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Production of desert rose seedlings under different cultivation techniques

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Abstract

Desert roses have gained notoriety in the ornamental market; however, the use of locally produced substrates is diverse. Three experiments were carried out using a completely randomized design, with treatments arranged in a 3x4 factorial. Physical and chemical analyses were carried out for the following substrates: carnauba bagana, carbonized rice husk, decomposed babassu stem, and soil. Experiment 1: three sowing depths, D1: 0mm, D2: 5mm and D3: 10 mm, combined with four substrates. Experiment 2: three substrates combined with four shading screens: thermal reflector, white shading, black shading and open sky. Experiment 3: three substrates combined with four irrigation levels: 100, 75, 50, and 25%. Measurements were made in the three experiments and data were tested by analysis of variance using the "F" test, at the levels of 1% and 5%. Regression and averages were explored using Tukey's test. It was concluded that the seedlings developed better under a level of 10 mm and substrate with 100% carnauba bagana, in association with an outdoor environment, and water levels between 50 and 75% of pot capacity.

Keywords: alternative agriculture, development, ornamental plants

Introduction

Desert rose (*Adenium obesum*) has gained notoriety in the ornamental flower market because of its beauty and exotic characteristics. The plant is easy to take care of, producing showy blossoms by natural and commercial hybrid varieties. However, technical standards to produce seedlings of the species are yet to be established (Colombo et al., 2018a).

When growing desert roses, certain factors must be considered, including the use of good quality substrates, sowing depth, irrigation scheduling, and shading (Colombo et al., 2018a). Using organic residues from agro-industrial activities as substrates allows the reuse of nutrients contained in such materials through mineralization, thereby reducing production costs and helping to mitigate environmental impacts (Araújo et al., 2017).

Locally produced substrates have been widely used, such as decomposed stems of babassu (*Attalea speciosa* Mart.), a promising substrate, especially for vegetables, that originates from the North and Northeast regions of Brazil (Andrade et al., 2017); carnauba palm straw (popularly known as "bagana"), a residue of wax extraction from carnauba palm leaves that is found in several states in the Northeast of Brazil and has been successfully used at the different stages of seedling development (Souza et al., 2016), and carbonized rice husk (*Oryza sativa* L.), residue originating from rice-producing regions and is often used in conjunction with other substrates (Kratz et al. 2013).

According to Silva et al. (2008), sowing depth exerts great influence on plant development. An adequate sowing depth provides good seed development, thus contributing to a uniform stand (Bottega et al., 2014).

When seedlings are subjected to different light incidences, they may exhibit different responses

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regarding growth and development (Shahak et al., 2002; Sabino et al., 2016). The application of excess water leads to leaching of nutrients and causes rotting of roots and stems (Mclaughlin & Garofalo, 2002; Lopes, 2005).

Considering some of the cultivation techniques of desert roses, in addition to the species' economic importance, the objective was to evaluate the effects of organic substrates associated with different sowing depths, shading types, and irrigation levels for the development and quality of desert rose seedlings.

Materials and Metods

Study site and climate

Experiments were carried out in the experimental area of the Floriculture and Fruticulture Research Group in Maranhão state (FLORIMA and FRUTIMA), at the Center for Agricultural and Environmental Sciences (CCAA) of the Federal University of Maranhão (UFMA), located in the municipality of Chapadinha, Maranhão state, Brazil (03°44'30"S, 43°21'37"W, and average altitude of 107 m). The climate has been classified as humid tropical (Selbach; Leite, 2008), with rainfall ranging from 1,600 to 2,000 mm per year (Nogueira et al., 2012) and average annual temperature above 27 °C (Passos et al., 2016)

Experiment I: Substrates and sowing depths on desert rose germination

A 3x4 factorial experiment was laid out in a completely randomized design. Factors consisted of three sowing depths, D1: 0 mm (on the surface of the substrate), D2: 5 mm and D3: 10 mm (depths standardized by a graduated manual driller), and four substrates based on carnauba bagana (CB), carbonized rice husks (CRH), decomposed babassu stems (DBS), and soil (SOIL). The substrate composition was as follows: S1: 100% CRH; S2: 100% CB; S3: 50% CRH + 50% CB; S4: 60% DBS + 40% SOIL. The experiment had four repetitions, and each repetition contained four plants, for a total of 192 seeds. Electrical conductivity, pH values, nutrient content (**Table 1**), as well as overall density, particle density, and porosity of the substrate were determined following the methodologies described by Brasil (2007) and Schmitz et al. (2002) (**Table 2**).

To prepare the substrates, CB and DBS were crushed until obtaining particles of the desired granulometry of approximately 5 mm, rice husk was carbonized using a homemade carbonizer in a 2 h long indirect burning process, turning over the material around the carbonizer to obtain uniform carbonization; and the soil (classified as Dystrophic Yellow Latosol) was sieved. Both soil and CB and DBS were crushed in a 5 mm sieve to even out the particles and to facilitate the formulation of the substrates. Sowing was carried out in polyethylene trays containing one seed in each cell. Watering was manually performed twice a day using a sprayer until substrate saturation.

Treatment effects were evaluated using the following variables measured at the end of the experiment, 30 days after sowing: germination (G%) and emergence rate index (ERI) by direct count of the number of germinated and emerged seeds over the days; number of leaves (NL), by directly count of fully expanded leaves of each plant; plant height in cm (PH), measured from ground level to the apex of the plant using a millimeter ruler; stem diameter in mm (D), measured using a digital caliper (Digimess®).

Analysis of variance was performed using the "F" test at levels of 1% and 5%. When an effect was significant, data referring to quantitative factors were explored by regression and the means referring to qualitative factors were compared by Tukey's test ($p<0.05$) using the Infostat® software, version 2015 (Dirienzo et al., 2011).

