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PRODUCTION OF SEEDLINGS OF *Psidium cauliflorum* Landrum & Sobral[1]

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ABSTRACT - In the absence of knowledge about the procedures for production of seedlings of particular tree species, determining the nursery production period and quality standards are normally priority aspects for studies. As there is no information on the propagation of *P. cauliflorum* in the literature, the objective of this study was to determine the length of stay in the nursery, the size of the container and the quality standards for the production of seedlings of this species, based on the performance in the nursery and in the field. The work was carried out in two stages. In the first, seedling growth was analyzed in the nursery and in the second stage their performance was analyzed in the field. We tested three container sizes: 55 cm³ (12.5 cm-length x 2.9 cm-internal diameter), 180 cm³ (13.5 cm x 5.2 cm) and 280 cm³ (19.0 cm x 5.2 cm) and different periods of seedling production in tubes (15, 30, 45, 60, 75, 90, 105 and 120 days). It is recommended that *P. cauliflorum* seedlings be grown in containers of 180 cm³ (13.5 cm x 5.2 cm) and remain in these containers for at least 120 days. The experiment to assess post-planting performance was crucial to obtain conclusive results for the production of *P. cauliflorum* seedlings.

Keywords: Container size. Seedling age. Quality standard.

PRODUÇÃO DE MUDAS DE *Psidium cauliflorum* Landrum & Sobral

RESUMO - Na ausência de conhecimento sobre os procedimentos para produção de mudas de determinada espécie arbórea, elegem-se, como aspectos prioritários para estudos, a determinação do tempo de permanência em viveiro e os padrões de qualidade das mudas. O objetivo deste trabalho foi determinar o tempo de permanência em viveiro, os padrões de qualidade e o tamanho de recipiente para produção de mudas de *P. cauliflorum* Landrum & Sobral*,* com base na performance em viveiro e em campo. O trabalho foi conduzido em duas etapas, analisando o crescimento em viveiro e posteriormente a performance em campo. Foram testados três tamanhos de recipientes: 55 cm³ (12.5 cm de comprimento x 2.9 cm de diâmetro interno), 180 cm³ (13.5 x 5.2 cm) e 280 cm³ (19.0 x 5.2 cm) e diferentes tempos de permanência das mudas no viveiro (75, 90, 105 e 120 dias). Recomenda-se que as mudas de *P. cauliflorum* sejam cultivadas em recipientes de 180 cm³ (13,5 cm x 5,2 cm) e que permaneçam nesses recipientes por pelo menos 120 dias. O experimento para avaliar o desempenho pós-plantio foi crucial para obter resultados conclusivos para a produção de mudas de *P. cauliflorum*.

Palavras chaves: Tamanho recipiente. Idade da muda. Padrão de qualidade.

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INTRODUCTION

The worldwide concern about changes in the climate and in the dearth of water resources has generated a high demand for seedlings of many tree species. Southeastern Brazil has a marketing network for seedlings from the Atlantic forest with a capacity to serve other regions (SILVA et al., 2017). However, according to Silva et al. (2017), in addition to this network being concentrated on the production of species of easier propagation, the number is still restricted in comparison to the great diversity of the flora of this forest. The recuperation and conservation of forests depend on the generation of knowledge about the production of seedlings of native species. As a result, it is necessary to understand the interaction between the different factors of production such as type and volume of container, substrate composition, irrigation quantity and regime, lighting conditions, depth of sowing, mineral nutrition and nursery production period.

Studies on container types and sizes and substrate composition predominate in the literature. These studies are mostly based on the results obtained just at the nursery stage (CORREIA et al., 2013) and generally consider quality standards of generic seedlings. Pezzutti and Caldato (2011) argue that the degree of seedling quality must be species-specific.

Some studies emphasize the efficacy of initial seedling morphology for predicting survival (TSAKALDIMI et al., 2013) and in most studies the quality standards are defined based on criteria observed just at the nursery stage (ABREU et al., 2015). However, the relationship between the dimensions of the seedlings upon leaving the nursery and subsequent survival and growth in the field should be determined (ZIDA et al., 2008).

The time spent in the nursery is one of the factors influencing seedling quality and post-planting performance (BAMBERG et al., 2013; MAFIA et al., 2005). However, this time and the quality of the seedling can be strongly influenced by pot size.

Research to define quality standards and length of stay in the nursery is scarce for Brazilian tree species. *P. cauliflorum* is a tree species of the Myrtaceae family, found in the ombrophiylous and seasonal forests of the Atlantic Forest (FLORA DO BRASIL, 2018; LANDRUM; SOBRAL, 2006). There is little knowledge about silviculture and the potential use of this species (OLIVEIRA et al., 2019; CARVALHO; SOUZA, 2018). The chromatographic profile of essential oils present in *P. cauliflorum* (BERNARDES, 2017) components with pharmacological potential (CARVALHO; SOUZA, 2018).

As there is no information on the propagation of *P. cauliflorum* in the literature, the objective of this work was to determine the length of stay in the nursery, the size of the container and the quality standards for seedling production of this species, based on the performance in the nursery and in the field.

MATERIAL AND METHODS

Nursery phase

The experiment was carried out in a greenhouse (ca. 50% full sunlight) in the experimental field of the Federal University of Reconcavo of Bahia (UFRB) in at the city of Cruz das Almas, Brazil (39º06'22"W/12º40'19"S), at an altitude of 220 meters. According to the classification of Köppen-Geiger (ALVARES et al., 2013), the climate is classified as Af, with an annual average temperature of 24 °C, annual average relative air humidity of 80% and annual average rainfall of 1200 mm.

The seeds were collected in September 2015 from the dominant trees of *P. cauliflorum* in the natural population at the Environmental Protection Area of Pedra do Cavalo in São Gonçalo city, Brazil (approximately 39º20'00" and 38º55'00"W/12'10'00" and 12'40'00"S). The seeds were sown in mother beds. After 70 days, the seedlings with two leaves were transplanted into the containers.

