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Substrates and irrigation levels for growing desert rose in pots

Substratos e níveis de irrigação no crescimento em vaso de rosa do deserto

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ABSTRACT

In the past decades, desert rose has become a very popular ornamental plant, especially among collectors, due to its exotic and sculptural forms. However, it has been grown on a commercial scale only recently, and little is known about how to best manage it as a container-grown plant, or even which potting medium (substrate) to recommend. Therefore, the aim of this study was to investigate the interactions between potting media and irrigation levels for growing desert rose as a potted ornamental plant. The experiment was conducted in a greenhouse using a 6 x 2 factorial arrangement with six replications, six potting media and two irrigation levels. The mixes were characterized by measuring their physical properties, specifically the density and water retention capacity (WRC), as well as chemical properties, such as the pH and electrical conductivity (EC). After 210 days, plant growth and plant water consumption were evaluated and measured. A lower dry density for the vermiculite mixes was observed in comparison to that for the sand mixes. However, WRC ranged from 428 to 528 mL L^{-1} among the mixes, values considered close to ideal. In general, plant growth exhibited higher increases in mixes consisting of coconut fiber + sand or vermiculite, regardless of the irrigation level. Mixes of vermiculite + coconut fiber and sand + coconut fiber can be used to grow desert rose in pots, as long as irrigation is used to maintain the moisture content of the potting medium (mix) between 60-70% and 80-90% of the WRC.

Index terms: *Adenium obesum*; water consumption; Apocynaceae.

RESUMO

Na última década a rosa do deserto ganhou destaque no mercado de flores, principalmente entre colecionadores, devido às suas formas exóticas e esculturais; porém, o cultivo da espécie em escala comercial é bastante recente e pouco se sabe acerca do manejo da cultura, inclusive no que diz respeito à recomendação de substratos. Assim, objetiva-se nesse trabalho estudar a interação entre substratos e níveis de irrigação no desenvolvimento de rosa do deserto em vaso. Conduziu-se o experimento em casa de vegetação em esquema fatorial 6 x 2, com seis repetições, adotando-se seis substratos e dois níveis de irrigação. As misturas foram caracterizadas mensurando-se suas propriedades físicas (densidade e capacidade de retenção de água – CRA) e químicas (pH e condutividade elétrica – CE). Aos 210 dias de cultivo avaliou-se o crescimento das plantas; além do consumo de água pela cultura. Para as misturas compostas por vermiculita verificou-se menor densidade seca em relação às compostas por areia; no entanto, a CRA variou de 428 a 528 mL L^{-1} entre as misturas, valores próximos aos considerados ideais. De modo geral, o crescimento das plantas teve maiores incrementos nas misturas compostas por fibra de coco mais areia ou vermiculita, independente do nível de irrigação. As misturas vermiculita + fibra de coco e areia + fibra de coco podem ser empregadas para o cultivo em vaso de rosa do deserto, quando se mantiver os níveis de irrigação entre 60-70% e 80-90% da CRA das misturas.

Termos para indexação: *Adenium obesum*; consume de água; Apocynaceae.

INTRODUCTION

Adenium genus belongs to the botanical family Apocynaceae, which includes many tropical ornamental species, such as *Catharanthus* spp., *Beaumontia* spp., *Carissa* spp., *Allamanda* spp., *Mandevilla* spp., *Nerium* spp. and *Plumeria* spp. (Colombo et al., 2015). The desert rose, *Adenium obesum* (Forssk.), Roem. & Schult., has become a popular plant because of its rusticity, exotic, sculptural shapes and spectacular flowers producedby natural and commercial hybrid varieties. However, despite these characteristics, when the production of an ornamental plant on a commercial scale is the objective, it is important to define the production system, starting with the potting medium to be used (Colombo et al., 2016). Irrigation management is also of paramount importance because relevant information on this species is still scarce in the literature.

There are different kinds of potting media that, alone or mixed, can be used to produce potted ornamentals plants. Plants grown in pots are characterized by a particularly high (and unbalanced) ratios between the aerial parts of the plants and the roots, and by much greater water, air and nutrient requirements than those grown directly in the soil (and in the open field), where growth rates are slower and the volume of soil available for the roots is theoretically unlimited (Gruda, 2012).

Therefore, the physical, chemical and biological potting medium properties can change and deteriorate with time and use, which may affect both crop management and behavior. Physical degradation of substrates can also alter the pore structure, which may in turn affect the retention and movement of nutrient solutions and root aeration (Colombo et al., 2016; Giuffrida; Leonardi; Mafrà, 2007; Verhagen, 2009).

