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Growth and development of *Tabebuia rosea* (Bertol.) DC. with controlled release fertilizers in the nursery

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ABSTRACT
Objective: To understand the effect of controlled release fertilizers on the growth and development components of *Tabebuia rosea* (Bertol.) DC.
Design/methodology/approach: In this research, a randomized block design with seven treatments and 50 replicates was used. Three treatments consisted of substrate with different mixtures of controlled release fertilizers (CRFs) at three concentrations each, of 4, 5 and 6 kg m^{-3} plus a control (without fertilization).
Results: The use of controlled release fertilizers such as Multicote™ Agri 8 and Basacote® Plus 9M demonstrated greater growth and development in pink trumpet seedlings on the components of plant height, basal stem diameter, aerial biomass, root biomass, among others. Of the seven treatments presented in this study, the concentrations of 5 and 6 kg m^{-3} proved to be the best nutritional alternative, which will result in a higher survival rate in the field.
Limitations on study/implications: Due to the loss of undisturbed specimens, it is becoming increasingly difficult to find trees with seed production capabilities.
Findings/conclusions: Multicote™ Agri 8 in concentrations of 5 and 6 kg m^{-3} is the best nutritional alternative for optimal growth and development of *Tabebuia rosea* (Bertol.) DC. It can be considered essential for reforestation in urban and rural areas of the region, and due to its floral beauty, which is part of culture in the state of Tabasco.

Keywords: Pink trumpet, Growth, Development, Quality Indices.

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INTRODUCTION

The species *Tabebuia rosea* (Bertol) DC., known as pink trumpet, is distributed in tropical areas; in Mexico, it is found from Tamaulipas to the Yucatan Peninsula, and in the Pacific gradient from Sinaloa to Chiapas (Herrera, 2015; Jasso-Mata, 2018). The beauty of its flowers is one of the qualities of this species, although its main use is the wood which is used for the elaboration of furniture and houses (Pennington and Sarukhán, 2005; Jasso-Mata, 2018).

Unfortunately, the demand for wood from this species has increased, and trees that are found in natural habitats are used mostly clandestinely and have not been entirely documented, so this species could be threatened. This is a concern that has been reported

since the 1940s (Benítez *et al.*, 2002; Jasso-Mata, 2018). The success of germination, establishment and survival of plants in a natural environment are determined by multiple biotic factors such as density, pests, diseases, pathogens, and abiotic factors such as availability of light, water, temperature, and nutrients in the soil (Harms and Paine, 2003; Pérez-Hernández *et al.*, 2011). Presently, these factors have been affected by the transformation of native forests into agricultural, livestock, industrial and urban areas, contributing to the degradation and disappearance of rain forests and ecosystems (Lanly, 2003). Therefore, the propagation of native species is necessary for the enrichment, reforestation and restoration of areas affected; unfortunately, the reforestation plans implemented in the American tropics are scarce in native species, since they promote mainly fast-growth exotic species, such as eucalyptus, teak, beechwood and acacia, creating monospecific forests with the aim of production of wood and cellulose. These forests are poor in biodiversity, since they displace native plants and animals (Pérez-Hernández *et al.*, 2011). Controlled release fertilizers favor the growth of nursery plants primarily because they do not leach in equal proportion to conventional fertilizers during irrigation, which are constant under this type of management (Reyes-Castro *et al.*, 2020). Currently, controlled release fertilizers are used under nursery conditions to produce small trees for commercial plantations of teak (Escamilla-Hernández *et al.*, 2015) and mahogany (Domínguez-Liévano *et al.*, 2023), among other species. However, they are not commonly used for species such as those in this study. Therefore, the objective of this research was to understand the effect of controlled release fertilizers (CRFs) on the components of growth and development, and quality indices of *Tabebuia rosea* (Bertol.) DC., in the nursery stage.

MATERIALS AND METHODS

The study was carried out in Colegio de Postgraduados Campus Tabasco, located on km 3.5 of the Cárdenas-Huimanguillo highway, Tabasco. According to Köppen's classification, the climate that predominates in the region is Am(g)w" which is characteristic of the humid tropics, where there is a total annual precipitation of 2.324 mm, with dry months like March and April (with less than 50 mm per month), and other rainy ones like September and October (up to 400 mm per month). The mean annual temperature is 26 °C, with the lowest temperatures found in the winter months and the highest ones in the summer (Palma-López *et al.*, 2007).