The containers were filled with commercial substrate (dry basis density of 260 kg m³), composed of pine bark, vermiculite, milled charcoal and phenolic foam, enriched with slow-release fertilizer (NPK: 15-9-12) at a dose of 1.5 kg m^{-3}. The seedlings were irrigated twice a day, according to requirements until saturation of 60%, in the early morning and late afternoon.

The factors evaluated were three sizes of containers, 55 cm³ (12.5 cm-length x 2.9 cm -internal diameter), 180 cm³ (13.5 x 5.2) and 280 cm³ (19.0 x 5.2) and eight evaluation periods, counted from the transfer of the seedlings from the sowing place to the containers (15, 30, 45, 60, 75, 90, 105 and 120 days), with seven repetitions. Each plot consisted of a tray with 34 seedlings. The containers were hard plastic tubes with conical shape.

We used 14 seedlings from each plot to measure the shoot length (cm) and root collar diameter (mm) growth at intervals of 15 days, up to 120 days after transplanting to the tubets. At 75, 90, 105 and 120 days, four seedlings were collected per treatment, for evaluation of leaf area (cm^2), shoot and root dry mass (g), main root length (cm), and fine root length (mm) (diameter ≤ 2 mm). To measure the total length of the fine roots, the substrate was sieved through a 500 µm mesh sieve. The roots were arranged on a scanner to obtain the digitized images. These images were processed in Safira Software (EMBRAPA, 2016) to calculate the total length of fine roots. To obtain the dry mass of shoots and roots, these were dried in an oven with air circulation at a temperature of 75 °C for 72 hours.

The indexes expressing seedling quality were calculated according to Dickson Quality Index (DQI) (DICKSON; LEAF; HOSNER, 1960) and the sturdiness quotient (ratio between height in cm and root collar diameter in mm).

The experimental design used to evaluate the effect of the treatments was completely randomized, in a scheme of split plots in time, with the size of containers evaluated in the main plots and the evaluation periods in the subplots. The data were subjected to analysis of variance with eight periods (15, 30, 45, 60, 75, 90, 105 and 120 days) for shoot length (cm), root collar diameter (mm) and sturdiness quotient (cm mm^{-1}); and four periods (75, 90, 105 and 120 days) for the destructive analysis (shoot and root dry mass (g), DQI, leaf area (cm^2), fine root length (mm) and main root length (cm). After the analysis of variance, the data were subjected to regression analysis and means comparison tests. The statistical analysis was performed using the R Core Team 3.4.0 program (R CORE TEAM, 2017).

Plantation phase

The study was carried out between May and December 2016 at the Experimental Farm of the Federal University of Reconcavo of Bahia in Cruz das Almas (Brazil). The soil is classified as Coarse Yellow Latosol, flat relief, medium texture, originating from sediments of the Barreiras Group (RODRIGUES et al., 2009). During the experiment, the monthly rainfall ranged from 34.6 to 157.2 mm (INMET, 2017) (Figure 1).

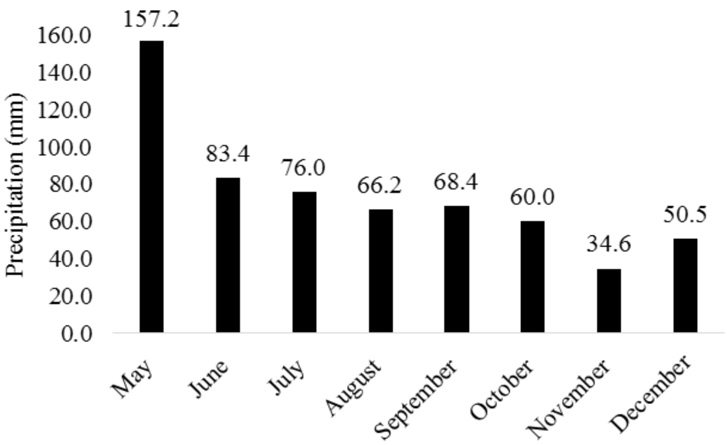

Figure 1. Monthly pluvial precipitation (PP) in Cruz das Almas, Brazil, WMO station: 83222 from 05/01/2016 to 12/31/2016 (INMET, 2017).

Before planting, the area was prepared with ploughing to a depth of 30 cm. A manual digger was used to open the pits (20 x 20 x 20 cm), spaced by 1.0 m in the row and 2.5 m between rows. The fertilization was performed with 200 grams of NPK 4-14-8 per pit. At the time of planting the seedlings were irrigated with four liters of water. In the absence of precipitation, the plants were irrigated, with about four liters of water per plant, three times a week, until the third month. After three months, irrigation was performed once a week.

The seedlings used in this experiment came from the nursery phase experiment, described previously. In field planting three container sizes (55 cm^3, 180 cm^3, 280 cm^3) and four seedling ages were tested. At 75, 90, 105 and 120 days, the seedlings were removed from the nursery and taken to the field. The experiment was carried out with a completely randomized design in a 4x3 factorial scheme, corresponding to four ages of seedlings (75, 90, 105 and 120 days) and three sizes of containers (55 cm^3, 180 cm^3, 280 cm^3) with three replications containing 18 plants per plot.

After the field experiment at the time of planting and every 30 days, the plants were measured for shoot length, root collar diameter and the number of dead plants was recorded until six months.

Analyses of variance were performed for split plots in time, followed by regression for the quantitative treatments and means comparison tests for the qualitative one. The statistical analysis was performed using the R Core Team 3.4.0 program (R CORE TEAM, 2017).

Relationships between the morphological attributes and the survival of the seedlings in the field

After the plants were measured for diameter and shoot length at the time of planting, class intervals were defined for these two variables using the Sturges rule. The numbers of dead and surviving plants (six months after planting) were measured per class of height and diameter and the Chi-Square test was used. The same procedures were adopted for the sturdiness quotient. The statistical analysis was performed using the R Core Team 3.4.0 program (R CORE TEAM, 2017).

