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Morphological quality of *Croton floribundus* seedlings influenced by thinning along the production cycle

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Abstract
In this study, we aimed to evaluate the morphological quality of *Croton floribundus* (known by common sense as capixingui) seedlings influenced by the moment of alternation during the production process at the nursery. The experiment was conducted in a completely randomized design consisting of four treatments: alternation at 60, 90, 120 days after sowing and seedlings without alternation (referred as the control group), with six repetitions of 48 plants. It was analyzed height (H), the stem diameter (DC), the H/D ratio and dry matter of aerial part (ADM), root (RDM) and total (TDM), and the Dickson Quality Index (DQI). It was concluded that the best moment to perform the thinning is between 120 and 148 days, because in this treatment, the seedlings had grown enough to respond to the reduction in density, reaching at the end of the production cycle, desirable height and diameter, higher root and total dry mater.
Key words: Alternation, Capixingui, Seedlings density

Introduction

Croton floribundus Spreng, an Euphorbiaceae species, is a Mata Atlantica pioneer specie, being one of the few species tolerant to low concentration of oxygen in the soil. Besides, it can present longevity in natural conditions and reach reproductive even with little size (Cardoso-Gustavson et al. 2014; Silvestrini and Santos 2015). Thus, *C. floribundus* seedling production is important for recovering areas, and for biodiversity maintenance.

High quality seedling production is one of the most important factors in forest implantation success. The quality of a seedling is influenced by the genetic material, physiology and environment and treatments the seedling underwent during the production cycle in the nursery (Kissmann et al. 2013; Santos et al. 2013; Mesquita et al. 2015).

Among the practices in the nursery, the most important are the substrate composition, the hardening process, pest and disease control and plant density management (Davide and Silva 2008; Melo et al. 2014). Density is the number of plants in a meter squared, which is influenced by the container type size used. Seedlings can be produced using either plastic bags or containers (Abreu et al. 2015; Pinto et al. 2016) and seedling density can be altered in varying intensity and moments along the production cycle, according to the species and objective.

José et al. (2005) studying *Schinus terebinthifolius* seedlings grown in two sized tubes and two density, observed that height and stem diameter were influenced by density and tube volume. Novaes et al. (2002) concluded as greater the seedling density, bigger are the stem diameter, the amount of roots and the percentage of standard seedlings produced, even though the seedling height tend to be smaller.

In the seedling production tube system, satisfying conditions for water and nutrition, light seeking is the determining factor for growth. Thus, light search is the main factor for height and foliar area growth, essential parts for photosynthesis and establishment in the field at initial stage (Caron et al. 2014).

Hence, at first, is good having seedlings under high density condition at the nursery, so they can grow in height because they are competing for light. Besides, it would occupy less space at the production area. Then, to stabilize growth in height and increase growth in diameter, thinning would be a manner to promote hardening as a matter to prepare seedlings to stand harsh field conditions.

Thus, when using tubes at seedling production, it is possible to vary seedlings density. It is very important to determine the right moment to do this intervention and its effects in seedling quality because it affect plantation establishment. The aim of this study was to analyze the moment to proceed with the thinning operation for high quality *Croton floribundus* seedlings (capixingui).

Material and methods

The experiment was made between July and December of 2011 at Federal University of Lavras, Forest Nursery, in Lavras, Minas Gerais, Brazil, at 918 meters of altitude, 21°14' S latitude and 45°00' W in longitude. Mean annual temperature is 19.4°C, and maximum and minimum temperatures are respectively 26.1°C and 14.8°C. According to the Köppen´s climatic classification, the nursery is at Cwb area (Alvares et al. 2013).

Croton floribundus seeds were collected from 12 trees at Lavras region and mixed in bulk and sown in 53 cm^3 polypropylene tubes, placed at full sun environment, on trays at 1 meter high, with capacity for 96 tubes. Irrigation was preceded 3 times a day, under microsprinkler system. The initial density was 384 seedlings per m^2. Substrate was composed by 4 parts of coconut fiber, tree parts of rice husk and tree parts of manare plus 6 $kg.m^{-3}$ of Osmocote® (19-06-10), a fertilizer with period of five to six months of nutrient release.

Treatments applied were the moment in time thinning were proceeded, that could be 60, 90, 120 days after sowing. The control group is referred here as "180", because the production cycle was 180 days, and this group was never submitted to thinning activity. The thinning activity consisted of reducing tray density in 50%. The experiment was installed in completely randomized design, composed by 4 treatments and 6 repetitions of 48 seedlings per plot.

Were analyzed height (H), stem diameter (SD), height/diameter ratio (H/D), root dry matter (RDM), aerial dry matter (ADM), total dry matter (TDM), Dickson Quality Index (DQI).