Results and discussion

There was a significant effect of substrates on germination percentage (G%), emergence rate index (ERI%), and number of leaves (NL). Sowing depths significantly influenced G% and ERI. There was no interaction between the tested factors (**Table 3**).

The coefficient of variation exhibited very high values for all the variables studied. This result might be explained by the fact that the genetic variability found in the seeds of desert roses is high, resulting in the high variation.

Substrates based on CB, CB + CRH, and Control showed equal averages (G%), but statistically superior to that of the substrate CRH (Table 3). This result may be associated with the seed quality, which favored plant development at germination. Peçanha et al. (2020) reported better results for seed germination and development using vermiculite substrate, with 95% of seeds germinated in 20 days, when evaluating the effect of different substrates on the germination and growth of *Adenium obesum*.

G% showed a positive linear relationship with sowing depths. ERI, on the other hand, showed a quadratic effect, with better results between depths of 5 and 10 mm (**Figure 1**). Such results may be related to the greater contact of the seeds with substrate particles, causing uniform wetting of seeds.

According to Silva et al. (2008), seeds must be

Table 1 . Values of pH, electrical conductivity (EC) and total content of (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) of decomposed babassu stem (DBS), carbonized rice husk (CRH) and carnauba bagana (CB)

Substrates	pH	CE	N	P	K	Ca	Mg	S
		dS m^{-1}	g Kg^{-1}	mg Kg^{-1}		______$cmol_c$ Kg^{-1}______		
CRH	5.3	0.56	4.02	89	3.88	19.80	10.40	34.6
DBS	5.32	4.34	5.88	33	3.63	20.60	15.20	41.5
CB	7.3	1.48	3.55	352	8.26	17.80	11.80	38.3
Soil	5.06	0.10	0.63	13	0.07	0.80	0.30	1.5

Table 2 . Overall density (OD), particle density (PD) and porosity of carbonized rice husk (CRH), decomposed babassu stem (DBS), carnauba bagana (CB) and soil

Substrates	DG	DP	Porosity (%)
	g cm^{-3}		
CRH	0.27	0.90	70.20
DBS	0.33	0.97	65.95
CB	0.48	1.54	69.18
Soil	1.44	2.67	45.99

Table 3. Mean squares, significance, and Tukey's test results for germination (G%), emergence rate index, number of leaves (NL), plant height (PH) and stem diameter (SD) of desert roses growing on substrates formulated based on CB, CRH and DBS, with different sowing depths

FV	Mean Squares				
	G%	ERI (%)	NL	PH (cm)	D (mm)
Substrates	4878,47**	0,21*	1,36 **	$0,35^{ns}$	$1,42^{ns}$
Depths	10091,15**	0,25*	$0,09^{ns}$	$0,73^{ns}$	$0,61^{ns}$
S x D	$646,70^{ns}$	$0,05^{ns}$	$0,48^{ns}$	$0,12^{ns}$	$0,47^{ns}$
Residue	381,94	0,05	0,25	0,31	0,67
C.V (%)	26,42	31,83	9,43	13,31	15,42
	Averages				
CRH	45,83 b	0,54 b	5,35 ab	3,55 a	3,63 a
CB	89,58 a	0,72 ab	5,68 a	3,45 a	7,78 a
CB + CRH	87,50 a	0,64 ab	5,33 ab	3,75 a	4,98 a
Witness	72,92 a	0,91 a	5,06 b	3,68 a	5,25 a
DMS	21,48	0,27	0,59	0,56	0,97

SV: source of variation; GL: degrees of freedom; CV: coefficient of variation; ** and *: there is a significant difference at the level of 1 and 5%, respectively, by the F test; ns: no significant difference, by F test. Means followed by equal letters in the columns do not differ significantly by the Tukey's test (p<0.05).

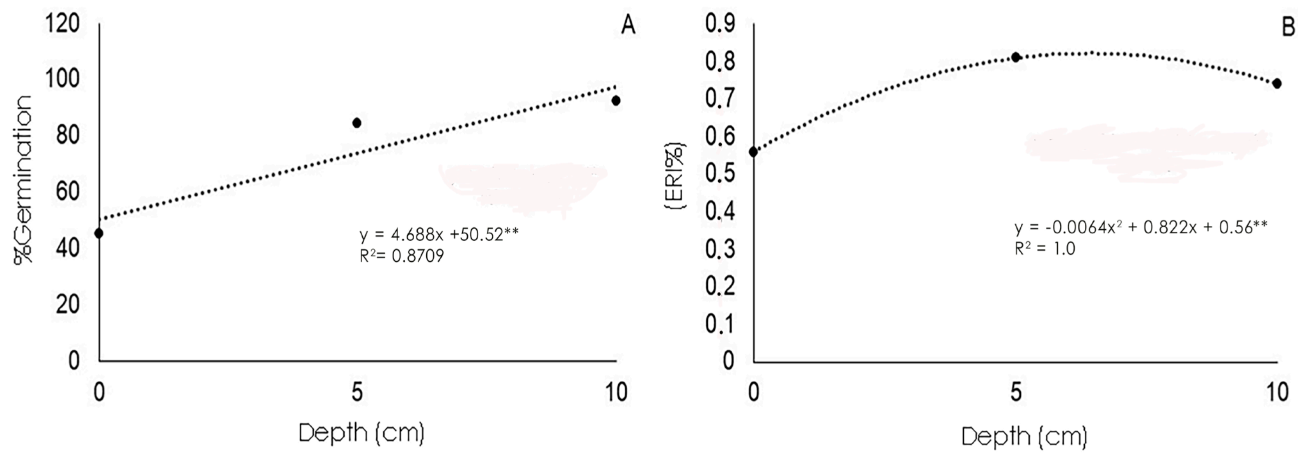

Figure 1. Percentage of germination (A) and emergence rate index (B) of desert rose seedlings growing on substrates formulated with carnauba bagana, carbonized rice husks and decomposed babassu stems, with different sowing depths.

sown at a depth that allows adequate contact with moist substrate, which generally results in a high percentage of emergence. Santos et al. (2015) observed that good moisture content in the substrate improves water uptake by the seed, which has a thin, easily permeable seed coat.

