Substrates and fertilizations in the initial growth of the desert rose[1]

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ABSTRACT

The desert rose (*Adenium obesum*) has been highlighted in the internal market, however there are not many studies related to its demands regarding its nutrition and substrates. The aim of this study was to evaluate the effect of different fertilizations and its interactions with different substrates in the initial growth of the desert rose. The seedlings of desert rose with 60 days have been potted transplanted with a capacity of 0.415 L, filled with two kinds of substrates: sand + coconut fiber and sand + composted pine powder. Four different fertilization managements have been done: without fertilization, application of the Hoagland & Arnon nutrient solution; application of NH_3NO_4 at 590 g L^{-1} of nitrogen (N); and the application of the Hoagland & Arnon nutrient solution modified through the addition of NH_3NO_4, increasing the concentration of N to 800 g L^{-1}. The solutions have been applied biweekly adding 50 mL per pot. The experiment has been entirely randomized in a 2x4 factorial design, with 10 repetitions. After 150 days from the beginning of the fertilizations the phytometrical parameters evaluated were: height of the shoot; diameter of the basal caudex; number of shoots; dry mass of the roots, caudex and leaves; and determination of the levels and accumulation of macronutrients in the shoot, and the pH and electrical conductivity of the substrates. The evaluated data have been submitted to an analysis of variance and the Tukey test compared through the test at 5% of error probability. For all the evaluated parameters, when the composted pine mixture was used, the seedlings showed a higher development compared to coconut fiber mixture. The seedlings had a better performance with the modified Hoagland solution for height, number of shoots, caudex diameter and leaf dry mass in both substrates. The use of the sand + pine powder (1:1 v v^{-1}) and the fertilization with Hoagland & Arnon solution combined with the NH_3NO_4 solution provided a better initial growth on the desert rose.

Keywords: *Adenium obseum,* nutrition, ornamental.

RESUMO

Substratos e fertilizações no crescimento inicial de rosa do deserto

A rosa do deserto (*Adenium obesum*) tem se destacado no mercado interno, no entanto não existem muitos estudos relacionados às suas exigências quanto à nutrição e substratos. O objetivo deste estudo foi avaliar o efeito de diferentes fertilizações e suas interações com diferentes substratos no crescimento inicial de rosa do deserto. As mudas de rosa do deserto com 60 dias foram transplantadas para vasos com capacidade de 0,415 L, preenchidos com dois tipos de substrato: areia + fibra de coco e areia + pó de pinus compostado. Foram realizados quatro diferentes manejos de fertilização: sem fertilização, solução nutritiva de Hoagland e Arnon; aplicação de NH_3NO_4 na concentração de 590 mg L^{-1} de nitrogênio (N); e aplicação da solução nutritiva de Hoagland & Arnon modificada pela adição de NH_3NO_4, elevando a concentração de N para 800 mg L^{-1}. As soluções foram aplicadas quinzenalmente adicionando 50 mL por vaso. O delineamento experimental foi inteiramente casualizado em esquema fatorial 2x4, com 10 repetições. Após 150 dias do início das fertilizações foram avaliados as seguintes variáveis fitométricas: altura da parte aérea; diâmetro basal do cáudice; número dos ramos; massa seca de raízes, cáudice e folhas; e determinação dos teores e acúmulo de macronutrientes da parte aérea, dos substratos foram avaliados o pH e condutividade elétrica. Os dados foram submetidos à análise de variância com posterior comparação de médias pelo teste de Tukey a 5% de probabilidade de erro. Para todas as variáveis fitométricas avaliadas os tratamentos contendo a mistura de areia + pó de pinus compostado, apresentaram maior desenvolvimento de mudas comparado a utilização de areia + fibra de coco. As mudas apresentaram melhor desempenho com a solução de Hoagland modificada para a altura, número de brotos, diâmetro de cáudice, e massa seca de folha em amos os substratos. O uso do substrato areia + pó de pinus e a fertilização com solução de Hoagland e Arnon combinada com solução de NH_3NO_4, proporcionou melhor crescimento inicial em rosa do deserto.