Species under study

It presents rapid growth with heights that range from 25 to 30 m and average diameter of 1 m; it develops in a large variety of habitats, primarily in soil with good drainage; the range of development of this species varies from 0 masl to 1200 m, with temperatures that fluctuate between 10 and 30 °C and have a mean annual requirement of 500 mm of rain (Flores and Marín, 2010).

Experimental design, treatments and study variables

The seeds were collected considering trees with adequate silviculture characteristics, and for this purpose visits were carried out in different plots of the alluvial plain of Tabasco.

The seeds were placed to germinate in a sowing bed of 1 m by 0.5 m with a height of 3 cm, and substrate made up of soil, peat moss and agrolite (2:1:1). The moisture was kept constant throughout the entire germinative stage; when a height of 5 cm was reached, the plants were moved to nursery bags of 5×6×22 cm height, with an approximate capacity of 500 g of substrate per bag.

A completely randomized block design with seven treatments and fifty repetitions was used, where six treatments are made up of substrates with different doses of two controlled release fertilizers (CRFs): Multicote™ Agri 8 (11.22.09+4 MgO+0.1 Boron) and Basacote® Plus 9M (16-8-12) at three concentrations each, of 4, 5 and 6 kg m^{-3} plus a control (without fertilizer); these CRFs have been recommended and used in nurseries for forest species. Then, they were placed for 3 months under shade mesh (75%).

Moisture of the seeds

A total of 100 pink trumpet seeds were selected, from which their fresh weight was obtained; they were stored in paper bags and introduced into a drying stove at 72 °C until constant weight; the value of moisture was obtained through a rule of thirds (Quinto *et al.*, 2009).

Weight estimation of 100 seeds

Three repetitions of 100 seeds were randomly selected, which were weighed in an analytical scale (Ohaus® AR0640) with precision of 0.001 g (Quinto *et al.*, 2009).

Estimation of percentage of germination

Because of the characteristics of the seeds of this species, sowing in seedbeds is recommended (Rueda-Sánchez *et al.*, 2014; Orozco *et al.*, 2019). A germination test without scarification with three repetitions of 100 seeds was carried out. Once the seeds were sown in germination beds, the percentage of germination was estimated 30 days after sowing (DAS), through the following formula:

$$\%\,of\ germination = \frac{Total\ of\ seeds\ germinated \times 100}{Total\ of\ seeds\ sown}$$

Morphological variables and quality indices

Four plants from each study treatment were randomly selected. In the seedlings selected for destructive sampling, the aerial and root system were washed with water to eliminate the particles of substrates, leaving them free of impurities. A compound sample for each treatment was carried out where the following variables were determined (Sáenz *et al.*, 2010; Rueda *et al.*, 2012): a) plant height (cm), with a ruler calibrated in centimeters, from the base of the stem to the apex; b) diameter of the root crown (mm), with a digital vernier calibrator series QL-V of 0-150 mm/0-6 in, resolution 0.001 mm, and accuracy of ±0.02 mm; c) dry weight and fresh weight of aerial biomass of leaves and stems (g); d) dry weight and fresh weight of root biomass (g^{-1}). The aerial and root biomass were placed in paper bags, to dry in a Shel®Mod stove. CE5F of forced circulation at 70 °C for 72 h; then, they were weighed on an analytical scale (Ohaus® AR0640) with precision of 0.001 g. With data from these variables, the quality indices of the plants were calculated: robustness index (RI), dry aerial biomass/dry root biomass ratio (DAB/DRB R), and Dickinson quality index (DQI) (Dickson *et al.*, 1960; Prieto *et al.*, 2003), using the following formulas:

Height/diameter ratio of the root crown or robustness index (RI).

$$RI = \frac{Height\ (\mathrm{cm})}{Diamenter\ of\ root\ crown\ (\mathrm{mm})}$$

Dry aerial biomass/dry root biomass ratio (DAB/DRB R).

$$DAB\ /\ DRB\ R = \frac{Dry\ aerial\ biomass\ (\mathrm{g})}{Dry\ root\ biomass\ (g)}$$

Dickinson Quality Index (DQI).

$$DQI = \frac{Total\ dry\ weight\ of\ the\ plant\ (\mathrm{g})}{\dfrac{Height\ (\mathrm{cm})}{Diameter\ of\ root\ crown\ (\mathrm{mm})} + \dfrac{Dry\ aerial\ biomass\ (\mathrm{g})}{Dry\ root\ biomass\ (\mathrm{g})}}$$

Where the results obtained will be compared in relation to the value ranges of Table 1.