RESULTS AND DISCUSSION

Nursery phase

The root collar diameter, the sturdiness quotient and the shoot length of the seedlings were influenced by the container sizes (Table 1).

Table 1. Degrees of freedom (d.f.) and mean square output from analysis of variance for the variables shoot length, root collar diameter and sturdiness quotient at the nursery stage of *Psidium cauliflorum* Landrum & Sobral.

Source of variation	d.f.	Shoot length	Root collar diameter	Sturdiness quotient
Container size	2	92.90**	1.10**	5.13**
Residual (a)	18	4.88	0.04	0.55
Periods	7	472.45**	11.36**	19.68**
Container size x Periods	14	10.40**	0.12**	0.34**
Residual (b)	126	0.71	0.005	0.08

**Significant at 0.01.

Larger volume containers favored the growth of *P. cauliflorum* seedlings. Larger containers usually result in increased seedling growth in the nursery (DOMINGUEZ-LERENA et al., 2006; FERRAZ; ENGEL, 2011) which can reduce the production cycle (FREITAS et al., 2013; SANTOS et al., 2000). The larger the container size the greater the availability of water and nutrients (GOMES et al., 2003; MALAVASI; MALAVASI, 2006), which favors growth. Considering just the growth of seedlings in the nursery, the recommendation will always be to use the largest possible container, but bigger container means higher costs in inputs and logistics. However, the ideal size of the container depends on the species, density, environmental conditions and duration of the growing season (TIAN et al., 2017).

The curves of growth in height, root collar diameter and sturdiness coefficient differed according to the container size used in the nursery phase (Figure 2). From 45 days the container sizes influenced the growth in the root collar diameter and the sturdiness quotient. For shoot length this effect was observed from 60 days. The highest root collar diameters, sturdiness quotient and height were observed in the 280-cm^3 containers.

The size of the container affected the shoot and root dry mass, Dickson's Quality Index (DQI), leaf area, main root length, fine root length (Table 2).

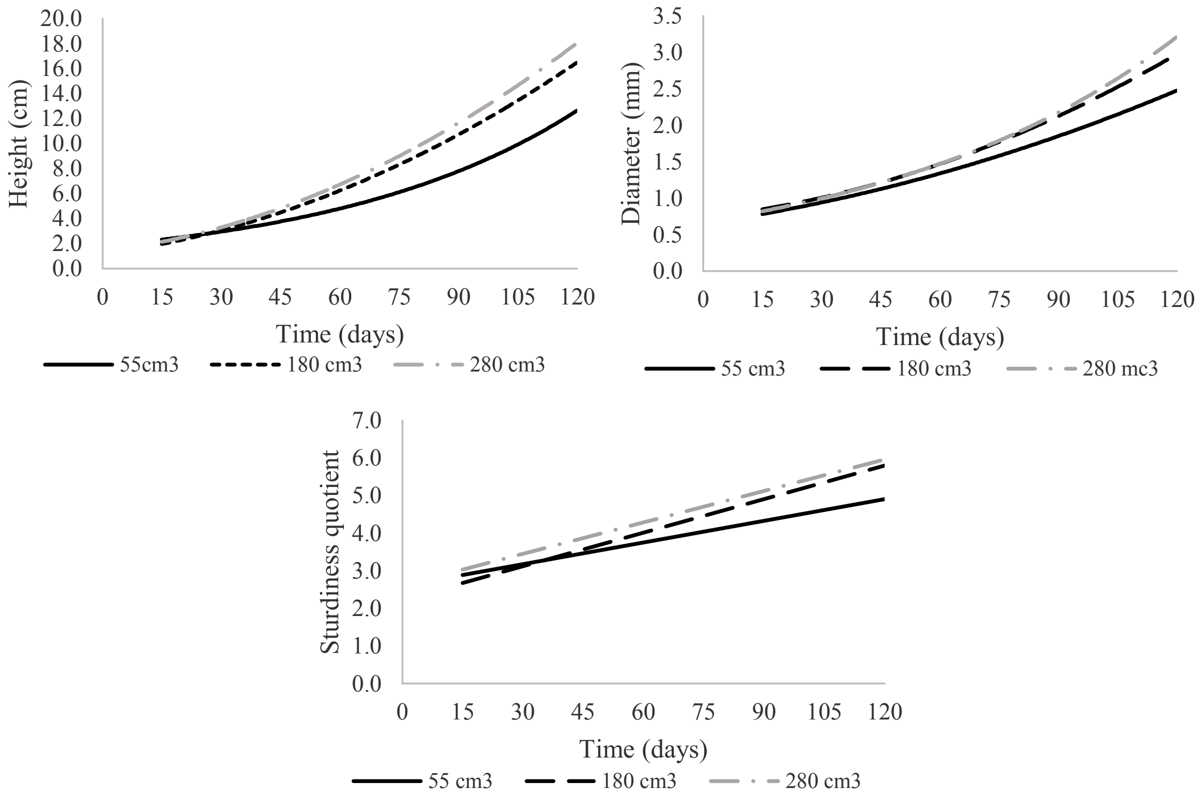

Figure 2. Height (H), Root collar diameter (D) and Sturdiness quotient (H/D) as a function of the time of permanence of the seedlings of *Psidium cauliflorum* Landrum & Sobral in the nursery. Equations adjusted for the containers of 55 cm^3- H = $2.10exp^{(0.01446x)}$ (R^2 = 0.93); D= $4.61/1+6.56exp^{(-0.0167x)}$ (R^2=0.93); H/D = 0.0192*x* + 2.5997 (r² = 0.79). Containers of 180 cm^3- H= $22.31/1+17.84exp^{(-0.032x)}$ (R^2 = 0.93); D= $8.29/1+11.51exp^{(-0.0152x)}$ (R^2=0.97); H/D=0.0298*x*+2.2247(r² = 0.97). Containers of 280 cm^3- H= $25.3/1+18.364exp^{(-0.031x)}$ (R^2 = 0.97); D= $0.6753exp^{(0.013x)}$ (r² = 0.97); H/D = 0.0279*x* + 2.6163 (r² = 0.93). exp = base of the Napierian logarithm; *x* = periods of stay in the nursery; r^2 or R^2 = coefficient of determination.

