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Nota Técnica

Seedling quality of *Cariniana pyriformis* produced under different containers in protected environment

Calidad de plántulas de *Cariniana pyriformis* producidas con diferentes contenedores en ambiente protegido

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ABSTRACT

Cariniana pyriformis is a native arboreal of Colombia with high forestry potential in pure plantations and agroforestry systems of *Theobroma cacao*. In an agricultural nursery with plastic cover, production and seedling quality were evaluated with a complete randomized block design and three replications using three plastic containers (treatments): bags (1700 cm^3), tube trays (700 cm^3) and multicellular trays (650 cm^3). Between 120 (bags) and 135 (tube trays) days after sowing (das), the seedlings reached 25 cm in height and 3 mm in stem diameter. The shoot dry mass (p= 0.0179) and root dry mass (p= 0.0327) of seedlings at 160 das were higher in the bags as compared to seedlings grown in the tube trays. In parallel, the production of *C. pyriformis* seedlings in multicellular trays achieved quality indexes very similar to those obtained employing the bags, but with a 60% reduction in the cost per seedling.

Keywords: Colombian mahogany; Propagation; Lecythidaceae; Nursery

RESUMEN

Cariniana pyriformis es una arbórea nativa de Colombia con elevado potencial en plantaciones puras y sistemas agroforestales de *Theobroma cacao*. En vivero agrícola con cobertura plástica, se evaluaron la producción y calidad de plántulas con un diseño de bloques completos al azar y tres repeticiones empleando tres contenedores plásticos (tratamientos): bolsa (1700 cm^3), bandeja portatubete (700 cm^3) y bandeja multicelda (650 cm^3). Entre los 120 (bolsa) y 137 (bandeja portatubete) días después de siembra (dds), las plántulas alcanzaron los 25 cm de altura y 3 mm de diámetro de cuello. El peso seco de la parte área (p= 0,0179) y peso seco del sistema radicular (p= 0,0327) de las plántulas a los 160 dds fueron superiores en la bolsa en comparación con las plántulas crecidas en la bandeja portatubete. En paralelo, la producción de plántulas de *C. pyriformis* en bandeja multicelda presentó índices de calidad muy similares a la bolsa, pero con una reducción en el costo por plántula entorno al 60%.

Palabras claves: Colombian mahogany; Propagación; Lecythidaceae; Vivero

1 INTRODUCTION

The abarco (*Cariniana pyriformis* Miers), also known as the colombian mahogany, is an arboreal species that grows naturally in the extreme northwest of South America and that forms important part of the biodiversity in zones with low and medium altitudes in the north, central, and west of Colombia, where it has potential use in systems with cocoa or pure plantations. (MORI *et al*., 2017; SUAREZ *et al*., 2019). During the last decades, the overexploitation and high rates of deforestation have provoked a drastic reduction of natural populations. At an international level the abarco is in the Near Threatened (NT) category and Critically Endangered (CR) in Colombia (CÁRDENAS *et al*., 2015; UICN, 2021).

In diverse management plans for the conservation of the abarco in Colombia, the supply of adult trees for the use and attainment of seeds continues to be limited. This is why sustainable exploitation actions are urgent since they include propagation protocols as a basic strategy (CAR, 2020). Recently, studies with the species have focused on the production of seedlings, since diverse factors influence their quality and growth such as the cultivation environment, substrates, pregerminated treatments and the length of stay in the nursery (ESPITIA; ARAMENDIZ; CARDONA, 2017; PRATO *et al*., 2019; PRATO *et al*., 2020). The correct selection of size and volume of the container has been widely studied in the forest species most planted commercially because these factors are related to the radical and aerial morphological quality of the seedlings produced. Therefore, the container offers the physical support for the substrate, air, water, and nutrients very probably influencing the success of the forest plantation (BUAMSCHA *et al*., 2012; MENDONÇA *et al*., 2020; CHU *et al*., 2020).

The global tendency is to replace plastic bags with tubes, rigid plastic trays, or biodegradable containers made from natural fibers of lesser volume that allow for better root formation and seedling architecture obtaining firmer root balls, with the option to reuse in some cases, which diminishes the costs of production (MUÑOZ *et al*., 2011; MENDONÇA *et al*., 2020). This study evaluated three types of containers to produce abarco seedlings in a protected environment, intending to increase options for the nurseryman.