Nutritional characteristics

When the nursery stage finished, a plant per repetition of each of the seven treatments was chosen randomly, which was separated into aerial biomass and root biomass, with the aim of quantifying the nutrients Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), and Magnesium (Mg). Each of the samples obtained were stored in paper bags and dried in a stove at a temperature of 65 °C for 72 hours, ground and pulverized in a sieve mill (Yinda®-YDGS-200) with a sieve of 1.0 mm diameter. A compound sample of four plants for each of the treatments was conducted. The methods to analyze the nutrients

Table 1. Values that qualify the quality of the plant with normal growth in a forest nursery.

Variable	Tipe of plant	Quality		
		Low	Medium	Hight
Height (cm)	Broadleaf	<12.0	12.0-14.9	≥15.0
Diameter (mm)	Broadleaf	< 2.5	2.5-4.9	≥ 5.0
Robustness Index (IR)	Broadleaf	≥ 8.0	6.0-8.0	< 6.0
R BSA / BSR	All	≥ 2.5	2.0-2.4	< 2.0
Dickson Index (ICD)	All	< 0.2	0.2-0.4	≥ 0.5

*DAB/DRB R=Dry aerial biomass and dry root biomass ratio.
Source: Data cited by Rueda *et al.* (2012) and Sáenz *et al.* (2010) with contributions from Santiago *et al.* (2007); Conafor (2009); and Escamilla-Hernández *et al.* (2015).

were: Semimicro-Kjeldahl (Bremer, 1965) for N, the method described by Alcántar and Sandoval (1999) for P and K, and finally the extracts were quantified in the Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer 400). To compare the concentrations of nutrients from the dry and root biomass, the intervals recommended by Drechsel and Zech (1991) and Jacobs and Landis (2014) were used, where they describe the nutrients for healthy plants of tropical species. Macronutrients: (N=1.50-3.50%, P=0.10-0.25%, and K=0.60-1.80%, Ca=0.50-2.5%); Micronutrients: (Mg=35-250 ppm).

Statistical analyses

The values obtained in the response variables evaluated were subjected to the Shapiro-Wild normality tests, and Bartlett homogeneity of variances, to verify the hypotheses of normality and homoscedasticity of the observations. Then, a variance analysis was conducted and, in the cases where significant effects from the treatments were detected, a multiple means comparison test was carried out via Tukey's method ($p<0.05$), with the statistical software R Studio 3.4.3. for Windows 11 from Microsoft Corporation (2024).

RESULTS AND DISCUSSION

Weight (g) of 100 seeds

An average of 43,951 seeds per kg was found, equivalent to 2.487 g for every 100 seeds. Because of the factors present during their growth and development, and their genetic diversity, these data presented great variability in comparison to those presented by Quinto *et al.* (2009), who obtained an average of 40,209 seeds per kg, less than what was reported in this study.

Moisture in the seeds

A fresh weight of 2.487 g was obtained and a final value of 2.260 g; through a rule of thirds the value of moisture obtained was 9.1%. This content was higher than what was presented by Quinto *et al.* (2009), where a moisture content of 8.74% was obtained.

Germination and sowing of seeds

There was 98% of germination, and this value was obtained 12 days after sowing. This result is similar to what was observed in Santiago de Tuxtla, Veracruz, by Quinto *et al.* (2009), where 99% of germination was found. Ríos-García *et al.* (2018) obtained 100% of germination from *T. rosea* and *T. donnell-smithii* when sowing them after collection, with a decrease of 20% of germination at twelve months of storage. The ageing of seeds is a factor that decreases their viability, being of utmost importance to understand the viability to determine the period when they can be conserved without significantly affecting the capacity for germination and managing to achieve successful propagation (Vázquez *et al.*, 1999; Ríos-García *et al.*, 2018).

