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BRS Gabriela (*Ricinus communis* L.) castor bean seedlings in function of substrate and container volume

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Castor bean (*Ricinus communis* L.) is an oleaginous of high economic value because its oil has numerous applications in the industry, such as in the manufacture of enamels and paints. Presently, its production is aimed at being used as a biodiesel. The main obstacle to a high production is the survival of the young plants in field in a no-tillage system. An alternative would be the production of seedlings. The objective of this research was to evaluate the initial growth of BRS Gabriela (*R. communis* L.) castor bean seedlings in function of different substrates and container volumes. The work was conducted at the nursery of the State University of Paraíba (UEPB), Catolé do Rocha, PB, Brazil. The experimental design was completely randomized (CRB) in a 4 × 2 factorial design with 6 replications. The factors consisted of 4 container volumes: 1, 0.5, 0.3, and 0.27 dm^{-3} and 2 substrates (S_1 = 50% soil and 50% earthworm humus, and S_2 = 40% soil, 30% earthworm humus and 30% sand). The analyzed variables were stem dry matter (SDM), root dry matter (RDM), plant leaf area (PLA), leaf biomass (LPM), stem biomass (SPM), water content (WC), plant height and stem diameter ratio (PHe/SD), root dry matter and dry shoot dry matter ratio (RDM/SDM), Dickson quality index (DQI) and succulence. The morphological characteristics were influenced by container volume and substrate. The largest container volume, together with the substrate S1 (50% soil and 50% earthworm humus), provided viable seedlings ready to be transplanted to the field.

Key words: *Ricinus communis* L., Initial growth, greenhouse, earthworm humus.

INTRODUCTION

Castor bean (*Ricinus communis* L.), an oilseed of the Euphorbiaceae family, originates from Ethiopia. Due to an easy propagation and adaptation to different climatic conditions, it spread to several regions of the world (Torres et al., 2013).

Because it is an oilseed with a high oil content in the seeds and because it can be used as a substrate for biodiesel, combined with the global crisis due to energy demand and the search for environmental sustainability based on a progressive substitution of petroleum-derived mineral fuels for alternatives sources, a real perspective was created for the expansion of castor bean cultivation

(Lira and Barreto, 2009). Favorable perspectives in the rational implantation of this culture for the production of biodiesel are raised because the oil contained in its seeds has important characteristics such as high density and alcohol solubility. It is also used in fine chemistry in more than 700 products, allowing a diversified industrial use (Marinho et al., 2010).

The production of castor bean seedlings is not a common practice, but it can be an alternative to planting in the semiarid region as a strategy to improve its planting during the short rainy season (Andrade et al., 2012). In order to obtain good results in agriculture, one of the most important factors is the quality of seedlings, which favors a good production. Vigorous seedlings become resistant to pests and diseases.

Among the several factors affecting seedling production, the most important are substrates and their volume, which may lead to a null or irregular germination, poor plant formation and symptoms of deficiency or excess of some nutrients (Mesquita et al., 2012). The definition of the container size for seedling production is an important aspect since it influences several characteristics of seedlings and may impact the percentage of survival in field and the crop productivity (Lima et al., 2006). Container volume is an important factor in the production of seedlings because containers with large volumes favor plant development, allowing plants to stay longer in the nursery without affecting them negatively. When small containers are used, plant growth is limited, resulting in low quality seedlings (Costa et al., 2009).

Substrate exerts great influence on the production of good quality seedlings. Its chemical and physical composition needs must be met with adequate nutrient values, good porosity, adequate leaching and a high cation-exchange capacity (CEC) (Andrade et al., 2015). Several organic and inorganic materials have been used for the formulation of substrates for the production of seedlings. It is necessary to determine the most appropriate ones for each species in order to meet their demand for nutrients and physical properties such as water retention, aeration, easy penetration of roots, and not favor the incidence of diseases (Lima et al., 2006).

The objective of this study is to evaluate the initial growth of BRS Gabriela castor beans (*R. communis* L.) according to different substrates and container volumes.