For ERI (Table 3), the control treatment showed results superior to the other treatments, with an increase of 68% when compared to CRH treatment, which had the lowest result. This result may have occurred due to the high water retention capacity of the control consisting of 60% DBS, thus increasing G% and ERI (Andrade et al., 2017).

As for NL (p<0.01), CB substrate statistically stood out over the others. This result may have occurred due to the availability of macronutrients, especially phosphorus and potassium provided by CB. Higher nutrient availability to plants occurs through mineralization of plant residues, converting from organic to inorganic form, and good substrate drainage, which may have contributed to the increase in NL. The NL is an important factor for desert roses because adult plants do not tolerate high levels of soil moisture, unlike seedlings, which in the present work obtained significant results with the substrates that retain greater moisture.

Stem diameter is an important trait both from a marketing and ornamental point of view. Desert roses are expected to have thick succulent stems, known as caudex, which gives the plant an exotic tree-like appearance. The seedlings with the greatest increase in stem diameter were those growing on substrate with 100% CB, and sown at a depth of 10 mm, statistically differing from the other treatments, with an average of 5.87 mm (**Figure 2**).

Experiments carried out by Colombo (2015) using other substrate sources report that only desert roses grown in sand + coconut fiber and vermiculite + coconut fiber substrates had thicker stems.

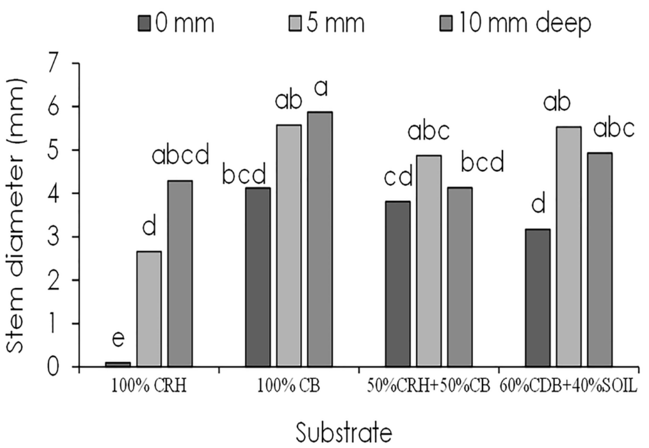

Figure 2. Stem diameter of desert rose seedlings produced in substrates based on carnauba bagana, carbonized rice husk and decomposed babassu stem, with different sowing depths.

Experiment II: Substrates and shading for desert rose production

The experiment was carried out with two stages, one of sowing in a tray and the other of transplanting (47 days after sowing) in polyethylene bags. A completely randomized design was used with treatments arranged in a 3x4 factorial composed of three substrates: 100% CB; 50% CB + 50% CRH; 100% CRH; 60% DBS + 40% SOIL, and four shading screens (thermo-reflective screen, white shading screen, black shading screen, and open sky). Four replications were used, with seven seedlings per replication.

Watering was carried out daily using watering cans with capacity of 5 L. The final evaluation was carried out 103 days after transplanting (150 days in total), when the following was measured: I) leaf area in cm^2 (LA), determined using the program ImageJ® ; II) plant height in cm (PH), determined from soil level to the apex of the seedling using a millimeter ruler; III) caudex height in cm (CH), using a millimeter ruler; IV) stem diameter in mm (SD): measured above the caudex region of the plants using a digital caliper (Digimess®); V) caudex diameter in mm (CD), obtained with a digital caliper (Digimess®) at the substrate level; VI) root length in cm (RL): measured using a ruler graduated in millimeters; VII) root volume in cm^3 (RV): determined by measuring the displacement of a water column in a graduated cylinder (Basso, 1999); VIII) shoot fresh mass (SFM) and IX) root fresh mass in g (RFM), weighed on a scale with precision of 0.01 g; X) shoot dry mass (SDM) and XI) and root dry mass in g (RDM). For the latter two, the plant material was placed in a forced air circulation oven at a temperature of 65 °C until it reached a constant weight.

Dickson Quality Index (DQI) was determined using the formula described by Dickson et al. (1960), as shown in (**Equation 1**).

$$IQD = \frac{MST\ (g)}{AP(cm)/DC(mm)/MSPA(g)/MSSR(g)}$$

Where, TDM: total dry mass; PH: plant height; ST: stem diameter; SDM: shoot dry mass and RDM: root dry mass.

For all experiments, analyses of variance were performed using the "F" test, at levels of 1% and 5%. When a significant effect was indicated, data referring to quantitative factors were explored by regression analysis and the means referring to qualitative factors were compared by Tukey's test (p<0.05) using the Infostat® software, version 2015 (Dirienzo et al., 2011).There was a significant effect regarding the substrate (p<0.05) for the variables shown in (**Table 4**), except for PH. However, regarding the shading factor, the results were different, as only three variables showed statistically significant values: leaf area (LA), root length (RL) and stem diameter (SD). The interaction between environmental and substrate factors was significant for CH, SD, CD, and RL.