Table 2. Degrees of freedom (d.f.) and mean square output from analysis of variance for the variables shoot dry mass, root dry mass, Dickson's Quality Index (DQI), leaf area, fine root length (< 2 mm) and main root length in the nursery stage of *Psidium cauliflorum* Landrum & Sobral.

Source of variation	d.f.	Shoot dry mass	Root dry mass	DQI	Leaf area	Fine root length	Main root length
Container size	2	1.59E+00**	6.00E-02**	1.36E-02**	3.67E+04**	1.95E+07**	2.26E+02**
Residual (a)	9	9.00E-02	1.00E-03	3.00E-04	2.37E+03	9.31E+05	4.80E+00
Seedling age	3	2.84E+00**	1.91E-01**	4.11E-02**	2.45E+04**	2.29E+07**	1.40E+00
Container size x Seedling age	6	2.90E-01*	1.10E-02**	2.50E-03*	3.12E+03	1.15E+06	3.50E+00
Residual (b)	27	1.10E-01	2.00E-03	1.00E-03	2.78E+03	1.26E+06	2.30E+00

*Significant at 0.05.
**Significant at 0.01.

The seedlings produced in the 180-cm^3 and 280-cm^3 containers had a higher shoot dry mass, root dry mass and Dickson's Quality Index (DQI) than the seedlings grown in the smaller tubes (55 cm^3). At 120 days the shoot dry mass and DQI of the seedlings from 180-cm^3 and 280-cm^3 containers were statistically equal (Figure 3).

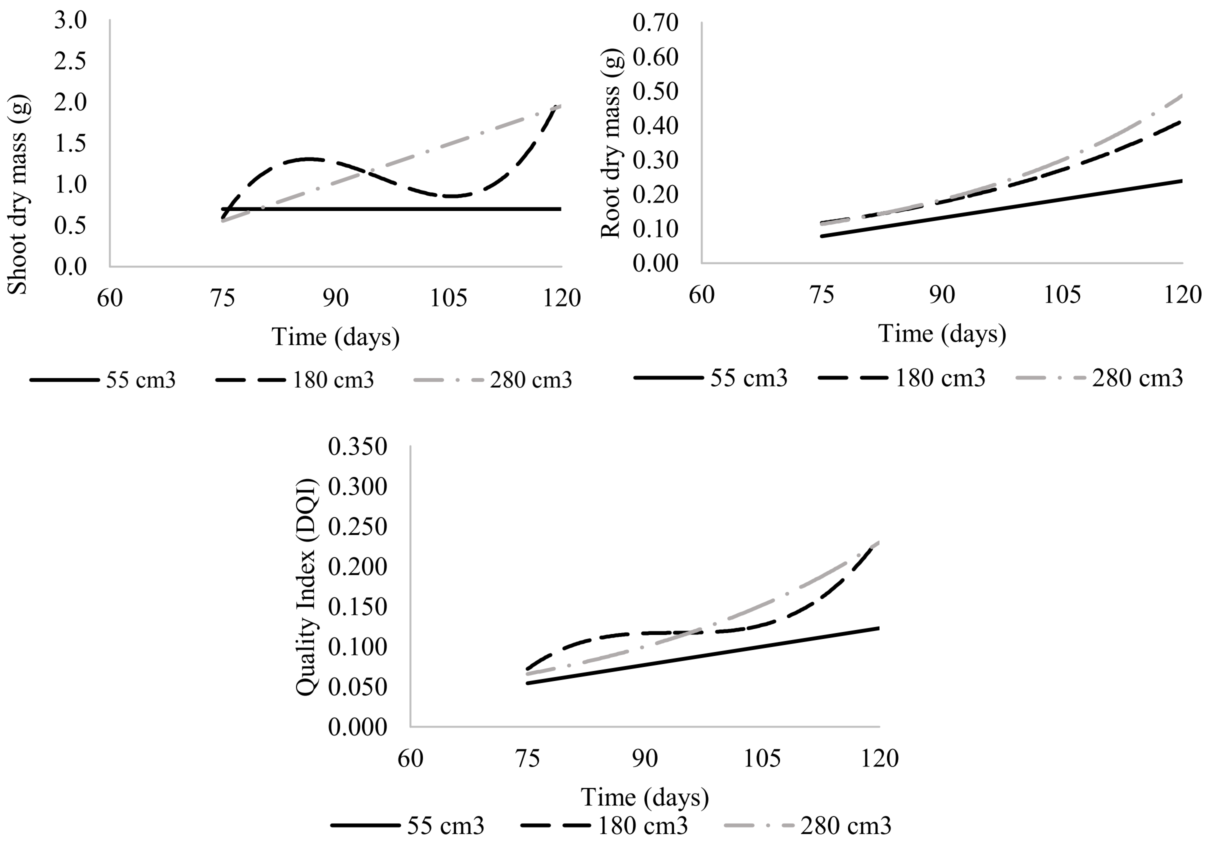

Figure 3. Shoot dry mass (SDM), Root dry mass (RDM) and Quality Index (DQI) as a function of the time of permanence of the seedlings of *Psidium cauliflorum* Landrum & Sobral in the nursery. Equations adjusted for the containers of 55 cm^3- SDW = $0.0105x - 0.3404$ ($r^2 = 0.96$); RDW = $0.0036x - 0.1899$ ($r^2 = 0.98$); DQI= $0.0015x - 0.0604$ ($r^2 = 0.85$). Containers of 180 cm^3- SDW = $0.0001x^3 - 0.0388x^2 + 3.6898x - 114.61$ ($R^2 = 0.99$); RDW = 0.02515exp(0.02943x) ($R^2 = 0.85$); DQI= 7E -06x^3 - $0.0018x^2 + 0.1733x - 5.3082$ ($R^2 = 0.87$). Containers of 280 cm^3- SDW = $0.0311x - 1.7753$ ($r^2 = 0.96$); RDW = 0.008exp(0.03457x) ($R^2 = 0.91$); DQI = 0.007476exp(0.028886x) ($R^2 = 0.77$). exp = base of the Napierian logarithm; x = periods of stay in the nursery; r^2 or R^2 = coefficient of determination.