Height and stem diameter were measured monthly from the second month until the end (sixth month) at the 15 central seedlings on the trays (each plot occupied a tray). Height was measured with a ruler. Stem diameter was measured with a caliper at base stem. H/D ratio was obtained by dividing height per the stem diameter for each seedling.

Dry matter was determined at the end of production cycle (180 days after sowing). To do so, the 15 central seedlings were used. The seedling were split in aerial part and roots. The root system was washed gently, to avoid missing parts, until removing all the substrate. After that, roots and aerial parts were identified and put to dry separately, in paper bags in the oven at 65 ºC until reach constant weight. Then, the dry matter was determined in digital scale, with 3 decimal cases. Dickson Quality Index was obtained from Dickson et al. (1960) as follows:

DQI = TDM (g) / [(H (cm) / (SD (mm)) + (ADM (g) / RDM (g))]

Results were submitted to variance analysis, and the treatments were compared by Tukey test with 95% of confidence. Also, dry matter and Dickson Quality Index were analyzed in time by a linear regression. Statistical analyzes were proceeded using SISVAR (Ferreira, 2000).

Results and discussion

Table 1 presents mean growth for height, diameter and height diameter ratio for each treatment at 60, 90, 120, 150 and 180 days after sowing. The number in parenthesis is the Tukey test result, with 95% of confidence. Figure 1 shows stem diameter and height growths along the production cycle for seedling for the applied treatments. Seedling morphology was influenced by tray density along time. In general, thinning reduced growth in height and increased diameter growth. Premature thinning (60 and 90 days after sowing) caused slow growth for both height and diameter, while seedlings which underwent through thinning at 120 days after sowing presented higher growth, when compared to the other treatments (for all vegetative parts analyzed, but height) at the final cycle. The control group was composed by the tallest and thinnest seedlings. Seedlings which were submitted to thinning at 60 and 90 days after sowing were the smallest ones, with statistically equal means.

Shortly after thinning, at 60 and 90 days after sowing, the treatments 60 and 90, respectively, answered by reducing growth (Figure 1). As it did not have stimulus for growth in height, because they do not need to compete for light, its foliar area remains short, with less possibility to photosynthesis and build more tissue. Otherwise, thinning at 120 days promoted sufficient growth in height because seedlings had to compete for light. Thus, they had foliar height enough to invest in diameter growth. The control group had the same density, and invested its resources majority in height growth, because they had to compete for sunlight. Thus, few resources was available for diameter growth.

Table 1. Means for height, diameter, height diameter atio for each treatment at 60, 90, 120, 150 and 180 days after sowing. Letters in parenthesis are the Tukey test result.

Days after sowing		60	90	120	150	180
		Height				
Treatment	180	1.6 (A)	4.0 (A)	14.8 (A)	18.4 (B)	23.7 (A)
	120	1.8 (A)	4.9 (A)	16.7 (A)	18.8 (A)	22.6 (B)
	90	1.3 (A)	3.7 (A)	6.4 (B)	7.6 (C)	11.9 (C)
	60	1.2 (A)	2.0 (B)	5.0 (B)	6.8 (C)	12.0 (C)
		Diameter				
Treatment	180	1.69 (A)	2.55 (A)	3.77 (A)	4.10 (B)	4.5 (C)
	120	1.82 (A)	2.66 (A)	3.90 (A)	4.35 (A)	4.95 (A)
	90	1.74 (A)	2.61 (A)	3.55 (B)	4.14 (B)	4.79 (B)
	60	1.61 (A)	2.30 (B)	3.31 (C)	3.83 (C)	4.70 (B)
		H/D				
Treatment	180	0.92 (A)	1.60 (A)	3.98 (A)	4.56 (A)	5.35 (A)
	120	0.96 (A)	1.86 (A)	4.38 (A)	4.44 (A)	4.57 (B)
	90	0.75 (A)	1.45 (A)	1.79 (B)	1.86 (B)	2.52 (C)
	60	0.87 (A)	0.88 (B)	1.53 (C)	1.79 (B)	2.59 (C)

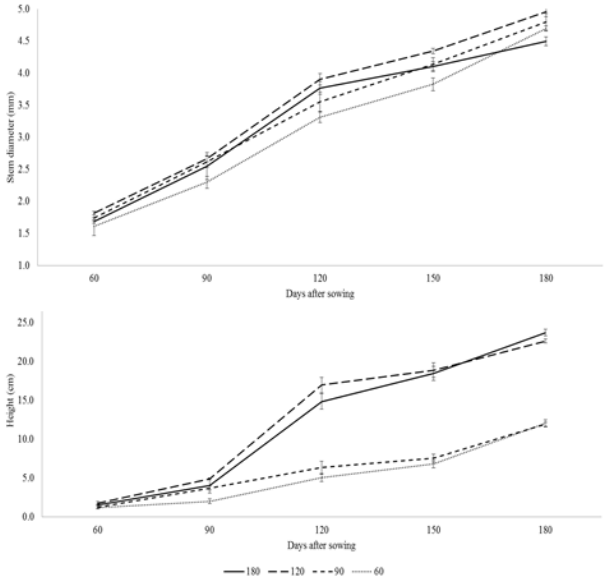

Figure 1 - Stem diameter and height for seedlings of Croton floribundus throughout the production cycle in the nursery, at Universidade Federal de Lavras, in Lavras, MG influenced by the moment of the thinning proceeding (60, 90, 120 or 180 days after sowing).