Table 4 . Mean squares, significance of the factors for the variables leaf area (LA), plant height (PH), caudex height (CH), root length (RL), stem diameter (SD), caudex diameter (CD) of desert roses produced in substrates based on CB and CRH, with different irrigation levels

FV	Mean Squares					
	LA (cm²)	PH	CH	RL	SD	CD
		---------------(cm)------------			---------(mm)-----	
Shading	4822.8*	0.0042^{ns}	12.21^{ns}	31.78*	15.15**	3.53^{ns}
Substrates	27423.9**	0.4035^{ns}	214.87**	121.51**	18.84**	78.41**
Sha. x Sub.	1059.9^{ns}	0.4664^{ns}	28.10**	27.40*	2.64**	7.40**
Residue	1347.9	0.4208	8.22	10.69	0.66	4.76
C.V. (%)	48.07	17.68	24.96	20.08	13.15	12.57
Shading	Averages					
Clear sky	82.80 ab	3.69 a	10.32 a	16.34ab	6,05 b	18.11 a
White screen	95.38 a	3.65 a	12.43 a	15.47 ab	6,37 b	17.20 a
Silver screen	48.17 b	3.67 a	10.96 a	14.77 b	4,81 c	16.84 a
Black screen	79.11 ab	3.65 a	12.21 a	18.52 a	7,55 a	17.22 a
Substrates	Averages					
Witness	39.55 b	3.49 a	7.78 c	13.45 b	5.05 c	15.40 b
CRH + CB	68.36 b	3.74 a	11.55 b	16.42 a	6.32 b	16.86 b
CB	121.18 a	3.77 a	15.10 a	18.95 a	7.21 a	19.75 a

SV: sources of variation; CV: coefficient of variation; ** and *: significant difference at 1 and 5% levels, respectively, by the F test; ns: no significant difference, by the F test. Means followed by equal letters in the columns do not differ significantly by the Tukey's test (p<0.05).

The LA of plants under white and black screens, and those cultivated in the open, showed equal averages. Leaf area under silver screen had the lowest result. Plants under different radiation spectra, mainly at wavelengths 670 nm (red) and 380 nm (blue), show greater morphological differences, due to the response of photosynthetic pigments to these wavelengths (Taiz et al., 2017; Sabino et al. al., 2016).

In the present work, there was an increase in CH, with greater expressiveness for CB substrate. In addition, the interaction between black shading screen and substrates presented better results, however, even with such a result, further studies are necessary (**Figure 3**A).

For SD, the results of the interactions CB x black screen and CB x open sky were higher ($p<0.01$) than those of the other combinations (Figure 4B). Therefore, the choice of using shading screens or not, strongly depends on the crop and its photoperiod. The black screen may have better results because it does not change the light spectrum, but rather, it reduces solar radiation by transmitting radiation uniformly under the plants (Oren-Shamir et al., 2001; Ferron et al., 2021).

Caudex diameter did not respond to the environment factor ($p>0.01$ and $p>0.05$). Conversely, the variable responded significantly to the interaction between the factors ($p<0.01$) and substrate factor ($p<0.01$). Caudex diameter had a higher mean in seedlings grown in CB, and the association of CB in the open air and under silver and black screens provided statistically equal means (**Figure 4**A). The thickening of the base of the stem is natural for desert roses, as the caudex serves to store water and nutrients in arid environments (Santos et al., 2015).

For RL, using CB and CRH+CB substrates resulted

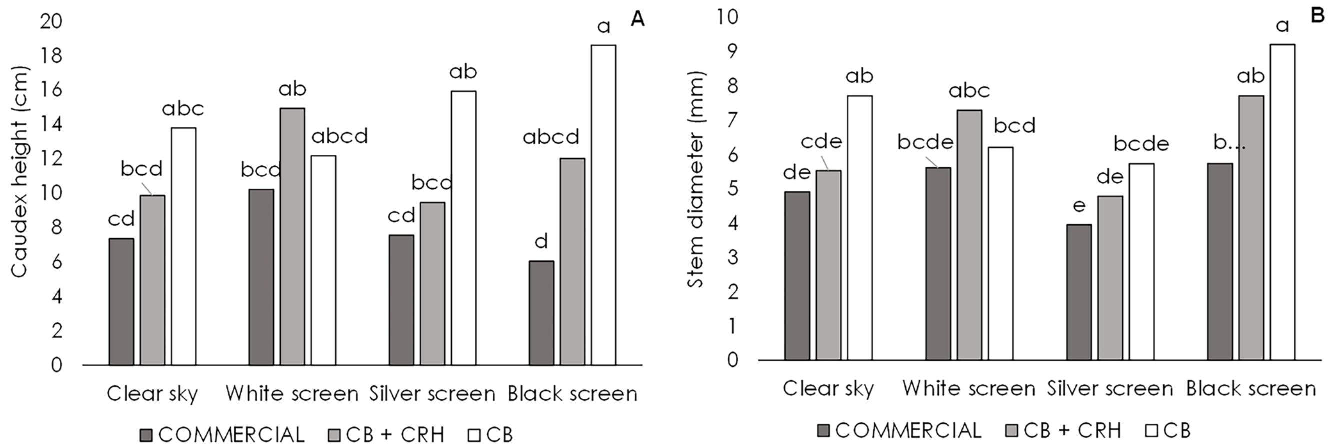

Figure 3. Caudex height (A) and stem diameter (B) of desert roses growing on carnauba bagana (BC) and carbonated rice husk (CRH) - based substrates, with different types of shading. Means followed by equal letters in the columns do not differ significantly by Tukey's test (p<0.05).