The physical characteristics of a potting medium, including the density and porosity, can be considered the most important properties because they can affect the air/water relationship of the potting medium, which can change during the growth cycle (Kämpf; Fermino, 2000; Verdonck, 1983). In terms of chemical characteristics, the pH and electrical conductivity (EC) of the material or mix are extremely important (Kämpf; Fermino, 2000) because the addition of a fertilizer can be managed by the producer.

However, for producing potted ornamental plants, some technical knowledge is required of the irrigation purposes, in addition to knowledge of the potting medium. It is very important to determine the appropriate irrigation frequency and water volume to be applied. Grant et al. (2008) report that in most cases, the frequency and volume of water applied is based on the producer's personal experience, and is often controlled by a timer. This method ignores the fact that the plant water use can vary from one day to the next, both throughout the season and as the growth cycle progresses. In this case, a water shortage can lead to water stress and nutrient absorption reduction by plants. On the other hand, excessive water can lead to nutrient leaching, and provide a microclimate favorable to pathogenic development (Lopes, 2005).

Therefore, the aim of this study was to investigate the interaction between potting media and irrigation levels for growing desert roses in pots.

MATERIAL AND METHODS

The experiment was conducted between December 2013 and July 2014 in a Van der Hoeven® climatized greenhouse, covered with polycarbonate sheets, using a humid cool system that switched on when the internal temperature reached 28 ºC and off when the internal temperature reached 26 ºC. The greenhouse was located at the Department of Agronomy, Londrina State University (UEL), Brazil.

Seedlings of *Adenium obesum* (Forssk.), Roem. & Schult., were grown in 50 mL plastic containers, which were filled with a 1:1 (v/v) mix of Lupa® + and composted bird litter. Plants were maintained in an agricultural greenhouse covered with a transparent polyethylene film and black plastic screening (Sombrite®) with 50% light retention.

Then, 270 days after sowing, seedlings were removed from these conditions and selected to obtain a homogeneous batch with the following average parameters: stem height (11.9 cm ± 1.1), caudex diameter (27.9 mm ± 2.5) and plant fresh weight (37.3 g ± 6.3). Plants were marked with a reference number, and the changes in these parameters were calculated during the final evaluation stage of the experiment.

To set up the experiment, 3 L black polyethylene pots were filled with the following respective potting media: sand + Amafibra® 47 coconut fiber (S+CF), sand + Lupa® (S+L), sand + modified Lupa® (S+ML), vermiculite + Amafibra® 47 coconut fiber (V+CF), vermiculite + Lupa® (V+L) and vermiculite + modified Lupa® (V+ML). The sand and vermiculite had average grain sizes of 0.2-0.6 mm and 0.50-1.19 mm, respectively. The modified Lupa® potting medium consisted of a mix of 70% Lupa® + 30% shredded pine bark, with an average grain size of 7 mm. All potting media were mixed in a proportion of 1:1 (v/v) of the respective materials.

The mixes used as potting media were analyzed to determine the physical characteristics the of dry density (g $L^{-1,}$) and water retention capacity (mL L^{-1}) and the chemical characteristics of the pH and electrical conductivity (mS cm^{-1}) according to the method proposed by Kämpf, Takane and Siqueira (2006).

Two irrigation levels were used, keeping each potting medium at 60 to 70% or 80 to 90% of the water retention capacity. Pot weight was measured daily during the experiment, adding the correct amount of water to reach the required retention capacity.

Every 30 days, one plant was removed from each potting medium to measure the fresh weight, enabling the calculated water volume to be added to each treatment to maintain the predetermined irrigation levels.

Fertilizer was applied to the plants monthly, except for the first application (45 days after beginning the experiment), using a 06-04-04 + 10 (NPK) commercial fertilizer solution plus micronutrients at 1% (Biofert®). Each pot received 50 mL of the solution. The plants were grown such that they maintained the main stem and two buds. The other buds were removed as needed.

At 45 days, a pre-evaluation was conducted measuring the stem height (cm) and the number of leaves and buds produced. At 210 days, the following characteristics were evaluated in six plants of each treatment: stem height (cm), caudex diameter (mm) at the base, fresh weight (g) of leaves, stems and roots, and volume of the root system (mL). The volume of the root system was measured using a graduated cylinder containing a known volume of water, by inserting the roots and reading the volume by water column displacement in the cylinder. The date on which each plant produced the first inflorescence was also recorded during the experimental period.

For the potting media, the pH and electrical conductivity were determined at the end of the experiment using the method proposed by Kämpf, Takane and Siqueira (2006). Average daily evapotranspiration and total evapotranspiration were measured for each potting medium during the experimental period.

A fully randomized experimental design was used in a factorial arrangement with two factors: six potting media and two irrigation levels, totaling 12 treatments. Six replications were evaluated for each treatment, each consisting of a single plant. Data were subjected to analysis of variance and the means were compared using the Tukey test at a 5% probability level.