Sanquetta et al. (2014) studying two densities in the tray (either 100% or 50%) growing in two environment: natural or in greenhouse, verify that those seedlings submitted to high density on tray presented higher biomass for both environments. To set a good tray density is important because it influence light capitation, what effects grow, as we can see from several studies (Dardengo et al. 2013; Lenhard et al. 2013; Albuquerque et al. 2015; Marana et al. 2015; Nery et al. 2016).

However, if height growth is much bigger than diameter and root growth, seedling can be stretched, as happened with seedlings from the control group. According to Maynard and Bassuk (1990), etiolated seedlings present some drawbacks, such as less chlorophyll production, elongation of the internode and a formation of softer tissues with less mechanical resistance due to lower lignification and thinner cell walls.

It is important to accurately assess stem diameter since this information is a good indicator of seedling health and the ability to thrive harsh environment on the field (Moreira and Moreira 1996; Cargnelutti Filho et al. 2014; Pinto et al. 2016). At 180 days after sowing, we can see that control group had the smallest diameter among all the treatments. This difference was noticed before the end of the production cycle (Figure 1).

Costa et al. (2001), studying acerola trees, found positive meaningful relations between height and foliar area, what according to Gomes et al. (2002) is true, because the taller is the seedling, bigger is the foliar area available for photosynthesis and transpiration, what increases growth even more. This conclusions agree with the results found in this study because seedlings submitted to immature thinning reduced diameter and height growth because they did not have foliar area enough to respond to thinning by growing, being unable to compete for light, what promoted height and foliar area growth reduction as consequence.

Foliar area was not assessed, but the argumentation is based on field observations at the experimental area every evaluation time (height and diameter measurements). Seedlings which underwent through thinning at 120 days presented means with 16.7 cm in height at thinning time, while seedlings alternated at 60 and 90 days were respectively 1.2 e 3.7 cm height, at the thinning moment (Figure 1). This information implies seedlings that went through tinning at 120 days had more foliar area than seedling that went through thinning at 60 and 90 days after sowing. Thus, the first ones had more foliar than the second ones, being more prepared to growth.

Standard values for height and diameter vary from specie to specie, and according to the aim of the production. According to Sobrinho et al. (2010), standard height for *Dipteryx alata* is 35 cm and stem diameter is about 7 mm. Moraes Neto et al. (2003), suggest values of 33 and 4 cm for height and stem diameter for *Croton floribundus* seedlings, which are close to the values found in treatment 120 days.

Hence, for height and diameter, the best treatment was 120 days, because seedlings which underwent to thinning at 60 and 90 days after sowing presented small height and the control group had small diameters and too big H/D ratio (Figure 2).

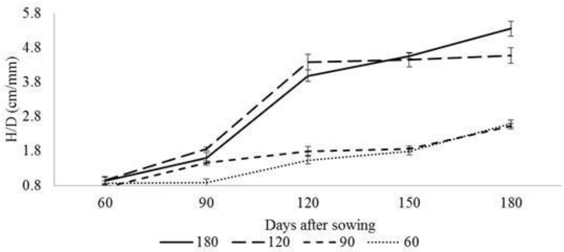

Figure 2 - H/D ratio of *Croton floribundus* seedlings throughout the production cycle in the nursery, at Universidade Federal de Lavras, in Lavras, MG, influenced by the moment of the alternation (60, 90, 120 or 180 days after sowing).

Height diameter (H/D) ratio shows the seedling equilibrium and health and it must be taken into account in assessing seedling quality, due to the operational ease of these measurements (Carneiro 1995). According to Sturion and Antunes (2000) H/D ratio is related to reserve accumulation, ensures greater strength and better ground fixation. Since the values of height stand diameter are within the ranges said to be ideal for seedlings, a lower value for H / D would be the most interesting (Aguiar et al. 2015). Thinning activity reduce H/D ratio because promote ticker seedlings.

Seedlings submitted to thinning at 60 and 90 days after sowing presented statistically equal values for H/D ratio, smaller than the values for seedlings from the other treatments, at the final production cycle (Table 1). However, the other parameters to assess seedling quality rather that H/D ratio, such as height and stem diameter, dry matter should be taken in account. Thus, seedling which underwent through thinning at 120 days after sowing presented satisfying values for all the parameters evaluated.