Growth and development of pink trumpet seedlings

Table 2 shows the monthly results of monthly diameter and height of pink trumpet seedlings in nursery stage. In the first month of growth and development, the Multicote (4 kg m^{-3}) treatment shows the best results compared to the other treatments; in the second month, the Multicote (5 and 6 kg m^{-3}) and Basacote (4 kg m^{-3}) treatments show they are statistically equal in height; and for the variable of basal diameter, the Multicote (5 and 6 kg m^{-3}) treatments showed the highest values. At three months old, the pink trumpet seedlings showed three statistically outstanding treatments, which were Multicote (5 and 6 kg m^{-3}) and Basacote (6 kg m^{-3}), with a height of 30.42, 33.37 and 33.00 cm, respectively; they both enter into the category of high quality according to Orozco *et al.* (2010), Rueda-Sánchez *et al.* (2014), and Orozco *et al.* (2019). These same authors show that the high quality of the basal diameter are values ≥5 where the Multicote (6 kg m^{-3}) treatment showed a diameter of 5.25 mm, which was statistically equal to what was obtained with Multicote (6 kg m^{-3}) with 4.94 mm, Multicote (4 kg m^{-3}) with 4.30 mm, and Basacote (6 kg m^{-3}) with 4.72 mm; these diameters entered into the category of average quality. In addition, these results of plant height obtained by treatments with CRFs plus the control were higher than those found by Rueda-Sánchez *et al.* (2014) in the Cepraf forest nursery in Nayarit, which at the same age of three months obtained an average height of 20.2 cm and a basal diameter of 5.0 mm, the last being outperformed by the Multicote (6 kg m^{-3}) treatment, and corroborated by Orozco *et al.* (2010) and Orozco *et al.* (2019). In addition to this, in the same state, in the nursery of San Agustín, they obtained a final height of 11.0 cm (low quality) at the age of three months and a basal diameter of barely 4.2 mm, which qualifies as average quality.

Quality Indices of seedlings

When the nursery stage ended, the pink trumpet showed a robustness index (RI) under the Multicote (4 and 5 kg m^{-3}) treatments, and average with the others (Table 3) (Rueda-Sánchez *et al.*, 2014), contrary case to what was found in the San Agustín forest nursery, where despite having lower plant heights, they obtained a high quality index with a value of 2.7 (Rueda-Sánchez *et al.*, 2014). For the dry aerial biomass and dry root biomass ratio, only the control shows high quality, followed by the Basacote (4 and 6 kg m^{-3}) treatments,

Table 2. Growth and development of *Tabebuia rosea* (Bertol.) DC. seedlings in nursery stage, in a period of 3 months.

Treatments (kg m^{-3})		Plant height (cm)			Basal stem diameter (mm)		
		1st month	2nd month	3rd month	1st month	2nd month	3rd month
Multicote	4	6.87 a	12.00 bc	26.27 b	1.66 a	2.95 ab	4.30 abc
	5	6.37 ab	14.06 ab	30.42 a	1.52 ab	3.20 a	4.94 a
	6	5.46 abc	15.00 a	33.37 a	1.36 abc	3.28 a	5.25 a
Basacote	4	5.37 bc	9.20 d	22.7 b	1.43 abc	2.14 c	3.10 d
	5	4.62 c	10.13 cd	24.33 b	1.33 abc	2.53 bc	3.73 bcd
	6	4.68 c	11.26 cd	33.00 a	1.16 bc	2.91 ab	4.72 ab
Control	0	4.62 c	9.73 cd	23.24 b	1.12 c	2.24 c	3.40 cd
Average		5.43	11.62	27.62	1.37	2.75	4.21
CV		25.46	18.67	13.72	25.72	19.71	24.82
Pr(>F)		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

*CV=Coefficient of Variation.; Pr(>F)=Significance Value; NS=No Significance; <.0001=Highly Significant, Tukey p≤0.05.

Table 3. Quality Indices obtained by *Tabebuia rosea* (Bertol.) DC.