MATERIALS AND METHODS

This work was conducted from May to June 2014 at the nursery of the State University of Paraíba (UEPB), Campus IV, Catolé do Rocha, PB (6°2'38"S; 37°44'48"W; 275 m). The greenhouse temperature was on average 28°C and humidity around 60%. The experimental design was completely randomized with a 4 × 2 factorial design and 6 replications. The treatments consisted of four container volumes (V_1 = 1 L polyethylene bags, V_2 = 0.5 L polyethylene bags, V_3 = 0.3 L tubes, and V_4 = disposable cups with a capacity of 0.27 L), and two types of substrates (S_1 = 50% soil and 50% earthworm humus, and S_2 = 40% soil, 30% earthworm humus and 30% sand). The water supply was made with the aid of a watering can at 7 o'clock in the morning and 17 o'clock in the afternoon.

Before the installation of the experiment, an analysis of the soil and earthworm humus used in the work was carried out. Soil samples collected at the layer 0 to 20 cm and the earthworm humus came from the UEPB (California earthworm). Both were taken to the Irrigation and Salinity Laboratory (LIS) of the Center for Technology and Natural Resources (CTRN) of the Federal University of Campina Grande (UFCG), PB, for chemical analysis (Table 1).

Substrate moisture was kept at 50% field capacity. The seeds used in the experiment were provided by the State University of Paraíba (UEPB), Campus IV. The sowing was performed at the depth 2.0 cm. The thinning was performed on the 3rd day after emergence, leaving one seedling (the most vigorous one). Weed control was performed manually whenever necessary.

Substrate moisture was kept at 50%. Invasive plants were manually removed as soon as they emerged, and the thinning was performed on the 3rd day after emergence using pruning shears, leaving the more vigorous seedling intact. Soil samples used in the experiment were collected from the layer 0 to 20 cm, and the earthworm humus came from the earthworm collection of the UEPB University, Campus IV. Chemical analyses of the soil and earthworm humus were made at the Irrigation and Salinity Laboratory (LIS) of the Center of Technology and Natural Resources (CTRN) of the Federal University of Campina Grande (UFCG), PB (Soil analysis; Table 1).

The analyzed variables were stem dry matter (SDM), root dry matter (RDM), plant leaf area (PLA), leaf biomass (LPM), stem biomass (SPM), water content (WC), plant height and stem diameter ratio (PHe/SD), root dry matter and dry shoot dry matter ratio (RDM/SDM), Dickson quality index (DQI) and succulence.

The stem and root dry matter were obtained after drying in a forced-air circulation oven at 65°C until constant weight and then weighed using an analytical balance (Mesquita et al., 2012). The leaf area was calculated by the formula:

$$S = 0.2398 \times (L + P) \times 1.9259$$

where L = leaf width and P = main vein length (Severino et al., 2004), then multiplied by the number of leaves to obtain the plant leaf area.

The stem and root biomasses were calculated using the equation:

$$PM = FM - DM \; PM = FM - DM \quad (1)$$

where PM is the biomass; FM is the fresh mass; and DM is the dry matter.

The water content (WC) in the tissues is considered the most accurate (it involves the "turgid weight"). It is an indicative of the water status in the plant (Peixoto and Peixoto, 2004). This water volume was calculated using the formula:

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Table 1. Results of soil chemical analysis and earthworm humus for the production of BRS Gabriela (*Ricinus communis* L.) castor bean seedlings subjected to different container volumes and substrates.

Parameter	pH	EC	P	K	Ca	Mg	Al	Na	T	V	OM
	H_2O	dS/m				cmolc/dm^3				%	
Soil	8.20	1.53	3.27	0.26	5.09	1.66	0.00	0.26	7.71	100	1.19
	pH	EC	P	K	Ca	Mg	Al	Na	S	NaCl	BS
	H_2O	dS/m					cmolc/dm^3				
Humus	7.38	2.11	55.14	1.41	35.4	19.32	0.00	1.82	57.95	1.82	56.13

OM: Organic matter; BS: base sum.

$$WC = \frac{FM - DM}{FM} \{0 ><\}0\{> eq.2 < 0\}$$

where WC is the water content; FM is the fresh mass; and DM is the dry matter.

The DQI was calculated in a balanced way using an equation that includes the ratios of morphological parameters such as TDM, SDM, RDM, He, and D. It was developed in a study carried out with seedlings of *Picea glauca* and *Pinus monficola* (Dickson et al., 1960), according to the formula:

$$DQI = \frac{MST}{\frac{H}{DC} \{0 ><\}0\{> + eq.3 < 0\} \frac{MSR}{MSPA}}$$

Succulence was calculated using the formula proposed by Mantovani (1999). The results were expressed in grams of H_2O m².

$$Succulence = \frac{LFM - LDM}{LA} \{0 ><\}0\{> eq.4 < 0\}$$

where LFM is the leaf fresh mass; LDM is the leaf dry matter; and LA is the leaf area.