RESULTS AND DISCUSSION

Based on the physical characterization of the potting media (Table 1) in terms of the bulk density, mixes (potting media) containing vermiculite exhibited lower dry densities (< 400 g L^{-1}) than the mixes containing sand (dry densities > 800 g L^{-1}). Bunt (1973) reported that the potting medium bulk density considered ideal for plant development was between 400 and 500 g L^{-1}. Kämpf and Fermino (2000) stated that the higher the potting medium density, the more difficult it was to cultivate the plant, whether due to limitations on plant growth or to difficulties in transporting the pots. These authors also recommended that dry densities should be between 200 and 400 g L^{-1} for pots, with a column of potting medium up to 15 cm deep, as it was in this study.

However, despite the significant differences between the densities of the potting media tested, water retention capacity (WRC) ranged from 428 to 528 mL L^{-1}. Therefore, mixes of with widely differing densities but little variation in WRC could be made. According to Burnett, Mattson and Williams (2016), substrates typically use a blend of various allowed bulk materials to achieve appropriate physical properties (water and air holding capacity). Furthermore, the WRC values of the mixes were close to the values recommended by Verdonck, Vleeschauwer and De Boodt (1981) as ideal for potting media and accounting for approximately 40 to 50% of the potting medium volume.

The chemical characteristics (pH and electrical conductivity (EC)) differed widely among the potting media used (Table 1). This should directly influence plant growth, whether by changing the availability of nutrients, or by their effects on physiological processes (Kämpf; Fermino, 2000). EC is also affected by the materials used. The EC of mixes containing sand is two times or more than that of mixes containing vermiculite.

The same chemical characteristics (pH and EC) were evaluated after 210 days of growth and compared at each irrigation level, and they showed no statistical differences (Table 2). Therefore, it is evident that at irrigation levels lower than the WRCs of the potting media, the values of pH and EC are not significantly altered, irrespective of the irrigation level adopted, since there is no leaching of the solution from the potting medium.

The pH values observed for the S+CF and V+CF mixes indicate that these mixes were subject to higher acidification as the experiment progressed, in accordance with the findings of Martinez (2002), whereas the pH values of the other mixes remained practically unchanged, tending towards neutral. According to Verdonck, Vleeschauwer and De Boodt (1981), it is important that the pH of a

Table 1: Characterization of the physical properties of dry density (DD) and water retention capacity (WRC), and chemical properties of pH and electrical conductivity (EC), of the six potting media.

[z]Substrate	DD (g L^{-1})	WRC (mL L^{-1})	pH	EC (mS cm^{-1})
S+CF	838.00	497.33	5.83	2.37
V+CF	136.67	528.00	6.11	0.79
S+ML	1,018.67	428.67	6.81	0.86
V+ML	273.33	486.00	6.66	0.41
S+L	1,042.00	460.67	7.36	1.06
V+L	337.33	510.67	7.07	0.41

[z]Sand + Amafibra® 47 coconut fiber (S+CF), sand + Lupa® (S+L), sand + modified Lupa® (S+ML), vermiculite + Amafibra® 47 coconut fiber (V+CF), vermiculite + Lupa® (V+L) and vermiculite + modified Lupa® (V+ML).

good potting medium does not change significantly during growth, as observed for the mixes without coconut fiber.

In terms of the water consumption of the desert rose, the average daily water consumption over the experimental period differed among the different potting media and in accordance with the irrigation level. This was mainly due to the hydro-physical differences among the analyzed potting media (Klein et al., 2000). Table 3 shows that during the first month of growth (December), average daily water consumption ranged from 35.56 to 43.15 mL/day.

The slight variation among the potting media could merely be due to the water evaporation capacity of each mix, especially because during this period, no likely significant difference between treatments was observed in terms of water loss by transpiration. This may be due to the fact that all plants have a similar evaporation surface area and are adapting to new growth conditions.

Table 2: pH and electrical conductivity (EC) values of the six potting media after 210 days' growth of potted *Adenium obesum*, with two irrigation levels: 60 to 70% and 80 to 90% of the potting medium water retention capacity (WRC).

zSubstrate	pH			EC (mS cm^{-1})		
	WRC 60-70%	WRC 80-90%	Mean	WRC 60-70%	WRC 80-90%	Mean
S+CF	4.23y	4.05	4.14	0.84	0.74	0.79
V+CF	4.72	4.52	4.62	0.73	0.70	0.72
S+ML	6.48	6.61	6.55	0.41	0.51	0.46
V+ML	6.54	6.60	6.57	0.59	0.42	0.51
S+L	7.14	7.19	7.17	0.61	0.81	0.71
V+L	7.24	7.25	7.25	0.89	0.71	0.80
CV (%)	5.83			27.31		

zSand + Amafibra® 47 coconut fiber (S+CF), sand + Lupa® (S+L), sand + modified Lupa® (S+ML), vermiculite + Amafibra® 47 coconut fiber (V+CF), vermiculite + Lupa® (V+L) and vermiculite + modified Lupa® (V+ML). yFor the pH and EC values investigated, no significant differences in the Tukey's test at a 5% probability level were observed when the two irrigation levels were compared.

