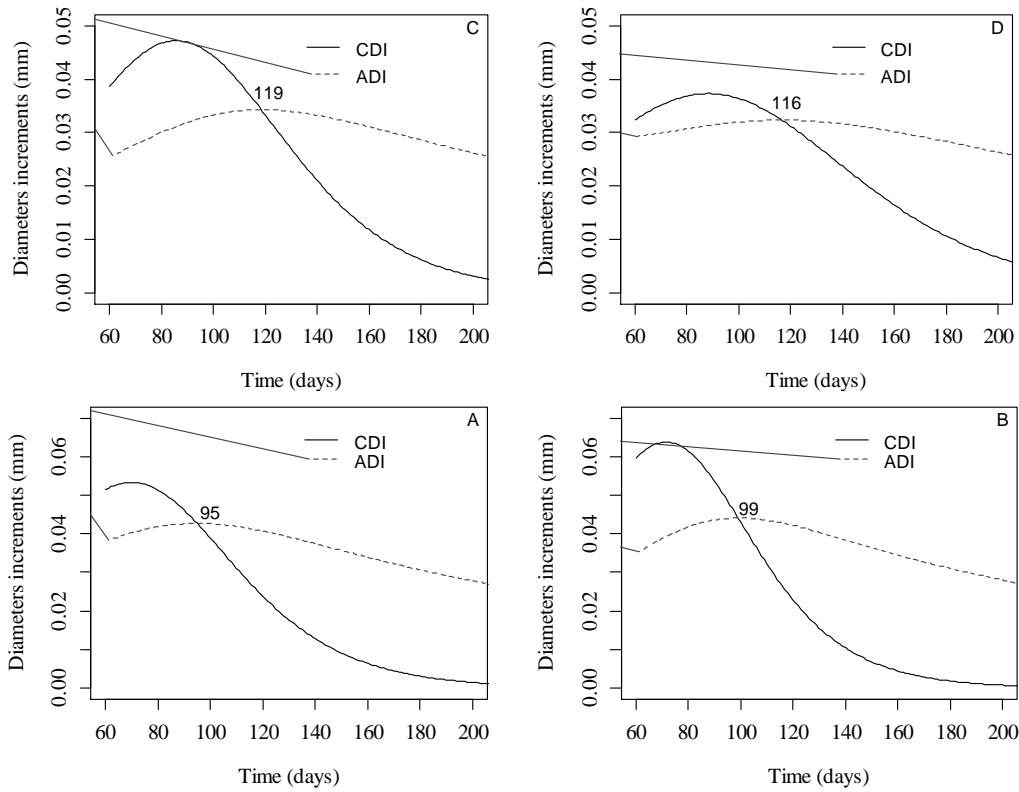


Figure 3: Current daily increments (CDI) and average daily increments (ADI) for the base diameter according to the age of the *Cordia americana* seedlings, according to the treatments: T1 = seedlings developing in large (170 cm³) in high density (237 tubes m⁻²) (A); T2 = in large tubes and medium density (118 tubes m⁻²) (B); T3 = medium tube (90 cm³) and high density (434 tubes m⁻²) (C) and T4 = medium tube + medium density (217 tubes m⁻²) (D).

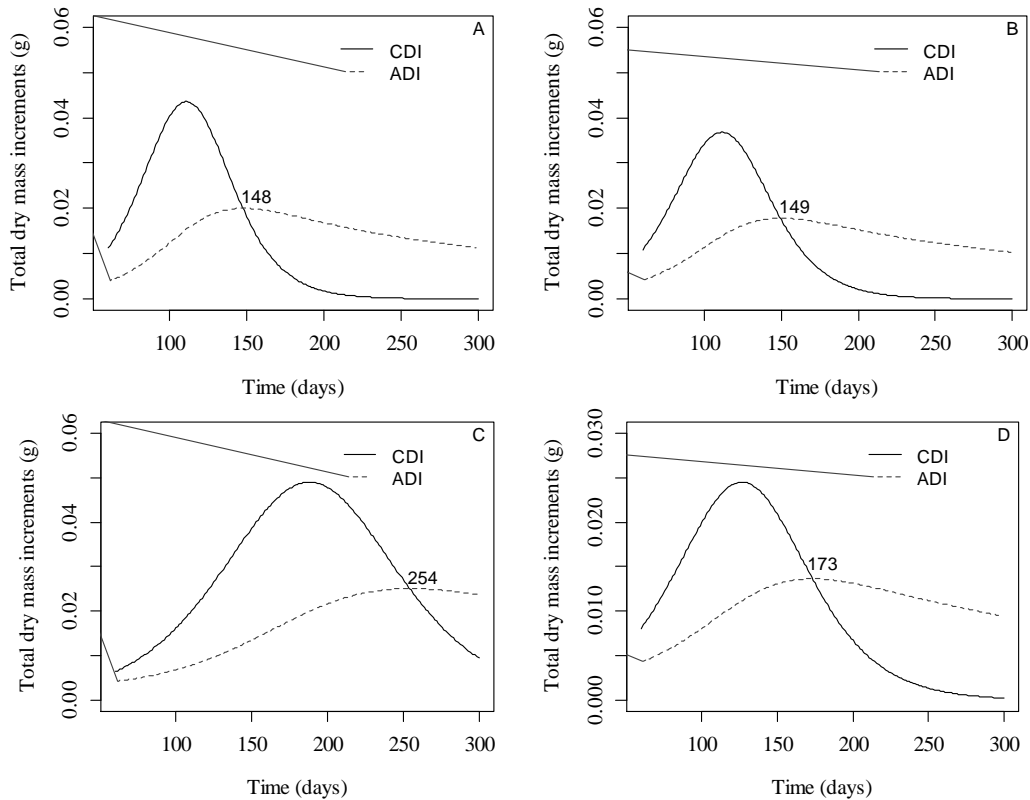


Figure 4: Current daily increments (CDI) and average daily increments (ADI) for total dry mass according to the age of the American *Cordia* seedlings, according to the treatments: T1 = seedlings developing in large tubes (170 cm³) in high density (237 tubes m⁻²) (A); T2 = in large tubes and medium density (118 tubes m⁻²) (B); T3 = medium tube (90 cm³) and high density (434 tubes m⁻²) (C) and T4 = medium tube + medium density (217 tubes m⁻²) (D).

The size of the tube and the density of the seedlings in the tray influence the growth of *Cordia americana* seedlings. In the present study, it was found that 148 (T1), 149 (T2), 254 (T3), 173 (T4) days were sufficient for the expedition of seedlings with a suitable quality standard in relation to the dry mass of plants.

Conclusion

The large tube and the density of 100% provided the shortest seedling time in the nursery. The intercept between the curves of daily increment and average daily increment, using the morphological parameters, is useful in the decision making to determine the period of permanence of the *Cordia americana* seedlings with a view to the evaluation of the quality standard of the seedlings.

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