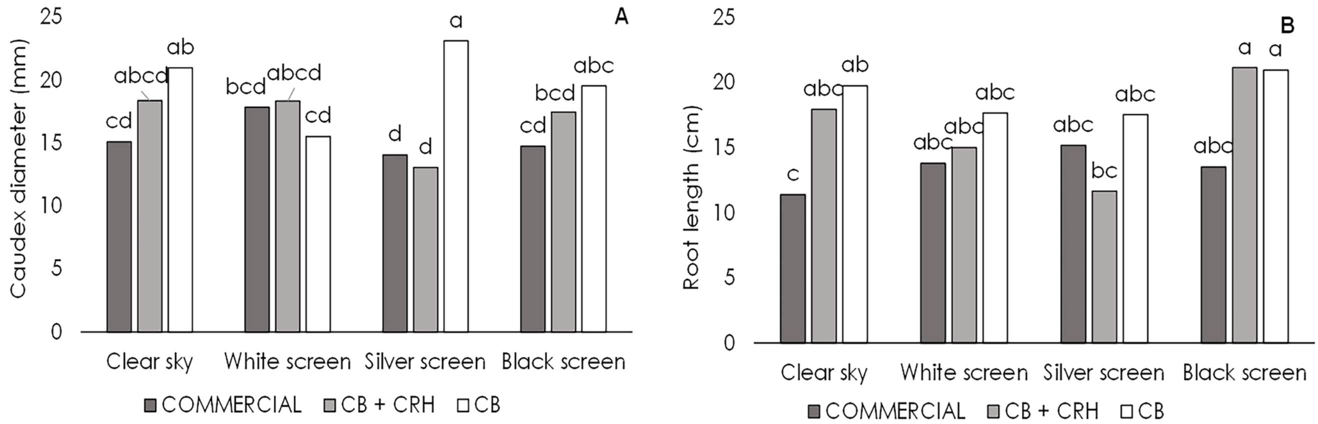

Figure 4. Caudex diameter (A) and root length (B) of desert roses produced on substrates formulated with CB and CRH, with different types of shading. Means followed by equal letters in the columns do not differ significantly by Tukey's test ($p<0.05$).

in statistically equal results. For environments, the best were open-air, white screen and black screen (Figure 4B). The association between these substrates with the tested environments promoted an increase in root length. An increase in RL demonstrates the plant's ability to develop beneficially in terms of substrate utilization, water availability, and cultural practices.

Shading, as well as the interaction with the substrate, did not significantly affect ($p>0.01$ and $p>0.05$) any of the variables shown in (**Table 5**). Regarding the substrate, there was a significant effect ($p<0.01$) for all variables.

The substrate composed of 100% CB had better results for root volume, fresh and dry biomass of plants and Dickson's quality index (DQI), differing significantly from the others. This may be linked to the porosity of the substrate, which promoted nutrient uptake by the crop, thereby improving the variables. It is worth noting that to obtain seedlings with uniform ratio of shoot to roots, these variables must be related and measured.

The higher the DQI, the better the quality of the seedling, as the index considers the relationships between total dry mass, shoot dry mass, root dry mass, PH, and diameter of the collar. Thus, the index is important when rating seedlings and is indispensable in seedling production.

Experiment III: Irrigation levels to substrates for production of desert roses

Sowing was carried out in trays containing the substrates under study. One seed was placed per cell. Forty-seven days after sowing, the seedlings were transplanted into polyethylene bags measuring 12x20 cm and containing their respective substrates.

A 3x4 factorial experiment was carried in a completely randomized design that consists of 4 plots with 2 seedlings per plot. Three substrates based on CB and CRH were tested: CB; CB + CRH (1:1); Control substrate (60% DBS + 40% SOIL), recommended in a study carried out by Santos (2019), and four irrigation levels: 100, 75, 50 and 25% of the pot capacity.

Tables 1 and 2 show the results of the chemical and granulometric analysis of the substrates. To determine the pot capacity for each substrate, samples of each dry materials were placed into containers used for the seedling production, weighed, saturated with water, covered with plastic film to prevent evaporation,

Table 5 . Mean squares, significance, and Tukey 's test for root volume (RV), shoot fresh mass (SFM), root fresh mass (RFM), shoot dry mass (SDM), root dry mass (RDM), and Dickson quality index (DQI) of desert roses produced in substrates formulated based on carnauba bagana (*Copernicia prunifera* Mill.) and carbonized rice husk (*Oryza sativa* L.), under different irrigation levels

FV	Mean Squares					
	RV	SFM	RFM	SDM	RDM	DQI
	cm^3		g			
Shading	4.21^{ns}	40.53^{ns}	5.81^{ns}	0.68^{ns}	0.016^{ns}	0.020^{ns}
Substrates	73.60**	871.69**	61.67**	8.32**	0.296**	0.355**
Sha. x Sub.	3.70^{ns}	63.39^{ns}	5.94^{ns}	0.25^{ns}	0.021^{ns}	0.024^{ns}
Residue	5.11	41.13	4.42	0.49	0.017	0.019
C.V. (%)	53.70	45.58	48.78	56.28	43.74	42.42
Shading	Averages					
Witness	2.53 b	8.12 b	2.72 b	0.61 b	0.18 b	0.79 b
CRH + CB	3.46 b	11.75 b	3.70 b	1.12 b	0.27 b	1.39 b
CB	6.62 a	22.33 a	6.05 a	2.03 a	0.45 a	2.48 a

and placed on benches. As water stopped draining, the samples were weighed again and then, by difference, the pot capacity was obtained (Parizi et al., 2010).

Irrigation levels relative to pot capacities, namely 100, 75, 50 and 25%, for CB substrate were, respectively: 57.53; 43.15; 28.76, and 14.38 mL. For the substrate CB + CRH: 172.20; 129.15; 86.10 and 43.05 mL. And for Control substrate: 147.02; 110.26; 73.51, and 36.75 mL.