The data were submitted for analysis of variance using the F test. After verifying the effects of the treatments (P <0.05), a Tukey test (P <0.05) compared means using the software SISVAR (Ferreira, 2014).

RESULTS AND DISCUSSION

It is possible to observe a significant effect for the isolated factors substrate and container volume for almost all variables, except for plant height/stem diameter ratio and water content. There was also a significant effect for the interaction between factors, except for stem and root dry matter.

For the variable stem dry matter, a decrease was observed in function of container volume. The highest value for this variable occurred in the 1 dm^3 container (Figure 1A).

As for the substrates used, it was observed that the substrate containing 50% soil and 50% earthworm humus provided the highest stem dry matter (Figure 1B). This may be associated with aggregation of particles of the substrate S_1. In S_2 (40% soil, 30% earthworm humus and 30% sand), nutrient losses may have occurred due to leaching by irrigation water since sand increases the porosity of the substrate.

Containers with high volumes provide a greater area to be explored and a better spatial distribution of the root system, allowing a greater absorption of water and nutrients (Andrade et al., 2012)

Figure 1C shows that the container with a volume of 1 dm^3 provided the highest root dry matter, corroborating the results obtained by Mesquita et al. (2012), who reported that the results for root dry matter of papaya plants subjected to increasing doses of cattle manure in the largest container volume were high. Similar results were obtained by Antoniazzi et al. (2013), who found a high root dry matter for large-volume containers in a *Cedrela fissilis* Vell. (Meliaceae) crop, however, differing from the observations made by Andrade et al. (2015), who did not verify effects on substrates for BRS Gabriela castor bean seedlings.

As for the action of the substrates on the variable root dry matter, it can be observed in Figure 1D that it followed the same behavior of stem dry matter. The substrate containing the highest percentage of earthworm humus provided the best development of roots.

The growth of the root system, besides being conditioned to the height of the containers, which in the case of plastic bags had a great height, is also related to the volume of each container, involving the root system and making the supply of production factors more efficient for seedling growth and development (Menezes Júnior et al., 2000). The amount of dry matter found in the tissues of a seedling is important as an indication of its quality, as it reflects its growth in function of total nutrients absorbed (Franco et al., 2007).

The variables plant leaf area, leaf and stem biomass and water content were influenced by the interaction between substrates and container volumes (Figure 2).

The interaction 1 dm^3 × S_1 provided the greatest plant leaf area. However, for the interaction container volume ×