Table 3: Average daily and total water consumption at 210 days for potted *Adenium obesum* plants, with potting media kept at two irrigation levels: 60 to 70% and 80 to 90% of potting medium water retention capacity (WRC).

zSubstrate	December			January		
	WRC 60-70%	WRC 80-90%	Mean	WRC 60-70%	WRC 80-90%	Mean
S+CF	43.23	43.07	43.15 ay	64.31 aA	71.38 aA	67.84
V+CF	35.42	40.14	37.78 bc	44.70 bB	63.34 aA	54.02
S+ML	40.15	43.14	41.65 ab	39.61 bcA	44.18 bA	41.89
V+ML	32.2	40.19	36.20 c	28.48 dB	37.16 bA	32.83
S+L	40.43	42.27	41.35 ab	39.69 bcA	39.09 bA	39.39
V+L	33.27	37.85	35.56 c	30.95 cdA	35.24 bA	33.09
Mean	37.45 B	41.11 A		41.29	48.39	
CV (%)	8.23			13.99		
Substrate	February			March		
	WRC 60-70%	WRC 80-90%	Mean	WRC 60-70%	WRC 80-90%	Mean
S+CF	70.86	82.21	76.53 a	58.84	65.96	62.40 a
V+CF	50.84	70.04	60.44 b	51.66	62.64	57.15 a

Continue...

Table 3: Continuation...

Substrate	February			March		
	WRC 60-70%	WRC 80-90%	Mean	WRC 60-70%	WRC 80-90%	Mean
S+ML	46.09	52.61	49.35 c	51.75	55.76	53.76 ab
V+ML	33.65	43.05	38.35 cd	38.26	48.69	43.46 bc
S+L	42.62	42.69	42.65 cd	47.75	40.33	44.04 bc
V+L	29.81	33.94	31.87 d	38.94	42.64	40.79 c
Mean	45.65 B	54.09 A		47.86 B	52.67 A	
CV (%)	18.41			19.95		
Substrate	April			May		
	WRC 60-70%	WRC 80-90%	Mean	WRC 60-70%	WRC 80-90%	Mean
S+CF	56.11	64.98	60.54 ab	34.12	47.56	40.84 a
V+CF	54.65	72.40	63.25 a	39.74	57.87	48.80 a
S+ML	52.81	55.14	53.98 ab	34.49	43.10	38.79 a
V+ML	42.75	51.90	47.33 ab	32.18	38.73	35.45 a
S+L	50.86	42.15	46.50 b	36.97	34.99	35.99 a
V+L	43.24	48.62	45.93 b	33.43	38.87	36.15 a
Mean	50.07 A	55.86 A		35.16 B	43.52 A	
CV (%)	26.20			29.94		
Substrate	June			Total water consumption		
	WRC 60-70%	WRC 80-90%	Mean	WRC 60-70%	WRC 80-90%	Mean
S+CF	20.05	27.04	23.54 ab	10,484.05 aA	12,129.35 abA	11,306.70
V+CF	23.35	38.60	30.98 a	9,080.71 abB	12,234.70 aA	10,657.70
S+ML	18.89	25.75	22.32 ab	8,588.04 abA	9,671.34 bcA	9,129.69
V+ML	19.63	27.99	23.81 ab	6,878.65 bB	8,710.57 cA	7,794.61
S+L	20.73	23.00	21.87 b	8,451.05 abA	8,006.85 cA	8,228.95
V+L	20.55	27.03	23.79 ab	6,982.45 Ba	8,012.48 cA	7,497.46
Mean	20.53 B	28.24 A		8,410.82	9,794.22	
CV (%)	29.99			16.40		

[z]Sand + Amafibra® 47 coconut fiber (S+CF), sand + Lupa® (S+L), sand + modified Lupa® (S+ML), vermiculite + Amafibra® 47 coconut fiber (V+CF), vermiculite + Lupa® (V+L) and vermiculite + modified Lupa® (V+ML). [y] Different lower case letters in the columns and upper case letters in the rows for each variable indicate a difference in Tukey's test at a 5% probability level.