Larger volume containers favored the growth of *P. cauliflorum* seedlings. Larger containers usually result in increased seedling growth in the nursery (DOMINGUEZ-LERENA et al., 2006; FERRAZ; ENGEL, 2011), which can reduce the production cycle (FREITAS et al., 2013; SANTOS et al, 2000). The larger the container size the greater the availability of water and nutrients (GOMES et al., 2003; MALAVASI; MALAVASI, 2006), which favors growth. Considering just the growth of seedlings in the nursery, the recommendation will always be to use the largest possible container, but bigger container means higher costs in inputs and logistics. However, the ideal size of the container depends on the species, density, environmental conditions and duration of the growing season (TIAN et al., 2017).

For root collar diameter and sturdiness quotient, as well as for height, there was no effect of container size until 45 and 60 days in the nursery, respectively (Figure 2). At 120 days the containers of 180 cm^3 and 280 cm^3 showed a similar performance with respect to shoot dry mass and Dickson's Quality Index (DQI) (Figure 3). Therefore, it is evident that the magnitude of the effect of container size on growth depends on the age of the seedling.

Therefore, before defining the ideal container size for a given species, it is necessary to define the time of stay in the nursery that will guarantee the production of quality seedlings. The quality standards are species-specific and may change depending on the conditions of the planting site. Studying the relationship between morphological and physiological attributes and the performance in the field of seedlings of *Quecus ilex* subsp. Ballota (Desf.) Samp, Del Campo; Navarro and Ceacero (2010) observed that in a drier year, smaller seedlings resulted in greater survival, and in wetter period the effect of quality attributes on field performance was masked by site factors. However, larger seedlings are not necessarily the best seedlings. According to Zida et al. (2008), success in the initial establishment of seedlings in the field depends on the equilibrium between the aerial evaporation and the water absorption capacity of the roots, and that large seedlings can compromise this balance, not necessarily showing better quality.

Therefore, the greatest growth of the seedlings observed in the largest container is not enough to conclude that this is the most adequate for the production of *P. cauliflorum* seedlings. This has to be checked after observing the performance in the field and defining the dimensions that characterize quality seedlings of the species under study.

Height, diameter and dry mass (Figures 2 and 3) did not stabilize until the maximum time of stay in the nursery, suggesting that the seedlings could be kept in the nursery for longer.

Regardless of the length of stay in the nursery, the leaf area (LA) and the length of fine roots (FRL) of the seedlings produced in the 180-cm^3 and 280-cm^3 containers were higher than the values of those grown in 55-cm^3 containers (Table 3). During the 120 days of growth in the nursery, the leaf area (LA = 2.0182x -58.114) and the length of fine roots (FRL = 67.143x - 3100.3) increased linearly with the age of the seedlings (x = length of stay in the nursery). The length of the main root did not respond to the length of stay in the nursery but was greater for the seedlings produced in the 280-cm^3 container.

Table 3. Leaf area, fine root length and main root length of *Psidium cauliflorum* Landrum & Sobral seedlings as function of pot size.

Container size	Leaf area (cm^2)	Fine root length (mm)	Main root length (cm)
55 cm^3	84.9 b	2181.8 b	12.3 b
180 cm^3	154.5 a	3942.2 a	14.6 b
280 cm^3	176.7 a	4214.3 a	20.2 a

Averages in the columns followed by equal letters do not differ statistically by the Tukey test at 5% probability.

Plantation phase

There was triple interaction of the factors upon height of the plants, whereas for the root collar diameter there were two significant interactions: evaluation time x container size, and evaluation time x nursery time (Table 4).

Table 4. Degrees of freedom (d.f.) and mean square output from analysis of variance for the variables height and root collar diameter in the plantation phase of *Psidium cauliflorum* Landrum & Sobral.

Source of variation	d.f	Height	Root collar diameter
Nursery time (NT)	3	129.10	0.66
Container size (PS)	2	583.61**	10.75**
NT * PT	6	36.29	0.52
Residual (a)	24	59.34	0.59
Evaluation time (ET)	6	2886.61**	152.26**
ET * NT	18	100.74**	1.78**
ET * PS	12	1.76	0.24**
ET*NT*PS	36	10.73*	0.12
Residual (a)	144	6.37	0.11

*Significant at 0.05.
**Significant at 0.01.

The growth in root collar diameter in the field phase was influenced by the container size up to three months, with the 180-cm^3 and 280-cm^3 containers performing better. From this period on, the differences in the effect of the container volumes disappeared (Table 5).

Table 5. Root collar diameter of *Psidium cauliflorum* Landrum & Sobral seedlings as function of evaluation time (ET) after transplant to the field and container size.

	Container size		
ET (months)	55 cm³	180 cm³	280 cm³
1	1.92 b	2.23 ab	2.40 a
2	2.49 b	2.91 a	3.14 a
3	3.43 b	3.99 a	4.33 a
4	4.45 a	5.10 a	5.30 a
5	5.43 a	6.19 a	6.18 a
6	6.52 a	7.23 a	7.04 a

Averages in the rows followed by equal letters do not differ statistically by the Tukey test at 5% probability.

The equations that model the growth in diameter are distinct for each period of permanence of the seedlings in the nursery (Table 6).

For the seedlings that remained in the nursery for 75 and 90 days, those grown in the 280-cm^3 containers showed greater growth in height (Figure 4). For the seedlings that stayed in the nursery stage for up to 105 days, differences in height growth due to container size disappeared after the fourth month of planting in the field (Figure 4). For seedlings of 120 days, the growth in height until the third month after planting in the field is favored by being planted in 280-cm^3 containers. However, from this period the seedlings from the 180 cm^3 containers outperformed those produced in 280-cm^3 containers (Figure 4).