Figure 3 shows a regression analysis for aerial dry matter, roots dry matter and total dry matter, and Dickson Quality Index, in time during the production cycle of *C. floribundus* seedlings. The lines show that to have the highest values for those characteristics, seedlings should be alternated at 142, 146 and 148 days after sowing, respectively. These values were calculated by determining the value for the x axis when the first derivation is equal to zero for all equations listed (It will be the maximum value for the variable). As highest values for height and stem diameter were found in seedlings which passed through thinning at 120 days after sowing, it is recommended to undertake thinning any time between 120 and 148 days after sowing for *C. floribundus* seedlings.

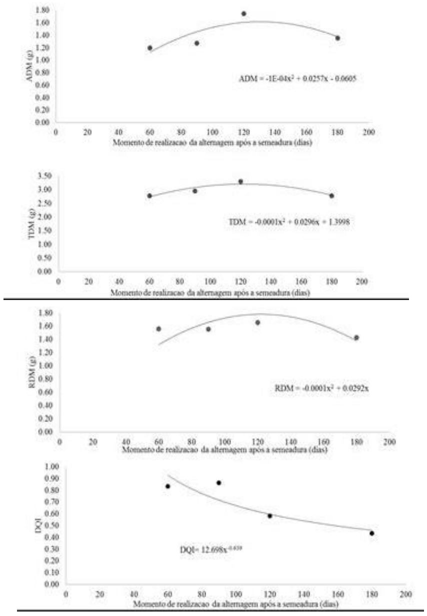

Figure 3 - Aerial dry matter (ADM), root dry matter (RDM), total dry matter (TDM) and Dickson Quality Index (DQI) of seedlings of *Croton floribundus* at 180 days after sowing, affected by the moment of the alternation, at Universidade Federal de Lavras, in Lavras, MG.

It is noteworthy that aerial part biomass is related to the quality and quantity of leaves, the main source of assimilates and nutrients, useful for post-planting seedlings adaptation. Dry matter values are in accordance to the values for height and diameter stem. Thus, higher dry matter values were found for those seedlings which underwent through thinning somewhere between 120 and 148 days. Higher values for stem diameter were found on those seedlings with higher root dry matter.

It is also possible to relate all evaluated morphological parameters in a single value, the Dickson Quality Index (DQI) (Figure 3D). This index has been used in several forest studies (Silva et al. 2015; Araújo et al. 2014; Pereira et al. 2016), because it combines in its calculation the main morphological parameters of seedling evaluation (height, stem diameter and dry matter), considering the vigor and the balance of the biomass distribution in the seedling.

Submitting seedlings through thinning between 120 and 148 days after sowing promote higher aerial part growth when compared to the treatments with earlier thinning (60 and 90 days), which resulted in lower values in the Dickson Quality Index, without, however, reduction in quality of such seedlings, because the values found for the DQI are above the minimum values cited as reference in studies with forest species seedlings production. José et al. (2005) found DQI of 0.31 for seedlings of *Schinus terebinthifolius* produced in 55 cm³ tubes, while Araújo et al. (2014) found interval of values of 0.21 to 1.12, 0.22 to 1.23 and 0.12 to 1.34 for *Rhizophora mangle*, *Avicennia germinans* and *Laguncularia racemose* seedlings respectively, produced on the same tube size.

Gomes et al. (2002) studying *Eucalyptus grandis*, observed that the higher DQI, higher is seedling quality.

However, it is necessary to evaluate the individual values of the parameters forming this index in order to verify if all are within acceptable standards for forest specie seedlings. The index, besides showing a balanced relation between the components of the seedlings, should present these components with minimum acceptable values.

Based on the values found in this paper, *Croton floribundus* immaturely thinned (60 and 90 days after sowing) show a reduction in growth rates, affecting negatively seedling quality. Those seedlings, even with the highest values for DQI, were not considered healthy because they did not present satisfactory growth. Control group (180 days) presented values relatively close to those values from seedlings alternated at 120 days after sowing, except for the characteristics that were positively affected by thinning (stem diameter and root dry matter).

Therefore, the nursery should use the thinning as a useful tool for managing seedlings at the nursery. However one needs to be aware that the results using this technique depend on the species with which is dealing with because it impacts the moment for thinning and seedling quality, and consequently, affect seedling establishment on the field.

Conclusions

Thinning time affects *C. floribundus* seedling quality, being the thinning operation recommended between 120 and 148 days after sowing because seedlings present the satisfactory height and stem diameter, bigger values for root, aerial and total dry matter, besides, Dickson quality index and H/D ratio at the standard.

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