2 MATERIALS AND METHODS

2.1 Experiment site and production of seedlings

The study was completed between September 2020 and January 2021 in the installations of the La Suiza Research Center (CI) of the Corporación Colombiana de Investigación Agropecuaria (Agrosavia), located in the municipality of Rionegro, Santander, Colombia (7°22'10" N, 73°10'39" W and 550 m of altitude). According to the Köppen classification, the region has a tropical rainforest climate (Af) and averages of 27.8°C and 1980 mm year^{-1}. The commercial seeds of *C. pyriformis* were collected in the municipality of Silvania (Tolima, Colombia) and they were soaked for 18 hours in 150 mg L^{-1} of gibberellic acid.

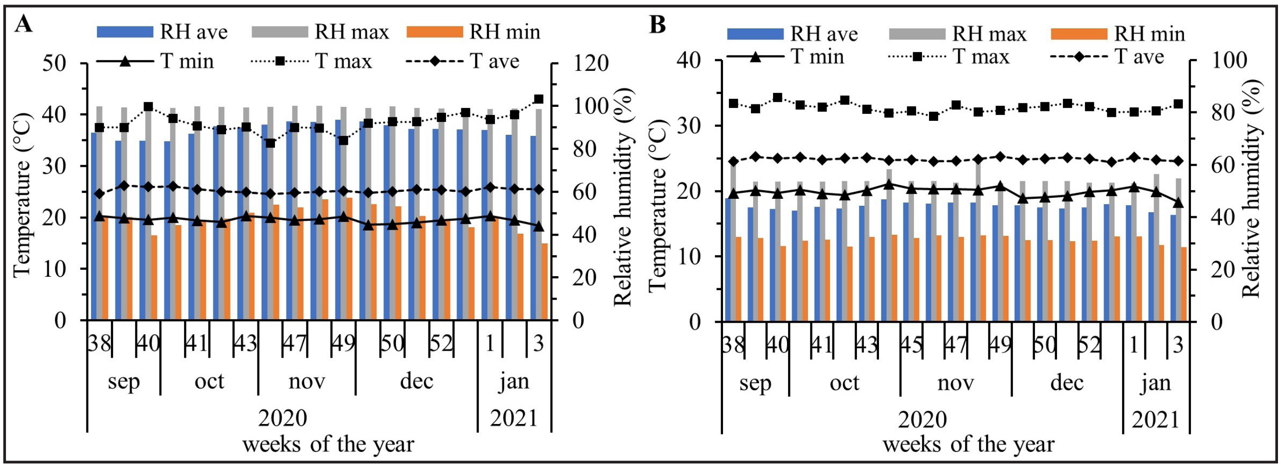
After 30 days, the germination reached 65% and seedlings with a height between 8 to 10 cm were transplanted to three types of plastic containers (treatments): bag or the most common container in the forest nurseries (10 cm diameter x 25 cm height, 1700 cm^3) and two of potential use, tuber trays of 24 conical cavities (8 cm major diameter x 1.8 cm minor diameter x 25 cm height, 700 cm^3) and multicellular trays of 18 conical cavities (8.4 cm major diameter x 3.2 cm minor diameter x 21.8 cm height, 650 cm^3). The experiment used a complete randomized block design with three repetitions. The block criterion is the longitudinal direction of the nursery for possible light and irrigation gradient. The experimental unit was 36 seedlings (4 rows of 9 seedlings), with a useful plot of 14 central seedlings.

The study was established in a nursery with a plastic “Agrofrio” cover and side and front opening providing 50% of shade. Irrigation was supplied via micro-sprinklers three times a day (irrigation controller) to maintain the substrate at field capacity. The volumetric formulation of the substrate without the addition of fertilizers, as used locally, consisted of 60% local soil + 20% commercial poultry manure compost + 20% river sand (sieves with 5 mm openings). A substrate sample was sent to the laboratory of the Universidad Nacional de Colombia - Medellín for their physicochemical characterization according to ICONTEC (2020), while the calculation of the bulk density was done by the MAPA method (2007). Sanitary management was not required.

2.2 Climate characteristics of the nursery

The climate conditions within the nursery were registered every 30 min with a datalogger (CEM DT-172) and on the outside a mobile weather station was employed (Watchdog 2900ET). The average maximum temperatures within the nursery stayed above 38.4°C, exceeding outdoor temperatures for several weeks by about 6°C, while the average temperatures (25.3°C) and average minimum (19.6°C) were similar. As for the relative humidity, the maximum and minimum values inside of the nursery reached an average of 99 and 48%, respectively, superior to the exterior (54.8 and 31.5%, respectively) (Figure 1).