Table 6. Growth equations of the root collar diameter (D) of *Psidium cauliflorum* Landrum & Sobral as function of nursery time (NT)

NT (days)	Equations	R²	F (p-value)
75	D=2.17exp(0.22965x)	0.92	2091.0 (<0.001)
90	D=1.1184x + 1.6833	0.99	4927.8 (<0.001)
105	D=8.47/(1+2.91exp(-0.498x)	0.94	2552.5 (<0.001)
120	D=0.7043x +2.8308	0.99	330.8 (<0.001)

e = base of the Napierian logarithm; x = time in months (evaluation time); R^2 = determination coefficient.

Field performance during the initial establishment phase of the seedlings was evaluated for survival and growth. Concerning growth, studies have shown that the effects of the container (CORREIA et al., 2013; BARBOSA; RODRIGUES; COUTO, 2013, KELLER et al., 2009) or age of the seedlings (CORREIA et al., 2013) disappear with time.

For height, the responses over time demonstrated an interaction between the age of the seedling and the size of the container. The effects of these factors did not disappear until six months after being planted in the field, except for seedlings of 105 days of age. Thus, the choice of container size will depend on the time of stay of the seedling in the nursery stage, reinforcing the supposition that seedling quality is strongly influenced by the effect of the interaction between container size and stay time in the nursery.

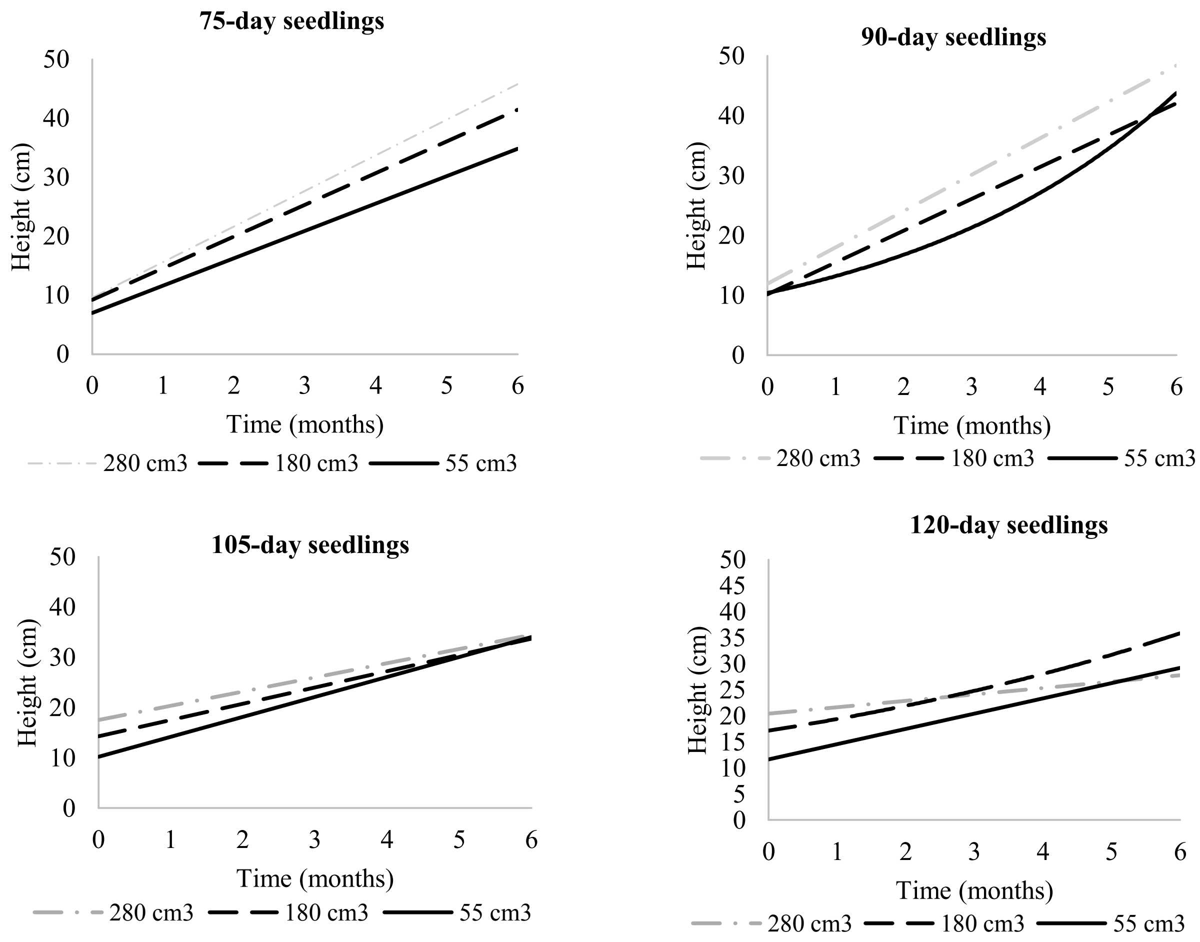

Figure 4. Growth in height in the field phase for seedlings of *Psidium cauliflorum* Landrum & Sobral that remained in the nursery for: 75, 90, 105 and 120 days. Equations adjusted for 75 days: containers of 55 cm^3- H = 4.6362x + 6.9965 (r^2 = 0.99); containers of 180 cm^3- H= 5.3817x + 9.1974 (r^2 = 0.99); containers of 280 cm^3- H = 6.0444x + 9.5661 (r^2 = 0.99); Equations adjusted for 90 days: containers of 55 cm^3- H = 12.00206exp(0.20287x) (R^2 = 0.82); containers of 180 cm^3- H = 5.3181x + 10.168 (r^2 = 0.99); containers of 280 cm^3- H = 6.0743x + 11.91 (r^2 = 0.99); Equations adjusted for 105 days: containers of 55 cm^3- H = 3.9625x + 10.233 (r^2 = 0.99); containers of 180 cm^3- H= 3.2276x + 14.307 (r^2 = 0.98); containers of 280 cm^3-H = 2.8221x + 17.527 (r^2 = 0.96). Equations adjusted for 120 days: containers of 55 cm^3- H = 2.9303x + 11.632 (r^2 = 0.96); containers of 180 cm^3- H = 17.591928$exp^{(0.115749x)}$ (R^2 = 0.96); containers of 280 cm^3- H = 1.2268x + 20.431 (r^2 = 0.84). exp = base of the Napierian logarithm; x = time in months; r^2 or R^2 = coefficient of determination.