Plants were watered daily. Final evaluation was carried out 103 days after transplanting (150 days total), when the following variables were measured: root volume in cm^3 (RV): performed by measuring the displacement of a water column in a graduated cylinder, according to methodology described by Basso (1999), shoot fresh mass (SFM) and root system (RFM) in g, weighed on a scale with a precision of 0.01 g, shoot dry mass (SDM) and root dry mass (RDM) in g, and the plant material was taken to an oven with forced air circulation at a temperature of 65 °C until reaching constant weight, and Dickson quality index (DQI), using the formula described by Dickson et al. (1960), as shown in Equation 1.

For all experiments, analyses of variance were performed using the “F” test, at levels of 1% and 5%. When a significant effect was indicated, data referring to quantitative factors were explored by regression analysis and the means referring to qualitative factors were compared by Tukey's test (p<0.05) using the Infostat® software, version 2015 (Dirienzo et al., 2011).

Substrates significantly influenced seedling growth by revealing differences in LA, PH, CH, RL, SD, and CD variables. In addition, there was a single effect of irrigation levels on PH and SD (**Table 6**). There was also a significant effect of the interaction between irrigation level and substrate only on LA and PH.

Seedlings growing on CB substrate had higher averages for LA, 276.46 cm^2, which is 3.5 times higher than the result obtained with the control substrate. The same substrate also provided superior results for PH, SD and CD (Table 6), which were 104%, 26% and 35% higher than that of Control, respectively.

This may be related to the higher levels of phosphorus and potassium, and other essential nutrients, in CB substrate. Both nutrients play important roles in vegetative development of plants and when in adequate levels, they contribute to increased LA, influencing photosynthetic rates. The photosynthetic capacity of plants is proportional to LA, which can then be associated with the production of photoassimilates and, thus, with growth of seedlings (Oliveira et al., 2020).

As with other crops, nitrogen (N) is responsible for much of the positive response reflected in proper vegetative growth of desert roses. (Colombo et al., 2018b). Potassium (K) plays key roles in protein synthesis, transport and storage of carbohydrates, in opening and closing of stomata, linking K the nutrient to plant water status, in vegetative growth, and in ionic balance. Phosphorus (P), on the other hand, acts in the initial growth of plants in general in storage processes, energy transfer and active uptake of other nutrients (Taiz et al., 2017).

Caudex heights of plants growing on CB and CB + CRH substrates were statistically equal and differed from Control. Desert flower growers describe the growth of caudex base structure as malleable to the position of the root in the container (Santos et al., 2015). As the plant grows and depending on the cultural practices, the caudex will grow and shape itself into appreciated sculptural forms. Therefore, the resulting forms are affected by the growth of the caudex and roots (Colombo et al., 2018a).

As for RL, the substrate CB + CRH had statistically

Table 6 . Mean squares, significance and Tukey 's test for leaf area (LA), plant height (PH), caudex height (CH), root length (RL), stem diameter (SD) and caudex diameter (CD) of desert roses produced in substrates based on carnauba bagana (*Copernicia prunifera* Mill.) and carbonized rice husk (*Oryza sativa* L.), with different irrigation levels

FV	GL	Mean Squares					
		LA (cm^2)	PH	CH (cm)	RL	DP	CD (mm)
Substrates	2	174771.37**	510.45**	10.17**	54.77*	18.79*	278,25**
Blades	3	2096.08^{ns}	33.42**	0.47^{ns}	31.12^{ns}	5.23*	20.87^{ns}
S x B	6	9243.25**	55.67**	0.76^{ns}	7.72^{ns}	1.19^{ns}	17.71^{ns}
Residue	36	1540.51	3.80	0,80	11.60	1.29	7.93
C.V. (%)	-	24.75	13.28	21.56	22.53	12.93	14.03
Substrates		Averages					
		LA	PH	CH	RL	DP	CD
CB		276.46a	21.05 a	4.90^a	17.20^a	10.01 a	24.69
CB+CRH		121.78b	12.67 b	4.2^a	14.46ab	8.43 b	16.59b
Witness		77.35c	10.30 c	3.31b	13.67b	7.93 b	18.21 b
DMS		31.91	1.68	0.77	2.94	0.98	2.43

SV: source of variation; DF: degrees of freedom; CV: coefficient of variation; ** and *: there is a significant difference at the level of 1 and 5%, respectively, by the F test; ^{ns}: no significant difference, by the F test. Means followed by equal letters in the columns do not differ significantly by the Tukey test (p<0.05).