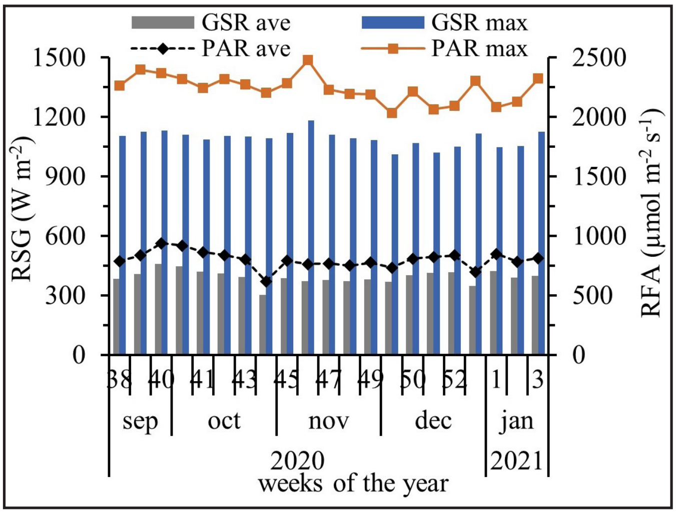
Figure 1 – Weekly average (T ave), minimum (T min) and maximum (T max) of temperature and average (RH ave), minimum (RH min) and maximum (RH max) of relative humidity recorded inside (A) and (B) outside the nursery during the time of evaluation. C.I La Suiza - Agrosavia, Rionegro (Santander)



Source: Authors (2021)

The weekly values of global solar radiation (GSR) and photosynthetically active radiation (PAR) outside of the nursery, between 6:00 and 18:00 hours, remained stable while registering averages of 394 W m^{-2} and 800 µmol m^{-2} s^{-1} respectively, with average maximum values of 1092 W m^{-2} and 2238 µmol.m^{-2} s^{-1} (Figure 2).

Figure 2 – Global solar radiation (GSR ave) average and maximum (GSR max), and B. Photosynthetically active radiation average (PAR ave) and maximum (PAR max) recorded outside the nursery between the 6:00 and 18:00 hours during the time of evaluation. C.I La Suiza - Agrosavia, Rionegro (Santander)



Source: Authors (2021)

2.3 Evaluated variables and statistical analysis

The stem diameter (SD) in the neck of the seedling was evaluated with a digital calibrator (0.01 mm) and the height (H) from the base of the stem to the apical bud with a flexometer (0.1 cm), 105, 130, 145 and 160 days after sowing (das). Destructive sampling of 160 das determined the total dry mass separated in the shoot (SDM) and root (RDM) of the seedlings. The vegetable material was dried in an oven at 65 °C until constant weight. The robustness index (H/SD) was determined and the SDM/RDM ratio. With these variables, the Dickson quality index (DQI) was determined (DICKSON; LEAF; HOSNER, 1960), with the following Equation (1):

$$\mathrm{ICD} = \frac{\mathrm{PSA+PSR}}{\frac{\mathrm{AP}}{\mathrm{DC}}+\frac{\mathrm{PSA}}{\mathrm{PSR}}} \tag{1}$$

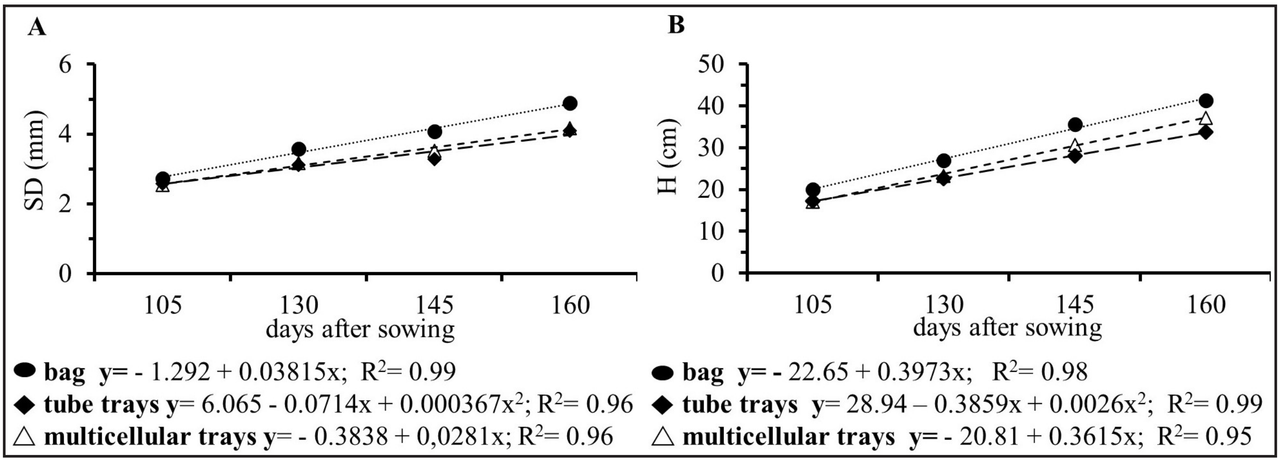
In where: DQI = Dickson quality index, SDM (g) = shoot dry mass + RDM (g)= root dry mass, H (cm) = height, SD (mm) = stem diameter.