Considering that the choice of container is related to the age of the seedling, containers of 280 cm^3 are recommended for seedlings that have been kept in a nursery for 75 or 90 days. For seedlings kept for 120 days in a nursery, the 180-cm^3 container is the recommended. The 55-cm^3 container led to poorer growth and survival compared to the other ones.

Six months after planting in the field, survival was higher among the seedlings produced in 180-cm^3 (71.3%) containers followed by those grown in 280-cm^3 (63.9%) and 55-cm^3 (45.4%) containers. There were no significant differences between seedlings grown in 180-cm^3 and 280-cm^3 containers. With each day of stay in the nursery, survival in the field increases by 0.62% (Figure 5).

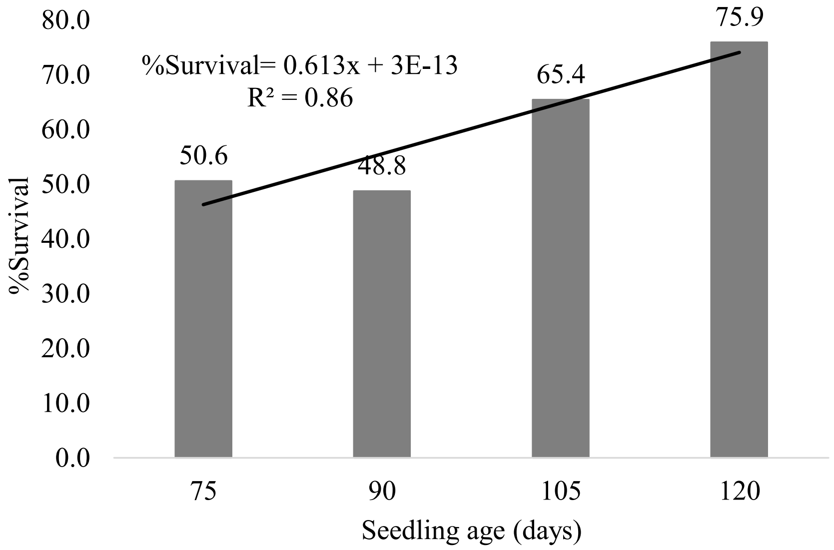

Figure 5. Survival percentage of *Psidium cauliflorum* Landrum & Sobral seedlings at six months after field planting according to response to seedling age (*x*).

The 120 day stay of the seedlings in a nursery resulted in lower mortality. However, the linear decreasing percentage of mortality in response to the age of the seedlings indicates that it is necessary to test longer periods of nursery stay for seedlings of this species (Figure 5). The growth of seedlings in height, diameter and dry mass in the nursery stage suggests that the ideal stay time may be over 120 days, since the growth curves of these variables did not stabilize at this stage (Figure 2 and Figure 3). From this perspective, considering that the seedlings should stay for at least 120 days in the nursery, the 180-cm^3 container is the most appropriate for the production of *P. cauliflorum* seedlings.

Relationships of morphophysical attributes with the survival of the seedlings in the field

The analysis of the frequency distribution of the number dead seedlings and surviving individuals as a function of classes of root collar diameter and height enabled us to identify the importance of these variables in the initial success in the establishment of seedlings in the field. Seedlings for planting with diameters between 2.3 and 3.3 mm (Chi Square = 27.86, p = 0.0002; Figure 6) and height between 11.0 and 18.4 cm (Chi Square = 22.91, p = 0.003; Figure 7) had greater survival rates in the field. However, the distribution of dead and surviving individuals did not depend on the sturdiness quotient (Chi-Square = 4.2; p-value = 0.84).

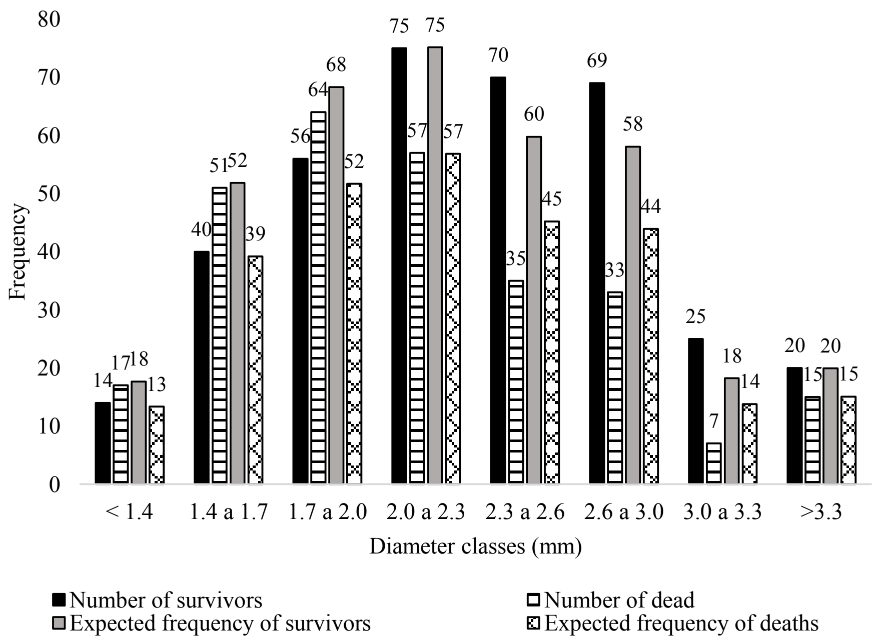

Figure 6. Distribution of the number of surviving and dead plants per root collar diameter class and expected frequencies of *Psidium cauliflorum* Landrum & Sobral according to the Chi-Square test (27.86; p-value = 0.0002).