In January, February and March, a comparison was investigated between the same organic waste materials (coconut fiber, Lupa® and modified Lupa®) combined with either sand or vermiculite. Mixes containing sand required more water than those containing vermiculite (Table 3). Water evaporates more rapidly from sand; therefore, more frequent irrigation is required, which means that more water is consumed.

Furthermore, in the first three months of the year, and in April and May, the plants consuming the most water were those grown in S+CF and V+CF, and this was the case for both irrigation levels. Bearing in mind that the initial characteristics of plants were similar when first evaluated at 45 days, only those grown in the S+CF and V+CF potting media exhibited stem growth, increases in height, and the production of new leaves and buds. Growth in the other plants stagnated (Table 4 and Figure 1). This led us to assume that from this point onward, these plants needed more water to accelerate growth because of the increased evaporation surface area.

Table 4: Stem growth (SG) in terms of height, number of buds (NB) and number of leaves (NL) produced by potted *Adenium obesum* plants at 45 days, with potting media kept at two irrigation levels: 60 to 70% and 80 to 90% of potting medium water retention capacity (WRC).

zSubstrate	SG (cm)	NB	NL
S+CF 60-70% WRC	5.0	6.0	10.9
V+CF 60-70% WRC	3.2	2.8	8.9
S+CF 80-90% WRC	6.4	5.1	10.9
V+CF 80-90% WRC	6.8	3.5	10.4

zSand + Amafibra® 47 coconut fiber (S+CF), vermiculite + Amafibra® 47 coconut fiber (V+CF).

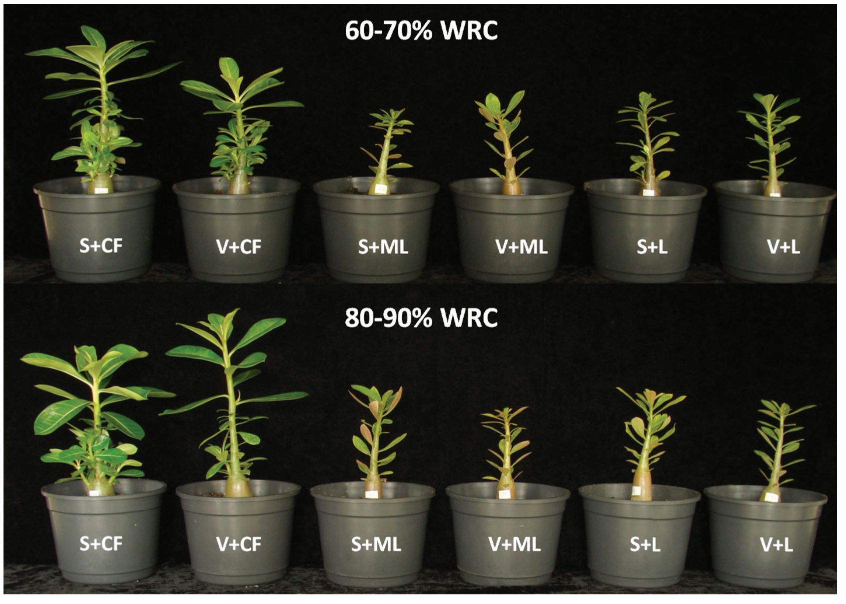

Figure 1: Growth of *Adenium obesum* at 45 days in pots containing the following potting media: sand + Amafibra® 47 coconut fiber (S+CF), sand + Lupa® (S+L), sand + modified Lupa® (S+ML), vermiculite + Amafibra® 47 coconut fiber (V+CF), vermiculite + Lupa® (V+L) and vermiculite + modified Lupa® (V+ML), kept at two irrigation levels: 60 to 70% and 80 to 90% of potting medium water retention capacity (WRC).

Figure 2 also shows that in general, high evapotranspiration occurred in all potting media and at both irrigation levels, although evapotranspiration decreased in May. However, it is important to observe that between January and April, average air temperatures are higher in the Northern region of Paraná state. This could cause an evapotranspiration increase requiring more irrigation water, even though plants were grown in a temperature-controlled greenhouse.

In terms of total water consumption, in the V+CF and S+CF mixes maintained at 80 to 90%, WRC presented a total consumption of 12,234.70 and 12,129.35 mL water per plant, respectively. This finding demonstrates the importance of higher irrigation amounts for accumulating fresh matter and increasing desert rose plant growth, which is in line with the data shown in Table 5, as calculated based on the initial parameters for each plant.

For all evaluated plant growth-related parameters, analysis of variance shows a significant interaction between irrigation level and potting medium for caudex diameter, fresh weight of stems and roots, and volume of the root system. However, aerial part height was not influenced by irrigation, and the effect observed on the fresh weight of leaves was not significant (Table 6).