Palavras-chave: *Adenium obesum*, nutrição, ornamental.

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1. INTRODUCTION

Many quality aspects of the ornamental species, such as plant height, shape and color are influenced directly by mineral nutrition. However, the nutritional demands of the ornamental species are not yet well established, resulting in the ineffective use of fertilizers, without respecting the requirements of each specie, as well as the adequate application timing. This lack information results in products with low quality and elevated production costs, which justifies the importance of the nutritional studies in ornamental plants (NETO et al., 2015).

The desert rose (*Adenium obesum*: Apocynaceae) has been noticed in the national market, in the last years, for showing rusticity, variated sculptural shapes and intense flowering (COLOMBO et al., 2016). Nevertheless, there are few studies in the literature about its mineral nutrition. McBride et al. (2014) describes that nitrogen (N) is the element with higher total content in the desert rose plants, followed by potassium, calcium, magnesium and phosphor, however to Colombo et al. (2016) the most absorbed nutrient by the desert rose is potassium (K), followed by N.

Among the nutrients, the N is highlighted for being related to physiological processes like as the breathing, developing and root activity (TAIZ and ZEIGER, 2009). In many production systems, the availability of N is almost always a limiting factor, influencing the plant growth more than any other nutrient (FERNANDES, 2006).

Besides the mineral nutrition, the substrate is another important issue to consider, since that desert roses are cultivated in pots containing substrates that can influence the development, the distribution of dry mass and the nutrient contents in the plants depending on the physical and chemical features of the substrates (LUDWIG et al., 2015). In its turn, these features can be altered by the different fertilizer management, which modifies the substrate mineralization and the nutrients availability (JACKSON et al., 2009).

The aim of this study was to evaluate the effect of different fertilizations and its interactions with distinct substrates in the initial growth of the desert rose.

2. MATERIAL AND METHODS

The experiment has been conducted in a Van der Hoeven®, acclimatized greenhouse, covered with polycarbonate plates, with 50% of luminous retention and internal temperature control, varying between 28 ± 3 °C between October of 2014 to february of 2015.

Seeds of desert rose were germinated in polystyrene trays with 128 cells, containing commercial substrate (Lupa) composed by pine powder, and received only manually irrigation twice a day. Sixty days from the seeding, the seedlings containing the following characteristics: height of the shoot (2.2 cm ± 0.3), caudex diameter (0.5 cm ± 0.1) and dry mass (0.07 g ± 0.02) have been transplanted in a black polypropylene pots with a capacity of 0.415 L, filled with two kinds of substrates in mixture with sand of medium granulometry, being: sand + coconut fiber (S+C) and sand + composted pine powder (S+P), in the proportion of 1:1 (v v^{-1}).

The mixtures of the substrates used showed the following characteristics: dry density (DD), water retention capacity (WRC), pH and electrical conductivity (EC), determined according to the methodology proposed by Kämpf et al. (2006) (Table 1).

Table 1. Characterization of the substrate properties: dry density (DD), water retention capacity (WRC), pH in water and electrical conductivity (EC).

*Substrate	DD (g L^{-1})	WRC (mL L^{-1})	pH H_2O	EC (mS cm^{-1})
S+C	838.00	497.33	5.78	2.43
S+P	1042.00	460.67	7.23	1.25

*Sand + coconut fiber (S+CF), sand + composted pine powder (S+P).

Four different fertilization managements were carried out: without fertilization, application of nutritive Hoagland and Arnon solution 2 (1950); application of 590 mg L^{-1} N from the dilution of NH_3NO_4 in water; and the application of the modified Hoagland & Arnon nutritive solution by adding NH_3NO_4, increasing the N concentration to 800 mg L^{-1}. The solutions were applied biweekly adding 50 ml of each solution per pot. The irrigation was done daily, manually, applying 4 mm of water in each irrigation, except on the fertilization days.