Treatments (kg m^{-3})		***Tabebuia rosea* (Bertol.) DC.**					
		IR	**Quality**	**R BSA. BSR**	**Quality**	**ICD**	**Quality**
Multicote	4	8.04	Low	2.90	Low	0.47	Medium
	5	8.62	Low	3.37	Low	0.80	Hight
	6	6.65	Medium	3.22	Low	0.87	Hight
Basacote	4	6.79	Medium	2.10	Medium	0.52	Hight
	5	6.98	Medium	3.12	Low	1.00	Hight
	6	7.27	Medium	2.10	Medium	0.77	Hight
Control	0	6.41	Medium	1.82	Hight	0.52	Hight
Average		7.25		2.56		0.71	
CV		18.22		34.18		37.82	

* RI=Robustness Index; DAB/DRB R=Dry Aerial Biomass and Dry Root Biomass Ratio; DQI=Dickson Quality Index; CV=Coefficient of Variation.

with average quality; the remaining treatments were of low quality. These data were similar to those found in the San Agustín, San Juan and Cepraf nurseries (Rueda-Sánchez *et al.*, 2014). The Dickinson quality index proves to be more representative to determine the quality of this species; only the Multicote (4 kg m^{-3}) treatment presents average quality, compared to the other treatments with high quality, including the control. These results are similar to those obtained by Orozco *et al.* (2010), Rueda-Sánchez *et al.* (2014), and Orozco *et al.* (2019).

Morphological values of pink trumpet seedlings

Table 4 shows the morphological values recorded in this species, where Multicote (5 kg m^{-3}) presents the greatest height of all the treatments, although it was statistically similar to all the treatments except for Multicote (4 kg m^{-3}) and the control, with the latter being of lower height; the coefficient of variation was 13.24%. In the variable stem height, there was no statistical difference between treatments; the general mean was 8.85 cm, the minimum value 8.50 cm was observed in the control, and the highest was 9.62 cm for the Multicote (4 kg m^{-3}) treatment. Regarding the basal diameter, there was no statistical difference between treatments. However, Basacote (6 kg m^{-3}) presented the largest basal diameter numerically with 6.63 mm, with the control being the one with smallest diameter (4.88 mm). Statistically significant differences were found for number of leaves, with the highest values being for Basacote (4 and 6 kg m^{-3}) and the lowest for Basacote (5 kg m^{-3}). The variable of fresh weight of leaves presented a statistically significant difference, with the highest value being for Basacote (6 kg m^{-3}) with 4.05, and the lowest for the control with 2.02. Regarding the dry weight of leaves, there was no statistically significant difference between treatments. The fresh and dry weights of roots presented statistically significant differences with coefficients of variation of 35.72 and 35.09%, respectively, and in both cases the highest value was found in Multicote (6 kg m^{-3}) with 5.25 g and 1.75 g, respectively, and the lowest in Multicote (4 kg m^{-3}) with 1.67 g and 0.52 g.

Table 4. Morphological values of *Tabebuia rosea* (Bertol.) DC.

Treatments (kg m^{-3})		Hight (cm)		Diameter (mm)		Number of leaves per plant	Leaves (g)		Stem (g)		Root (g)		Root length (cm)
		Plant	Stem	Basal stem	Root collar		Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	
Multicote	4	49ab	9.62a	5.23a	5.28a	8.75ab	2.75 ab	0.72a	3.75b	1.17ab	1.67b	0.52b	24.50a
	5	61.00a	8.75a	5.98a	6.36a	9.75ab	2.85 ab	0.75a	5.65ab	1.82ab	3.12ab	1.20ab	26.25a
	6	60.50a	7.87a	6.22a	6.31a	8.50ab	2.32 b	0.75a	5.90ab	2.05a	3.60ab	1.17ab	22.25a
Basacote	4	60.50a	9.25a	6.21a	6.11a	12.00a	2.72 ab	0.70a	6.42ab	2.05a	4.02ab	1.72a	27.75a
	5	57.50a	9.00a	6.05a	6.31a	7.50b	2.60 ab	0.87a	5.92ab	2.12a	3.50ab	1.27ab	24.50a
	6	58.25a	9.00a	6.63a	6.9a	12.00a	4.05 a	0.70a	7.69a	2.42a	5.25a	1.75a	24.75a
Control	0	36.25b	8.50a	4.88a	5.11a	9.50ab	2.02 b	0.62a	2.82b	0.52b	2.00b	0.55b	28.00a
Average		54.71	8.85	5.89	6.05	9.71	2.76	0.73	5.45	1.73	3.31	1.17	25.42
CV		13.24	25.04	14.99	14.76	19.12	26.74	40.23	30.12	33.7	35.72	35.09	20.39
Pr(>F)		<.0001	NS	NS	NS	0.0159	0.0293	NS	<.0001	<.0001	<.0001	<.0001	NS

* CV=Coefficient of Variation.; Pr(>F)=Significance Value; NS=No Significance; <.0001=Highly Significant, Tukey p≤0.05.