Aerial part height was greater in the V+CF mix, with an average increment of 29.48 cm over the experimental period (Table 5). Because this mix has the highest WRC (528 mL L^{-1}) of all the experimental mixes, plants were subjected to less water stress, and therefore growth was not affected even at an irrigation level of 60 to 70% WRC. Coconut fiber is recommended for growing potted desert rose plants, whether alone or mixed with inorganic materials, due to its high moisture retention and rapid drainage (Dimmitt; Joseph; Palzkill, 2009).

For the caudex diameter, interaction was noted between irrigation level and the potting medium, as evidenced by the V+CF mix maintained at 80-90% WRC, with an average increment of 38.40 mm. In comparison, the S+CF mix, irrespective of the irrigation level, showed average caudex diameter growth of 33.76 mm, with no statistical difference from the V+CF mix maintained at 80-90% WRC. However, with the S+L mix maintained at the same irrigation level, the average increase in the caudex diameter was 20.42 mm (Table 5). This shows that the potting medium directly influenced this variable. Similar results were described by Colombo et al. (2016), in which the desert rose plants cultivated in these substrates presented caudex grown and build-up of nutrients higher than the other potting media.

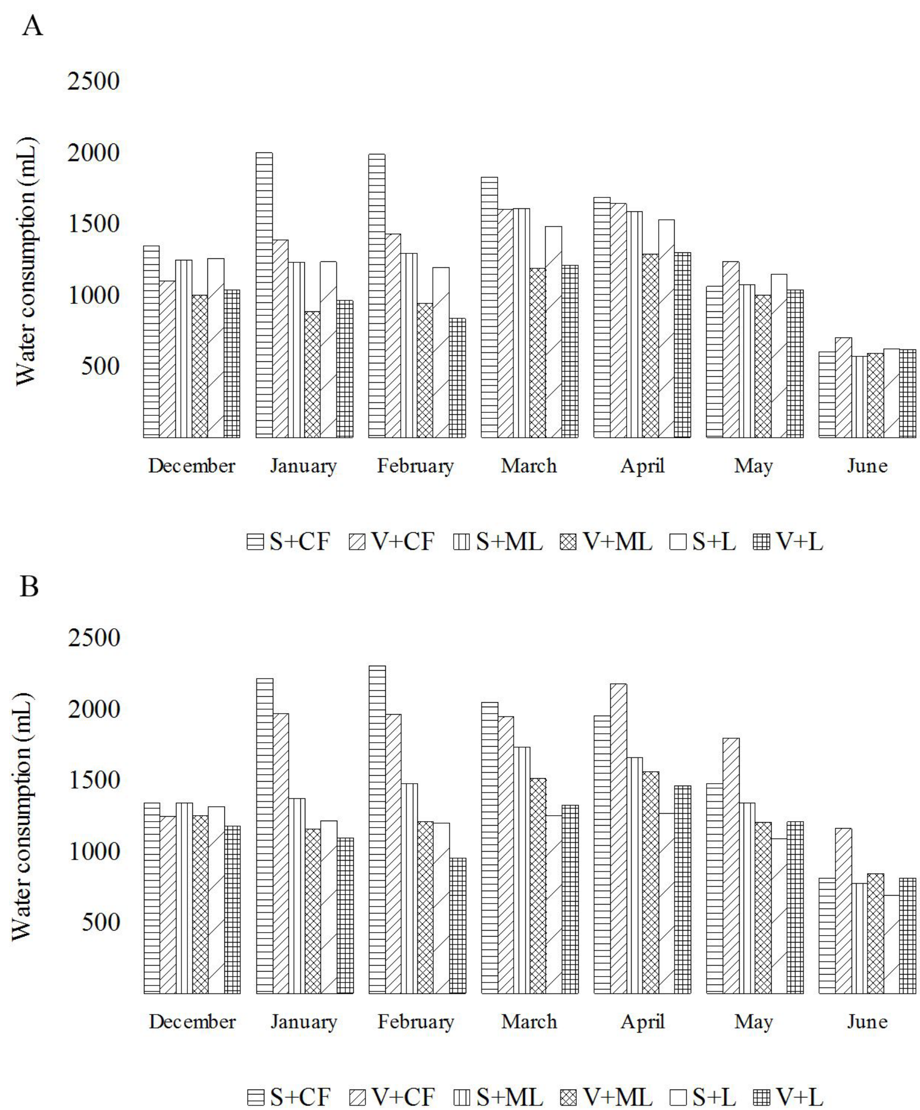

Figure 2: Average monthly water consumption (mL) by *Adenium obesum* plants at 210 days, grown in pots containing the following potting media: sand + Amafibra® 47 coconut fiber (S+CF), sand + Lupa® (S+L), sand + modified Lupa® (S+ML), vermiculite + Amafibra® 47 coconut fiber (V+CF), vermiculite + Lupa® (V+L) and vermiculite + modified Lupa® (V+ML) at two irrigation levels: 60 to 70% (A) and 80 to 90% (B) of potting medium water retention capacity (WRC).