Altogether for the conduction of the experiment, 80 plants have been used, being the design completely randomized in a 2x4 factorial scheme, considering: two substrates, coconut fiber (S+C) and composted pine powder (S+P) and four fertilization managements, without fertilization (C), Hoagland & Arnon solution (HA), solution of NH_3NO_4 (N) and modified Hoagland & Arnon solution (HA+N), constituting eight treatments at all. Each treatment was composed of 10 repetitions, being one pot containing one plant, considered as an experimental unity.

After 150 days the plants have been removed from the pots and the roots washed in running water for the removal of adhered substrate, afterwards these were sectioned in roots and shoot, of which the leaves were also separated. The different tissues were washed with distilled water for further evaluation of the following phytometric parameters: height, caudex basal diameter, number of shoots, dry mass of the roots, caudex and leaves; and determination of the contents and accumulation of macro nutrients in the shoot. In the substrates, the electrical conductivity (EC) and the pH were evaluated.

The plant's height was measured, from the plant's base up to the top of the highest branch, the basal diameter was obtained, measuring the diameter on the caudex base, the number of shoots per plant was obtained by counting, the dry mass of the roots, caudex and leaves was obtained after drying the tissues in a forced ventilation oven at 55 °C until achieving constant mass and further weighting in an analytical scale, with a precision of 0.001g.

From the dry tissues of leaves and caudex, the contents and accumulation of macro nutrients have been determined. The samples have been ground, in an analytical mill model A11 IKA® and the contents of nitrogen (N), phosphor (P), potassium (K), calcium (Ca), magnesium (Mg) were quantified according to Malavolta et al. (1997).

The determination of pH and electrical conductivity were carried out according to the method described by Abreu et al. (2007), by the method of 1:2 (v v^{-1}) extraction of substrate and deionized water, a pH meter and a conductivity meter was used for reading. The evaluated data were submitted to an analysis of variance and the means compared through the Tukey test at 5% of error probability.

3. RESULTS AND DISCUSSION

The substrate containing composted pine powder (S+P), promoted significantly higher increases for all phytometric variables than coconut fiber (S+C). In average values each substrate varied from 9.19 cm to 13.59 cm for height, 0.83 to 1.50 for the number of shoots, 2.62 cm to 3.35 cm for the caudex diameter, 1.58 to 2.75 for caudex dry mass, 0.39 g to 0.79 g for leaves dry mass and 1.04 g to 1.23 g for roots dry mass, when the respective substrates S+C and S+P were compared (Table 2).

Table 2. Phytometric development of desert rose, cultivated in different substrates and fertilizations

		Height (cm)	Shoots (nº)	Diameter (cm)	CDM[3]	LDM	RDM
					(g)		
	C[2]	4.58 c[4]	0.30 b	1.41 d	0.50 c	0.05 c	0.15 c
	HA	5.66 c	0.40 b	2.11 c	0.98 c	0.65 a	0.54 b
S+C[1]	N	10.32 b	0.60 b	2.76 b	2.08 b	0.30 b	1.70 a
	HA+N	16.20 a	2.00 a	4.21 a	2.75 a	0.50 a	1.77 a
	Average	9.19 B	0.83 B	2.62 B	1.58 B	0.39 B	1.04 B
	C	8.05 d	0.70 b	2.59 b	1.59 b	0.34 c	0.55 c
	HA	10.87 c	0.80 b	2.70 b	1.41 b	0.33 c	1.23 b
S+P	N	14.22 b	2.10 a	4.09 a	4.04 a	0.84 b	1.49 ab
	HA+N	21.20 a	2.40 a	4.00 a	3.96 a	1.63 a	1.63 a
	Average	13.59 A	1.50 A	3.35 A	2.75 A	0.79 A	1.23 A
	CV(%)	9.29	15.25	9.48	22.61	21.51	29.51

[1]Substrates: sand + coconut fiber (S+C); sand + pine powder (S+P). [2]Fertilizations: absent/control (C); Hoagland and Arnon solution (HA); solution of NO_3NH_4 (N); modified Hoagland and Arnon solution (HA+N). [3]Caudex dry mass (CDM); leaf dry mass (LDM); roots dry mass (RDM). [4]The same capital letter between groups and lower-case letters within each group did not differ by the Tukey test at 5% of error probability.