The data were analyzed with parametric methods (ANOVA) and the Tukey test to the separation of averages in the treatments to 5% of significance. A regression analysis was performed for the H and SD variables, evaluating the linear and quadratic regression of the models, selecting the one that presented the highest determination coefficient (R^2) and significance through the F test. All the analyses were performed with the statistics program SAS 9.4. Finally, the cost per seedling was estimated (USD $ 1= COP $ 4912 / 31th October 2022) considering only the volume of the substrate required to fill each container.

3 RESULTS AND DISCUSSION

The increase of stem diameter and height of the *C. pyriformis* plantings in function of time showed a strong linear relationship ($R^2 > 0.95$) for the bag and multicellular trays, and a quadratic relationship ($R^2 > 0.96$) for the tube trays (Figure 3). From 105 das, the seedlings produced in the bag (2.68 mm) presented a stem diameter slightly greater than that of the multicellular trays (2.57 mm) and tube trays (2.61 mm); these differences are maintained and were evident at 160 das reaching 4.77 mm in the bag followed by the multicellular trays (4.12 mm). This last one with a slight increase compared to the tube trays (4.04 mm) (Figure 3A). Concerning the height, at 105 das the bag (19.1 cm) was superior to the multicellular trays and the tube trays which presented almost identical values (17.2 cm); once again, the differences were stronger at 160 das with 41, 37, and 34 cm, respectively (Figure 3B).

Figure 3–- A. stem diameter (SD) and B. height (H) of *Cariniana pyriformis* seedlings produced in three different containers up to 160 days after sowing. C. I. La Suiza - Agrosavia, Rionegro (Santander)



Source: Authors (2021)

In DAVIDE *et al*. (2015) suggest an adequate forest seedling pattern of 25 to 30 cm of height and stem diameter of the upper neck at 3 mm for its establishment in the field. PRATO *et al*. (2020) reported *C. pyriformis* seedling dimensions (H= 21.7 cm and SD= 2.75 mm) produced in a nursery with the same plastic cover and in bags of 550 cm^3 at 95 das even less than said values. In the present study, the seedlings in the bag (H= 25 cm and SD= 3.25 mm) at 120 das were observed as having reached the adequate seedling pattern, while in the multicellular trays and tube trays took more time, 127 and 137 das, respectively (Figure 3). At the end of the evaluation (160 das) the robustness index had an average of 8.6 cm mm^{-1} without significant differences between the containers (p= 0.5857). That is, a value very close to the adequate one because when it is less than 8 cm mm^{-1}, the seedlings are less prone to tree fall or mortality in sites with limited humidity, strong winds, and frost (MELO *et al*., 2018).

It is important to consider the possible effect of the competition for light and water due to the nursery growing density. In the case of the bag, the density was 100 seedlings m^{-2} and for the tube trays and the multicellular trays it was greater by 18% (116 to 118 seedlings m^{-2}). For example, in *Schinus terebinthifolius* the reduction of nursery growing density increased the seedling quality (CLEITON *et al*., 2005). As the seedlings grew an increment of leaf area was generated that can interpose branches and leaves, which involves a stem lengthening in search of light, but reduces the increment in diameter. Said morphological adaptation of the seedlings together with the additional effect caused by the plastic covering of the nursery was what probably occurred in the present study, as mentioned by LAMNATOU *et al*. (2013). On the other hand, upon increasing the diameter of the container, the distribution of irrigation water is facilitated so that the plant´s foliage can pass through and reach the substrate; the conditions for this were perhaps more favorable with the bag. In *Hevea brasiliensis* seedlings in bag production were more suitable than containers of lesser diameter and volume (SANTIAGO *et al*., 2015).

In Table 1, higher values of SDM in the bag were observed (4.04 g $seedling^{-1}$) comparatively with the tube trays (2.90 g $seedling^{-1}$) and multicellular trays (3.04 g $seedling^{-1}$). The RDM (0.77 g $seedling^{-1}$) and the DQI (0.350), this last one being the one that unites various morphological variables and indicates that the greater the value the greater the quality of the seedling, only being significantly greater with the tube trays. The SDM/RDM ratio did not depend on the container (p= 0.1125) and its average value of 5.19 was inferior to that which is recommended in other forest species, between 2 and 3 (MELO *et al*., 2018). These indexes, although destructive, are crucial to predict the seedling's adaptation in the field because the SDM is related to the photosynthetic capacity and the RDM to the absorption of nutrients and water (MUÑOZ *et al*. 2011).