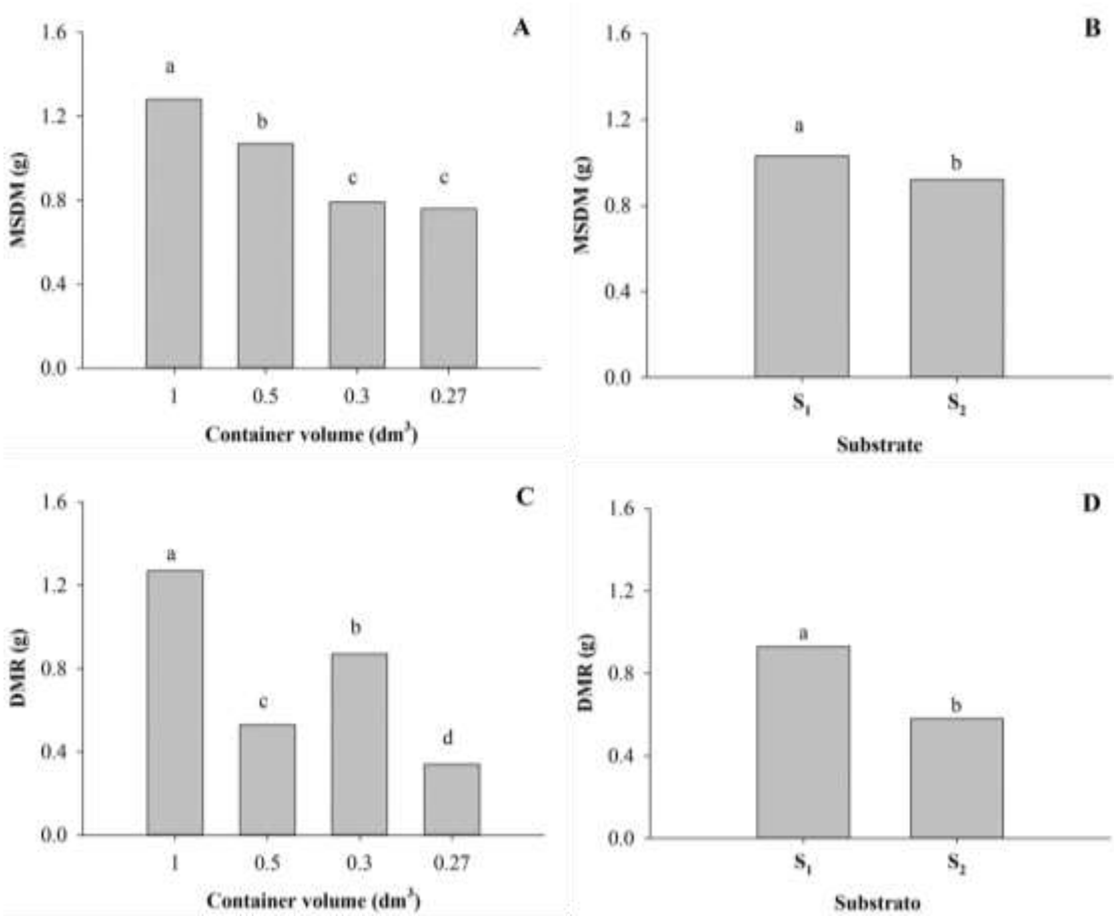

Figure 1. Mass of stem dry matter subjected to different container volumes (A) and substrates (B); mass of root dry matter in different container volumes (C) and substrates (D) for the production of BRS Gabriela castor bean seedlings (*Ricinus communis* L.)

substrate S_2, there was no significant differences regarding this variable (Figure 2A). From the moment the containers limit the development of the root system and, consequently, of shoots, they become an indication that seedlings are at the stage of planting in field, which for the culture of castor bean, occurs close to 30 days after sowing (Andrade et al., 2012).

The highest results for leaf biomass were found in the substrate interaction S_1 with 1, 0.5 and 0.3 dm^3. This was probably because the highest percentage of earthworm humus in this substrate provided nutrients for seedlings (Figure 2B). These results corroborate Lima et al. (2006), who reported that larger containers and alternative substrates promoted a greater development of castor bean seedlings.

In the interaction $S_1 \times 1$ dm^3, the variable stem biomass presented a higher value (Figure 2C). According to Andrade et al. (2012), a container with a high volume provides better quality seedlings at 21 and 36 days after sowing of castor beans. It is important to note that the use of containers with high volumes favors time for the installation of the crop in the field, which under low rainfall conditions, may make a difference (Andrade et al., 2012).

The interaction of the factors $S_2 \times 1$ dm^3 positively influenced the relative water content of castor bean seedlings, differing statistically from the other volumes (Figure 2D). As the substrate S_2 was composed of 30% sand, the root system probably occupied the whole containers, thus providing a fast absorption of water and nutrients since the substrate was kept at a 50% soil moisture.

Figure 3 shows the unfolding of substrate × container volume for the variables plant height and stem diameter ratio (PHe/SD), root dry matter and shoot dry matter ratio (RDM/SDM), Dickson quality index (DQI) and succulence.

For the variable plant height/stem diameter ratio, it can be seen that the interaction S_1 × container volume did not present a significant difference. The highest ratio is observed for S_2 using the volume 0.3 dm^3 (Figure 3A).