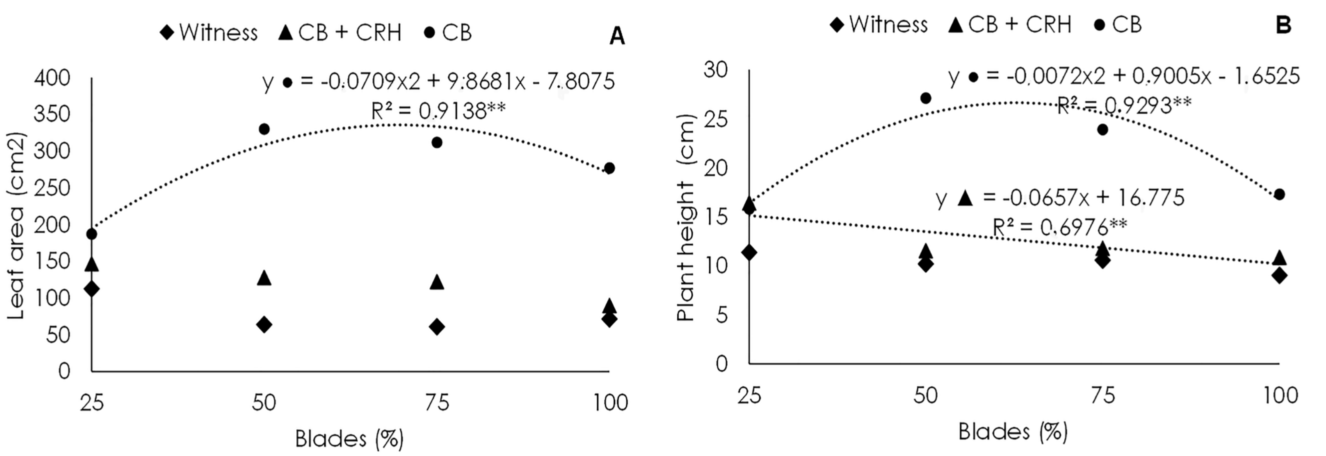

Figure 5. Leaf area (A) and plant height (B) of desert roses produced in substrates formulated with carnauba bagana base (Copernicia prunifera Mill.) and carbonized rice husk (Oryza sativa L.), with different irrigation levels.

equal results to the other substrates. The porosity of both substrates is relatively similar, which may have influenced the result (Table 6). Santos (2019) also reported greater porosity results in greater root growth of desert roses.

Conversely, RL of the seedlings grown in CB substrate stood out to those obtained with the seedlings grown on the Control substrate. There is a disparity regarding the P and Ca content of the two substrates, as CB substrate has higher P and Ca contents. Both elements play important roles in root growth and development (Silva et al., 2017). We can conclude that CB substrate provided superior results by combining good aeration and better nutrient Ca and P contents.

Regarding LA and PH, irrigation levels led to different effects on each substrate. Therefore, average LA values of the seedlings of the Control and CB+ CRH substrates did not fit any regression model, and were lower than those obtained with the use of the CB substrate.

In this substrate, a quadratic effect was observed (**Figure 5**) as a function of the irrigation levels, the regression equation indicated 69.5% of pot capacity as the optimal level, providing a LA of 335 cm^2.

The CB substrate has a lower water retention capacity, so a higher irrigation level is necessary to meet the water needs of the seedlings and to ensure greater LA, expanding the photosynthetic capacity, which implies faster growth rates (Silva et al., 2017).

Plant height behaved similarly to LA, fitting a quadratic regression model with the use of CB substrate as a function of the irrigation levels (Figure 5). A level of 62.5% would result in the optimal expression of PH, reaching an estimated height of 26.5 cm. On the other hand, a decreasing linear model was fitted to the average height of the seedlings growing on CB + CRH substrate. A 25% pot capacity level is the one that provided the best result because CB + CRH substrate has a greater water retention capacity than the other substrates.

The maximum pot capacity (water retention) referring to CB substrate was 57.53 mL of water, on the other hand, a higher value was observed for the substrate with the same residue mixed with carbonized rice husks, 172.20 mL. This influenced the growth of seedlings. Desert rose requires substrates with excellent drainage; excess water can result in reduced growth (Mclaughlin & Garofalo, 2002).

The irrigation levels influenced SD (**Figure 6**). A reduction in diameter was caused by raising the irrigation level above 25% of the substrate capacity, fitting a negative linear regression model, in such a way, the decrease in diameter may be related to the increase in nutrient leaching.

Since, the increase in nutrient leaching rate can be caused by high irrigation depths. These, together with the small volume of the containers, negatively influence

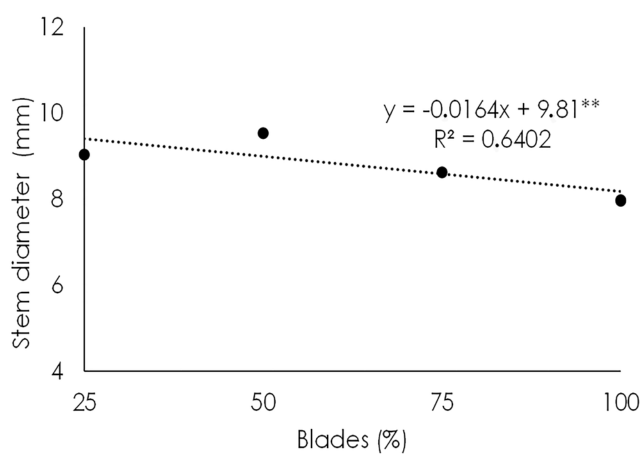

Figure 6. Stem diameter of desert roses produced on substrates based on carnauba bagana (Copernicia prunifera Mill.) and carbonized rice husk (Oryza sativa L.), with different irrigation levels.

Table 7 . Mean squares, significance, and Tukey 's test for root volume (RV), shoot fresh mass (SFM), root fresh mass (RDM), shoot dry mass (SDM), root dry mass (RDM), and Dickson quality index (DQI) of desert roses produced on substrates based on carnauba bagana (*Copernicia prunifera* Mill.) and carbonized rice husk (*Oryza sativa* L.), with different irrigation levels

FV	G.L	Mean squares					
		RV	SFM	RDM	SDM	RDM	DQI
		cm^3		g			
Substrates	2	128.8**	2125.6**	184.21**	9.42**	0.39**	0.21**
Blades	3	1.75^{ns}	60.84^{ns}	1.45^{ns}	0.22^{ns}	0.009^{ns}	0.011^{ns}
S x B	6	5.99^{ns}	116.33*	8.84^{ns}	1.17**	0.034^{ns}	0.022^{ns}
Residue	36	5.99	46.13	10.20	0.31	0.029	0.018
C.V. (%)	-	48	34.22	55.37	34.93	45.51	41.62
Substrates		Médias					
		RV	SFM	RDM	SDM	RDM	DQI
BC		8.37 a	33.08 a	9.68 a	2.49 a	0.55 a	0.45 a
CB + CRH		3.42 b	14.42 b	3.86 b	1.23 b	0.26 b	0.23 b
Witness		3.50 b	12.02 b	3.75 b	1.10 b	0.31 b	0.29 b
DMS		2.11	5.86	2.76	0.48	0.14	0.11

FV: variation factors; GL: degrees of freedom; CV: coefficient of variation; ** and *: there is a significant difference at the level of 1 and 5%, respectively, by the F test; ns: no significant difference, by the F test. Means followed by equal letters in the columns do not differ significantly by the Tukey test ($p<0.05$).

the nutrient content of the substrates, and prevent them from being made available in adequate amounts (Wendling & Gatto, 2002).