Table 5: At 210 days, an average growth of *Adenium obesum in pots* containing potting media kept at two irrigation levels: 60 to 70% and 80 to 90% of potting medium water retention capacity (WRC).

[z]Substrate	Aerial part height (cm)			Caudex diameter (mm)		
	WRC 60-70%	WRC 80-90%	Mean	WRC 60-70%	WRC 80-90%	Mean
S+CF	19.48	24.22	21.85 b[y]	35.28 aA	32.25 abA	33.76
V+CF	29.25	29.72	29.48 a	27.99 aB	38.40 aA	33.20
S+ML	18.28	23.40	20.84 b	28.57 aA	24.66 bcA	26.62
V+ML	19.45	18.47	18.96 b	28.82 aA	22.85 bcA	25.83
S+L	18.92	21.30	20.11 b	25.62 abA	20.42 cA	23.03
V+L	19.83	22.12	20.97 b	17.36 bB	30.20 abcA	23.78
Mean	20.87 A	23.20 A		27.28	28.13	
CV (%)	28.35			21.35		

Substrate	Plant fresh weight (g)		
	WRC 60-70%	WRC 80-90%	Mean
S+CF	450.55 aA	413.24 bA	431.9
V+CF	407.72 abB	528.42 aA	468.07
S+ML	319.68 bcA	323.74 bcA	321.71
V+ML	297.79 cA	313.57 cA	305.68
S+L	311.69 bcA	248.93 cA	280.31
V+L	264.85 cB	336.74 bcA	300.79
Mean	342. 04	360.77	
CV (%)	16.09		

[z]Sand + Amafibra® 47 coconut fiber (S+CF), sand + Lupa® (S+L), sand + modified Lupa® (S+ML), vermiculite + Amafibra® 47 coconut fiber (V+CF), vermiculite + Lupa® (V+L) and vermiculite + modified Lupa® (V+ML). [y]Different lower case letters in the columns and upper case letters on the row for each variable showed a difference in Tukey's test at a 5% probability level.

Table 6: Phytometric parameters evaluated at 210 days in potted *Adenium obesum* in potting media kept at two irrigation levels: 60 to 70% and 80 to 90% of the potting medium water retention capacity (WRC).

[z]Substrate	Aerial part height (cm)			Caudex diameter (mm)		
	WRC 60-70%	WRC 80-90%	Mean	WRC 60-70%	WRC 80-90%	Mean
S+CF	31.33	36.58	33.96 ab[y]	64.34 aA	59.64 abA	61.99
V+CF	40.83	42.50	41.67 a	55.49 abB	67.10 aA	61.30
S+ML	30.75	36.08	33.42 b	56.94 aA	53.00 bcA	54.97
V+ML	31.33	30.17	30.75 b	56.43 aA	52.61 bcA	54.52
S+L	30.58	34.37	32.47 b	55.92 aA	47.25 cB	51.58
V+L	31.83	34.42	33.12 b	44.65 bB	56.27 abcA	50.46
Mean	32.78 A	35.69 A		55.63	55.98	
CV (%)	18.82			11.65		

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Table 6: Continuation...

Substrate	Leaves fresh weight (g) ns			Stem fresh weight (g)		
	WRC 60-70%	WRC 80-90%	Mean	WRC 60-70%	WRC 80-90%	Mean
S+CF	30.39	38.73	34.56	322.38 aA	218.89 abB	270.63
V+CF	37.17	43.40	40.29	276.79 abA	242.24 aA	259.52
S+ML	34.57	32.71	33.64	204.56 cdA	165.70 bcA	185.13
V+ML	34.52	34.45	34.49	176.53 cdA	167.14 bcA	171.83
S+L	34.24	32.46	33.35	207.73 bcA	137.48 cB	172.60
V+L	30.60	37.50	34.05	134.53 dA	182.34 abcB	158.43
Mean	33.58	36.54		220.42	185.63	
CV (%)	22.33			20.68		
Substrate	Root fresh weight (g)			Root volume (mL)		
	WRC 60-70%	WRC 80-90%	Mean	WRC 60-70%	WRC 80-90%	Mean
S+CF	136.02 aB	191.27 bA	163.64	131.17 aB	190.83 bA	161.00
V+CF	127.86 aB	278.05 aA	202.96	126.67 aB	276.67 aA	201.67
S+ML	118.61 aB	166.16 bcA	142.39	117.67 aB	165.83 bcA	141.75
V+ML	124.67 aA	154.87 bcA	139.77	123.33 aA	155.83 bcA	139.58
S+L	113.86 aA	116.73 cA	115.30	109.67 aA	117.83 cA	113.75
V+L	136.37 aA	151.32 bcA	143.64	132.50 aA	151.17 bcA	141.83
Mean	126.23	176.40		123.50	176.36	
CV (%)	27.08			27.17		