Almeida et al. (2014) found better results of PHe/SD in seedlings of *Croton floribundus* in the interaction between

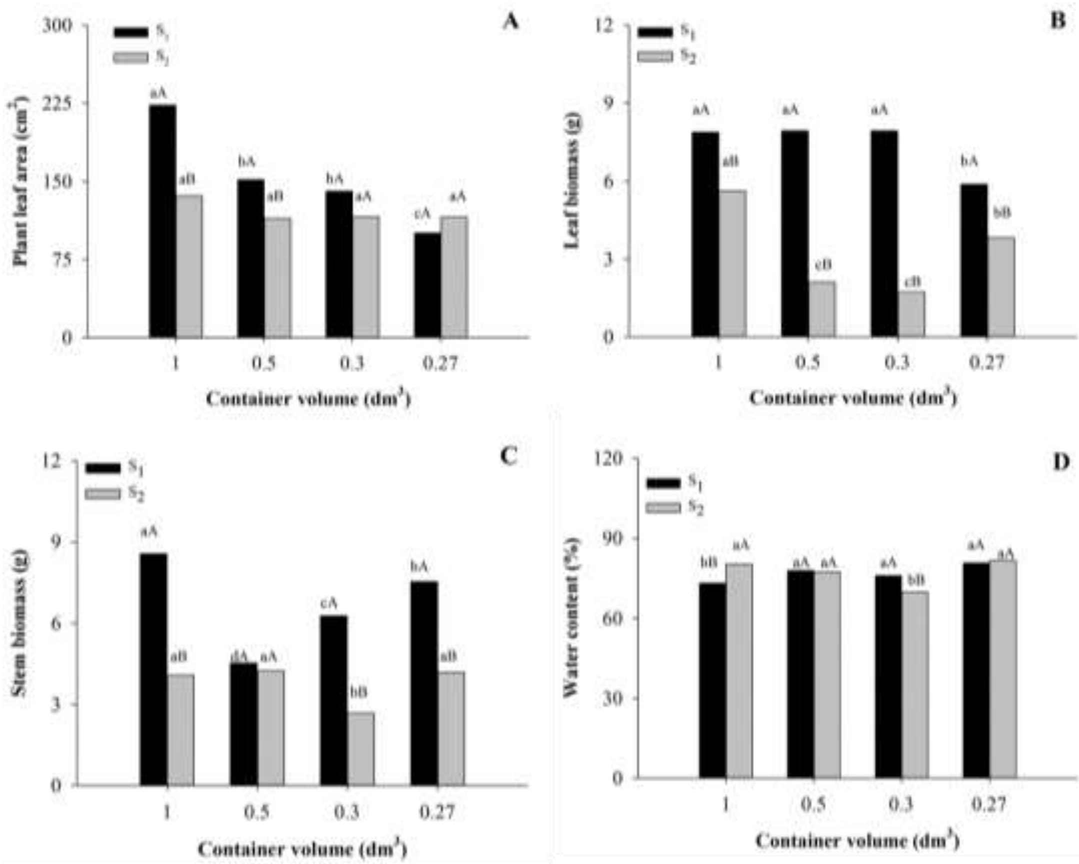

Figure 2. Plant leaf area (A), leaf biomass (B), stem biomass (C) and water content (D) in different container volumes and substrates for the production of BRS Gabriela (*Ricinus communis* L.) castor bean seedlings. Means followed by the same lowercase letter for volume and upper-case letter for substrate do not differ statistically by Tukey test at 5% probability.

volume and the highest capacity of a substrate based on cattle manure. According to the authors, this may be associated with a high plant height growth in greater container volumes, which directly affected the values of the ratio.

The relation PHe/SD is a characteristic that expresses the quality of seedlings to be taken to the field, since a balance in the development is expected (CAMPOS and UCHIDA, 2002).

It can be seen in Figure 3B that for the RDM/SDM variable, the interaction between V_1 and the substrate S_2 presented a higher increase for that variable (0.53 g), differing from the results obtained by Ferraz and Engel (2011), who did not report effects on seedlings of golden trumpet trees (*Tabebuia chrysotricha*) produced in different container volumes. The absence of a significant difference indicates the occurrence of an efficient pattern of dry matter distribution between the two organs of the seedlings (Dutra et al., 2012).

When the Dickson quality index (DQI) was evaluated, it was observed that the volume 1 dm³ stood out in relation to the others in the two substrates. However, the highest increase was observed for the interaction 1 dm^{-3} × S_1 (1.3) (Figure 3C). These results differ from those observed by Oliveira et al. (2011), who did not observe significant effects for DQI, cultivation time and container volume for a seedling production of *Copernicia hospital.*

Upon evaluating the succulence of plants, higher values were found in the unfolding S_1 × 0.3 dm^3. These results can be justified by a possible increase in the volume of spongy mesophyll cells to the detriment of the volume of palisade parenchyma cells (Oliveira et al., 2011). According to Trindade et al. (2006), succulence has important anatomical and physiological linkages in plants submitted to some type of stress.