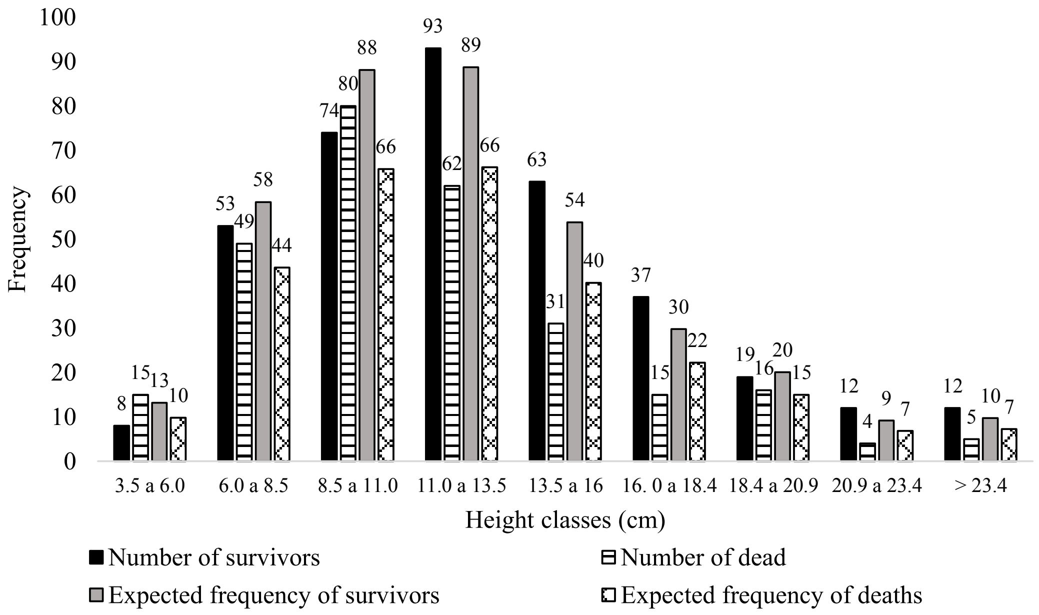

Figure 7. Distribution of the number of surviving and dead plants by height class and expected frequencies of *Psidium cauliflorum* Landrum & Sobral according to the Chi-Square test (22.91; p-value = 0.003).

The evaluation of seedling quality is performed for several attributes. However, it is not necessary to destroy the plant to do this. Non-destructive analysis can provide the necessary data on the attribute before the seedling is taken to the field and can be used in subsequent monitoring of its post-planting performance. The height, diameter and sturdiness coefficient have this advantage as there is no need to destroy or damage the seedling in order to obtain these measurements. The choice of the attribute to evaluate the performance of the seedlings in the field is dependent on the species. However, root collar diameter is usually among the best quality indices (LI et al., 2011; ZIDA et al, 2008; TSAKALDIMI et al., 2013; DEL CAMPO; NAVARRO; CEACERO, (2010); BAYALA et al., 2009; IVETIĆ; DAVORIJA; VILOTIĆ, 2013; STJEPANOVIĆ; IVETIĆ, 2013). Root collar diameter has the potential to predict post-planting performance (ZIDA et al, 2008) and can be positively correlated with survival (TSAKALDIMI et al., 2013) and root volume (ROSE; HASSE, 1995). Seedlings with a low root collar diameter tend to tip over after planting in the field, which compromises plant survival, growth and quality (REIS et al., 2008).

While height and sturdiness quotient are not always good predictors of performance, they have already proved satisfactory for some species. Height has been considered a good predictor of performance for *Larix olgensis* Henry (LI et al., 2011), *Eucalyptus tereticornis* Sm. (CHAMSHAMA; HALL, 1983), *Q. ilex* (DEL CAMPO; NAVARRO; CEACERO, 2010) and *Prunus avium* L. (STJEPANOVIĆ; IVETIĆ, 2013). The sturdiness coefficient was considered a good indicator of the quality of seedlings of *Quercus coccifera* L. (TSAKALDIMI et al., 2013).

Under the conditions of this study, the analysis of the frequency distributions of dead and surviving plants by diameter and height enabled the identification of the best performance of *P. cauliflorum* seedlings in the field (diameter between 2.3 and 3.3 mm and height between 11.0 and 18.4 cm). These results contradict the idea that the larger the sizes of the seedlings when transported to the field, the better their post-planting performance. Del campo; Navarro and Ceacero (2010) found that for *Q. ilex* the best performing seedlings were those of intermediate size (diameter between 3.5 and 4.8 mm and height between 12 and 17 cm). Tsakaldimi et al. (2013) found that seedlings of a certain diameter showed no gains related to field performance, with values of 5 mm for *Pinus halepensis* Mill. and 7 mm for *Pistacia lentiscus* L. *Pinus palustres* Mill seedlings of larger diameters survived better with the value of 9 mm and, from this diameter, survival decreased (SOUTHA et al., 2005). These results highlight the importance of defining the quality standards of the seedlings for different tree species, based on measurements which are easy to obtain, such as diameter and height.

CONCLUSIONS

It is recommended that *P. cauliflorum* seedlings be produced in a 180-cm³ container (13.5 x 5.2 cm) and that they stay in these containers for at least 120 days.

Stay times longer than 120 days should be tested for the production of seedlings of this species.

The analysis of the frequency distribution of the number of dead and surviving individuals in the diameter and height classes can be considered a useful tool to help in the definition of seedling quality standard for tree species, with the advantage of not requiring destruction or damage to the seedling in order to obtain these measurements.

The experiment to assess post-planting performance was crucial to obtain conclusive results for the production of *P. cauliflorum* seedlings.

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