Irrigation levels had no effect on RV, SFM, RFM, SDM, RDM and DQI. However, substrates significantly affected all these variables. The interaction between the two was significant only for SFM and SDM (**Table 7**).

In seedlings cultivated on CB substrate, higher averages were obtained in relation to the other substrates, for all the variables mentioned above, and the CB + CRH and Control substrates were statistically equal. The nutritional quality and good aeration of CB substrate in relation to the others caused this result.

The better development of the root system, demonstrated by RV of seedlings on CB substrate, is mainly related to the physical properties of this substrate. Low-density organic materials can provide reduced physical resistance to the growth of the root system, facilitating the distribution of roots over a larger area, which improves water and nutrient uptake (Colombo et al., 2018a).

Consequently, this favors the accumulation of biomass, also linked to the greater LA provided by CB substrate. Brito et al. (2017) when evaluating different substrates in the production of lettuce seedlings, also reported improved dry mass of seedlings growing on substrates containing CB.

The same substrate favored the DQI of desert rose seedlings, with the highest average (0.45). Since it includes the morphological variables of height, stem diameter, and biomass, according to Monteiro Neto et al. (2019), proves to be efficient in the evaluation of the components that qualitatively favored the growth of seedlings.

Regarding the interaction of irrigation levels with substrates, there was a quadratic effect for CB substrate and a decreasing linear effect for the CB + CRH substrate, for the SFM and SDM variables (**Figure 7**A and B).

SFM and SDM were higher in CB substrate seedlings in levels between 50 and 75%, with the first having reached its maximum point at 65.60% and the

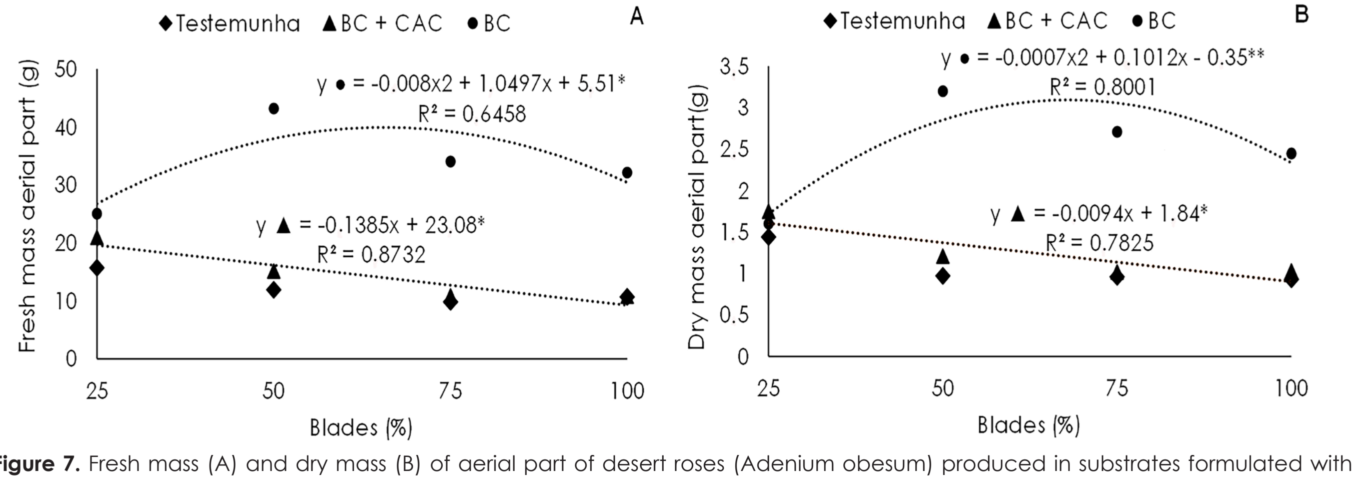

Figure 7. Fresh mass (A) and dry mass (B) of aerial part of desert roses (Adenium obesum) produced in substrates formulated with carnauba husks (Copernicia prunifera Mill.) and charred rice husk (Oryza sativa L.), with different irrigation levels.

second at 72.28%. The results obtained in this work with the adoption of CB substrate were superior to those obtained by Santos (2019). In CB + CRH substrate, the depths above 25% provided a reduction in the accumulation of biomass. Since the accumulation of biomass linked to water uptake is directly related to the substrate and water retention capacity (Colombo et al., 2018a).

Confirming the importance of studies to assess irrigation levels in species growing on different substrates, both factors can influence the growth and development of seedlings.

Conclusions

Desert rose seedlings developed better under a sowing depth of 10 mm and substrate consisting of 100% carnauba bagana. Shading screens used as an environmental factor were not effective in improving crop performance. The use of 100% carnauba bagana as a substrate in association with an open-air environment is recommended. A better growth and quality of seedlings growing on carnauba bagana substrate requires irrigation levels between 50 and 75% of pot capacity. For the remaining substrates, which retain more water, an irrigation level of 25% is recommended.

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