Conclusion

The following conclusions were drawn:

(1) The volume of the container V_1 (1 L polyethylene bags) using the substrate S_1 (50% soil, 50% earthworm humus) results in BRS Gabriela castor bean seedlings

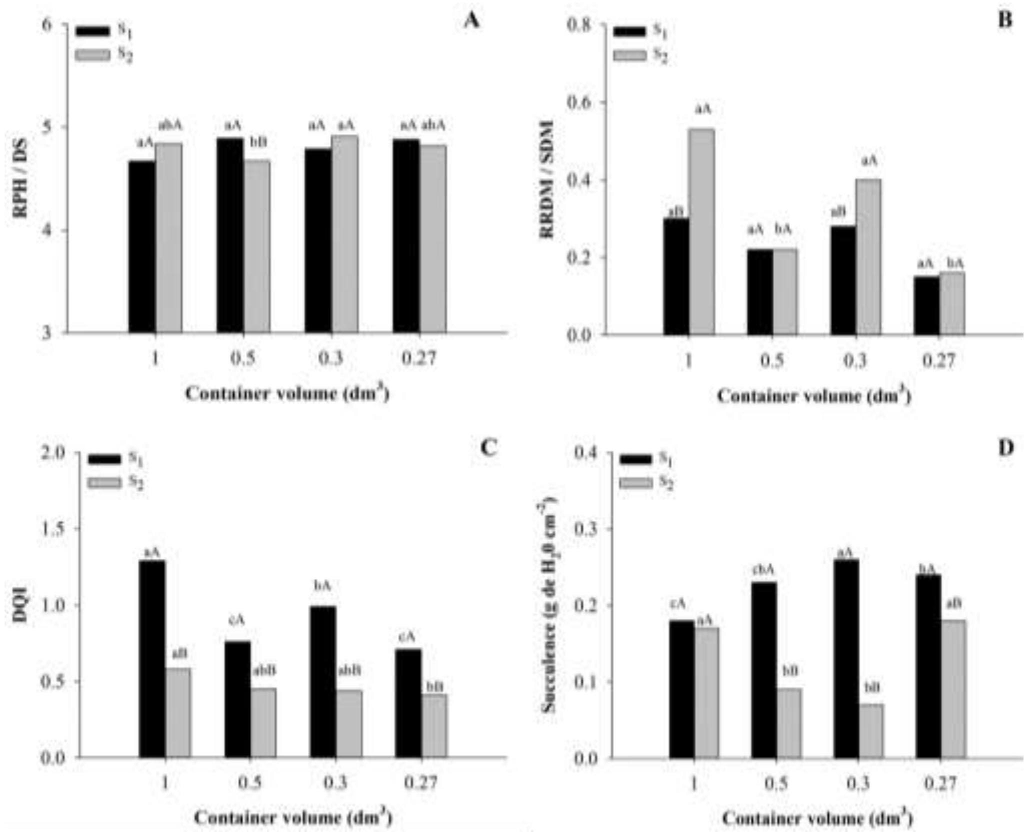

Figure 3. Plant height and stem diameter ratio (A), root dry matter and shoot dry matter ratio (B), Dickson quality index (C) and succulence (D) in different container volumes and substrates for the production of BRS Gabriela castor bean seedlings (*Ricinus communis* L.). Means followed by the same lowercase letter for volume and upper-case letter for substrate do not differ statistically by Tukey test at 5% probability.

(*R. communis L.*) suitable for field transplantation;

(2) The substrate S_1 provided the highest stem and root dry matter;

(3) The interaction between factors (substrate e container of volume) promoted better results for almost all variables (Plant leaf area, leaf biomass, stem biomass, water content, plant height, stem diameter ratio, root dry matter, shoot dry matter ratio, Dickson quality index and succulence);

(4) The main oleaginous prospect with high oil content in the seeds and because it can be used as a substrate for biodiesel. In the face of climate change can be a great opportunity within the renewable bushes. With this, the production of seedlings is essential to ensure the survival of the plants in the field and guarantee their production. The present work indicates which is the best volume of container and substrate for castor bean production.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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