The results found in this study differ from those reported by Colombo et al. (2016), for the authors the mixture of sand and coconut fiber as substrate is recommended in desert rose cultivation. This divergence lies in the fact that coconut fiber used in the experiments was from different manufacturers. That way, the chemical features can change depending on where the coconut is cultivated (EVANS et al., 1996).

Interactions between the substrates and fertilization management were observed. However, the ammonium nitrate solution (N) or its combination with the Hoagland and Arnon solution (HA+N) were the treatments with the higher averages for all variables, in comparison to the control in both substrates (Table 2).

On S+C, the fertilization with (HA+N) was the highlight treatment, because it presented higher growth than the other fertilizations, for almost all variables. In this configuration, the treatment had: 16.20 cm of height, 2.00 shoots, 4.21 cm of caudex diameter, 2.75 mg caudex dry mass, 0.50 mg leaves dry mass, and 1.77 mg root dry mass (Table 2).

For the S+P substrate, the (N) and (HA+N) fertilizations were the best treatments. Were verified that these treatments had on average: 14.22 cm and 21.20 cm height, 2.10 and 2.40 shoots, 4.09 cm and 4.00 cm caudex diameter, 4.04 mg and 3.96 mg caudex dry mass, 0.84 mg and 1.63 mg leaf dry mass and 1.49 mg and 1.63 mg root dry mass for the treatments (N) and (HA+N) respectively (Table 2).

On the S+P substrate, the (HA+N) treatment was superior to the (N) treatment, for the height and leaf dry mass, but for all another growth variables, the performance between the fertilization managements was similar. However, on the S+C substrate, the (HA+N) was higher than (N) for the most of phytometric variables evaluated, except for dry root mass (Table 2).

The superiority of the (HA+N) over then (N) fertilization on the S+C substrate, is due to the complete nutrient supply, not only N. The deficiency of any nutrient is limiting to the plants' growth, law of minimum (MALAVOLTA, 2006), thus on S+C substrate, a balanced fertilization is essential to attend nutritional needs, making itself necessary to turn viable the coconut fiber substrate use (MATTOS et al., 2015).

In bromeliads, the fertilization with N and K results in leaf number gains, only when coconut fiber and cattle manure are mixed, however, when coconut fiber is used without mixing, the fertilization with N and K have no any effect on growth, although it increases the foliar contents of these nutrients (AMARAL et al., 2009).

The growth also presented significant correlations with the contents of N, K, Ca, and Mg. The N showed positive correlations for height (0.67), caudex diameter (0.59), roots (0.52), shoot (0.45) and total dry mass (0.52). On the other hand, for Ca, the correlations were negatives for height (-0.69), caudex diameter (-0.76), roots (-0.66), shoot (-0.70) and total dry mass (-0.75) (Table 3). In addition, among nutrients, the N was negatively correlated with Ca (-0.54) and Mg (-0.46) (Table 3). As the N is a proteins and enzymes constituent, this nutrient can be considered as one the most important in carbon fixation (TEGEDER and MASCLAUX-DAUBRESSE, 2018), thus, in (N) and (HA+N) treatments, the N supply increased the dry mass accumulations, which led to a relative dilution in the Ca and Mg contents, and consequently in negative correlations between the vegetative growth variables with Ca and Mg.

Table 3. Pearson correlations for nutrients contents and phytometric characteristics of desert rose, cultivated in different substrates and fertilizations.