[z]Sand + Amafibra® 47 coconut fiber (S+CF), sand + Lupa® (S+L), sand + modified Lupa® (S+ML), vermiculite + Amafibra® 47 coconut fiber (V+CF), vermiculite + Lupa® (V+L) and vermiculite + modified Lupa® (V+ML). [y] Different lower case letters in the columns and upper case letters on the row for each variable showed a difference in Tukey's test at a 5% probability level. ns: not significantly different.

The V+CF mix maintained at 80-90% WRC also had a positive effect on root system growth, expressed in terms of increased fresh matter and root volume. It is likely that the low density of this medium (136.67 g $L^{-}1$) offered less physical resistance to root system growth. In addition, the roots were able to spread through a higher volume of potting medium and absorb more water and nutrients. Colombo et al. (2016) observed the best growth rates for desert roses in the same substrate.

Other mixes with low dry densities, consisting of organic and inorganic materials, are also used for growing the desert rose. These include 65% peat + 20% perlite + 15% vermiculite (McBride et al., 2014). McLaughlin and Garofalo (2002) also recommend rooting desert rose seedlings in a mix of peat and perlite (1:3, v/v).

Furthermore, low-density potting media are ideal for commercially producing potted plants because lighter weight pots are easier to handle and to transport. Moreover, increments in caudex diameter and root systems, although slight, are important to the producer when it comes to marketing the product, since caudex and root growth affect the sculptural shapes of the desert rose and attract buyers' attention.

The pH values of the V+CF (6.11) and S+CF (5.83) potting media (Table 1) may also have influenced higher growth rates of plants grown in these mixes. According to Kämpf and Fermino (2000), the ideal pH range of a potting medium varies according to the species cultivated. However, a range of 5.0 to 6.5 can be considered to offer higher availability of the majority of nutrients.

With regard to flowering, desert rose flowers between 8 and 12 months after sowing, depending on growing conditions (Dimmitt; Joseph; Palzkill, 2009). Table 7 indicates the times at which the first inflorescences were produced by different treatments. Plants grown in the S+CF and V+CF mixes produced inflorescences, irrespective of the irrigation level. However, earlier flowering was observed in plants grown in these mixes at an irrigation level of 60-70% of the WRC, for which the first flowers were produced in February. In contrast, for plants grown at an irrigation level of 80-90% of the WRC, flowering did not begin until March. Further studies to evaluate the relationship between irrigation levels and flowering are necessary. It is likely that flowering time can be controlled by irrigation frequency, and this allows production and sales to stagger.

Table 7: Flowering of *Adenium obesum* over the 210-day growth period in pots containing potting media kept at two irrigation levels: 60 to 70% and 80 to 90% of potting medium water retention capacity (WRC).

[z]Substrate	WRC 60-70%		WRC 80-90%	
	NPI[y]	MIP[x]	NPI	MIP
S+CF	6	February-April	6	March
V+CF	5	February-April	6	March-April
S+ML	2	April-May	2	April
V+ML	2	April	3	April-May
S+L	1	April	1	May
V+L	2	April	2	April

[z]Sand + Amafibra® 47 coconut fiber (S+CF), sand + Lupa® (S+L), sand + modified Lupa® (S+ML), vermiculite + Amafibra® 47 coconut fiber (V+CF), vermiculite + Lupa® (V+L) and vermiculite + modified Lupa® (V+ML). [y]NPI: number of plant with inflorescences. [x]MIP: month of inflorescence production.

At both irrigation levels, in addition to delaying the production of inflorescences, the other mixes induced lower flowering in plants cultivated under these conditions and in the time period evaluated. However, despite producing less significant growth increments and flowers in desert rose plants, these mixes can be used for growing the species, provided that in the producer region, availability and the cost of materials justifies their use.

With regard to the irrigation level, conditions of higher water stress may encourage flowering in this species because plants maintained at an irrigation level of 60-70% WRC, and especially those grown in S+CF and V+CF, flowered earlier.

CONCLUSIONS

Mixes of vermiculite + coconut fiber and sand + coconut fiber can be used for growing potted desert roses if irrigation levels are maintained at 60-70% and 80-90% of the water retention capacity of the potting media. Desert rose plants cultivated in S+CF and V+CF and maintained at an irrigation level of 60-70% of the WRC can flower earlier than other plants.

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