Table 1 – Values (average ± standard error) of shot dry mass (SDM), root dry mass (RDM), SDM/RDM ratio, robustness index and Dickson quality index (DQI) in *Cariniana pyriformis* seedlings produced in three different containers, at 160 days after sowing. C.I La Suiza - Agrosavia, Rionegro (Santander)

Container	SDM	RDM	SDM/RDM ratio	Robustness index (cm mm^{-1})	DQI
	(g seedling^{-1})				
bag	4.04 ± 0.18 a	0.77 ± 0.04 a	5.33 ± 0.46 ns	8.6 ± 0.28 ns	0.350 ± 0.01 a
tube trays	2.90 ± 0.03 b	0.51 ± 0.04 b	5.73 ± 0.38	8.3 ± 0.25	0.245 ± 0.01 b
multicellular trays	3.04 ± 0.18 b	0.68 ± 0.05 ab	4.51 ± 0.12	9.0 ± 0.18	0.278 ± 0.02 ab
average	3.33	0.65	5.19	8.6	0.291

Source: Authors (2021)

In where: Averages with the same letters do not present statistical differences with the Tukey test ($p<0.05$). ns – not significant.

In the nursery, the *C. pyriformi*s seedlings maintained a high average of relative humidity (> 80%); however, in regions with prolonged dry periods, the imbalance in favor of aerial biomass could cause losses in the field. However, the greatest substrate volume of the bag and therefore of nutrients, water, and space contributed to the seedlings presenting better growth (CABREIRA *et al*., 2019; CHU *et al.*, 2020), probably, without fertilization it will continue being insufficient to reach a better equilibrium between the shoot and root. Additionally, the pH (8.2) of the substrate was above the suggested value of 5.5 to 6.5 (Table 2), since the use of soil usually involves undesired sanitary, physical, and chemical characteristics (SCHAFFER *et al*., 2015).

Table 2 – Physical and chemical attributes of the substrate used in the production of *Cariniana pyriformis* seedlings in three different containers. C.I La Suiza - Agrosavia, Rionegro (Santander)

Bd	pH (2)	O.M (3)	C (4)	Texture	Ca^{+2} (6)	Mg^{+2} (6)	K^{+1} (6)	P (7)
g cm^{-3} (1)	kg m^{-3}	%		(5)	cmol $(_+)$ kg^{-1}			mg kg^{-1}
1.26	8.2	3.40	1.97	Sandy loam	8.22	3.63	4.03	432.2

Source: Authors (2021)

In where: The method employed: (1) bulk density – Bd by MAPA (2007) and organic matter – O.M (3), organic carbon - C (4), (5), (6) and (7) by ICONTEC (2020).

FONTANA (2011) found that for *Cariniana estrellensis* the 560 cm^3 bag was more adequate than the tubes (53, 115, 180 and 280 cm^3) but for *C. pyriformis* it was reported as insufficient (PRATO *et al*., 2020). The differences found between containers in the nursery could prove not to continue in the field, as was verified in the *S. terebinthifolius* seedlings (CLEITON *et al*., 2005), *Eucaliptus globulus* (CLOSE *et al*., 2006), *Mimosa caesalpiniifolia* (MELO *et al*., 2018), and *Schizolobium parahyba* (CABREIRA *et al.*, 2019), but were confirmed in *Psidium cauliflorum* (MENDONÇA *et al*., 2020). Other aspects not evaluated in this study that also vary according to specie, such as the facility of extraction of the seedlings from their containers at the time of establishment can influence the convenience of the use of a type of container.

Finally, the estimated cost per seedling was higher in the bag with a value of COP $1377, while in the tube trays (COP $567) and the multicellular trays (COP $527) the reduction was similar (60%). In practice, the 16% increase in height and stem diameter and 31% in the biomass of the seedlings that the bag promoted at 160 das compared with the tube trays, which may not be relevant in the field. These differences in vigor were even less with the multicellular trays. The urgent need for investigations to identify morphological parameters and quality indexes unique in the production of *C. pyriformis* seedlings in order to standardize the minimal requirements for commercialization is clear.

4 CONCLUSIONS

The bag container provided the greatest stem diameter, height, Dickson quality index, shoot and root dry mass of the *C. pyriformis* seedlings followed by the multicellular trays and finally, the tube trays.

All containers achieved the recommended quality indexes in other forest species to establish seedlings in the field.

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