The control presented the greatest root length, value that contrasts with what was found by Martínez-Nevárez *et al.* (2023), who found greater root length with higher concentration of CRF. Concerning the plant height, Orozco *et al.* (2010) obtained an average height of 22.5 cm and average basal diameter of 4.4 mm in two-month-old pink trumpets; the plants were sown in tubes of 170 cm^3 capacity. Rueda-Sánchez *et al.* (2014) found a plant height of 25.4 cm in three-month-old pink trumpets, which is lower than what is presented in Table 4, and a basal diameter of 5.1 mm, slightly lower than the general mean obtained in this study (5.30 mm).

Nutritional values of pink trumpet seedlings

The Multicote (5 kg m^{-3}) treatment yields the highest content of nitrogen in aerial and root biomass (Table 5), while the control shows the lowest values of concentration of this element. For phosphorus (P), Multicote 8M (6 kg m^{-3}) shows the highest content in aerial biomass, and this value is slightly higher than the optimal reported by Jacobs and Landis (2014). Something interesting found in this species is that the Basacote (5 kg m^{-3}) treatment yielded the highest contents of K in aerial and root biomass with 2.37% and 1.97%, respectively; both values are slightly above the optimal reported by Jacobs and Landis (2014). The values of nitrogen, phosphorus and potassium are similar to those reported by Orozco *et al.* (2010) for pink trumpets, obtaining concentrations of 1.63%, 0.36% and 2.17%, respectively.

Calcium proves to be the nutrient of greatest presence compared to the others, in the seven treatments. Basacote (6 kg m^{-3}) presented the highest concentration both for aerial and for root biomass, with 7.79% and 5.68%, respectively. These concentrations are above the optimal recommended by Jacobs and Landis (2014). Regarding magnesium, the

Table 5. Nutritional values of *Tabebuia rosea* (Bertol.) DC.

Treatments (kg m^{-3})		Biomass	Nutritional content				
			N (%)	P (%)	K (%)	Ca (%)	Mg (%)
Multicote	4	Aerial	0.97	0.20	2.10	7.25	0.26
	5	Aerial	2.50	0.25	2.13	6.00	0.29
	6	Aerial	1.12	0.26	1.89	5.49	0.26
Basacote	4	Aerial	1.32	0.24	2.22	7.36	0.34
	5	Aerial	1.20	0.21	2.37	6.28	0.36
	6	Aerial	1.49	0.24	1.94	7.79	0.32
Control	0	Aerial	0.91	0.23	0.94	7.79	0.32
Multicote	4	Radical	0.55	0.13	1.14	2.66	0.27
	5	Radical	1.24	0.18	1.51	3.07	0.19
	6	Radical	0.62	0.14	1.11	2.53	0.26
Basacote	4	Radical	0.61	0.18	1.26	2.43	0.21
	5	Radical	0.99	0.28	1.97	4.08	0.74
	6	Radical	0.78	0.26	1.55	5.68	0.74
Control	0	Radical	0.60	0.27	1.34	5.54	0.46

Basacote (5 kg m^{-3}) treatment showed the highest values, with 0.36% in aerial biomass and 0.74% in root biomass. Rueda-Sánchez *et al.* (2014) found similar values in total biomass. For potassium, the values ranged between 0.9% for the control treatment and 2.37% for the Basacote (5 kg m^{-3}) treatment. The contents of N, P and K in this study were similar to those found by Rueda-Sánchez *et al.* (2014).

CONCLUSIONS

The use of the controlled release fertilizer, Basacote, in concentrations of 5 and 6 kg m^{-3} favored the growth and development of pink trumpets in the nursery stage in a better way, which is reflected in the better quality indices of the plant.

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