	N	P	K	Ca	Mg	RDM	SDM	TDM	Height	DC
N	1.00	0.01	0.00	-0.54	-0.46	0.52	0.45	0.52	0.67	0.59
P	ns	1.00	0.29	0.25	0.01	-0.29	-0.29	-0.32	-0.08	-0.17
K	ns	ns	1.00	-0.31	-0.22	0.20	0.49	0.44	0.40	0.40
Ca	**	ns	ns	1.00	0.63	-0.66	-0.70	-0.75	-0.69	-0.76
Mg	**	ns	ns	**	1.00	-0.55	-0.38	-0.47	-0.41	-0.54
RDM	**	ns	ns	**	**	1.00	0.59	0.78	0.61	0.67
SDM	**	ns	**	**	**	**	1.00	0.97	0.83	0.84
TDM	**	ns	**	**	**	**	**	1.00	0.84	0.87
Height	**	ns	**	**	**	**	**	**	1.00	0.84
DC	**	ns	**	**	**	**	**	**	**	1.00

*Significant to 5% of probability; ** Significant to 1% of probability; ns: Non-significant. RDM = Roots dry mass; SDM = Shoot dry mass; TDM = Total dry mass; DC = Caudex diameter.

The reduction in nutrient contents due to mass gains is known as the dilution effect (RIEDELL, 2010). This phenomenon, associated with negative correlations between N and Ca, was also observed by Colombo et al. (2016), studying different substrates in desert roses.

For the leaves nutrient contents, the desert roses had lower contents of P (5.24 g kg^{-1}) and K (27.58 g kg^{-1}) in the substrate S+C, than in relation to the substrate S+P, which obtained 6.20 g kg^{-1} of P and 38.78 g kg^{-1} of K. These results indicate that the pine powder presented greater availability of P and K than coconut fiber (Table 4).

Table 4. Nutrients contents of desert rose leaves cultivated in different substrates and fertilizations.

		N[3]	P	K	Ca	Mg
		---------------------------g kg^{-1}---------------------------				
	C[2]	16.05 c[4]	5.40 a	23.70 b	37.51 a	3.55 a
	HA	18.34 c	5.60 a	32.74 a	14.06 b	2.49 b
S+C[1]	N	24.76 b	4.07 a	25.53 b	13.07 ba	2.40 b
	HA+N	36.13 a	5.89 a	28.35 ab	5.83 c	1.84 b
	Average	23.82 A	5.24 B	27.58 B	17.62 A	2.57 A
	C	20.51 b	7.67 a	39.83 a	24.17 a	2.62 a
	HA	21.13 b	7.10 ab	36.05 a	18.84 a	2.60 a
S+P	N	19.40 b	4.75 c	38.98 a	8.10 b	2.31 a
	HA+N	29.10 a	5.29 bc	40.25 a	7.31 b	2.32 a
	Average	22.53 A	6.20 A	38.78 A	14.61 B	2.46 A
	CV(%)	13.0	18.6	11.2	27.0	23.3

[1]Substrates: sand + coconut fiber (S+C); sand + pine powder (S+P). [2]Fertilizations: absent/control (C); Hoagland & Arnon solution (HA); solution of NO_3NH_4 (N); modified Hoagland & Arnon solution (HA+N). [3]Nitrogen (N); phosphor (P); potassium (K); calcium (Ca); magnesium (Mg). [4]The same capital letter between groups and lower-case letters within each group did not differ by the Tukey test at 5% of error probability.

The nutrient availability is related to the cations exchange capacity (CEC) of the substrates. As the pine powder is mainly composed of cellulose and hemicellulose (ARGUM et al., 2009), which in turn have carboxyl radicals (COOH) in their structures, the cations adsorption occurs on negative charges produced by the dissociation of COOH in COO- (KERBAUY, 2012). The CEC of pine powder varies from 33 to 216 $mmol_c$ dm^{-3}, depending on the granulometry (ALTLAND et al., 2014), and can be considered higher than the coconut fiber which presents around 34 $mmol_c$ dm^{-3}.

Not only the substrate but also the fertilization promoted changes in the leaf nutrient contents. Considering that the N provided by the treatments were: 0 mg L^{-1} (C), 210 mg L^{-1} (HA), 590 mg L^{-1} (N) e 800 mg L^{-1} (HA+N), were observed N accumulations in the treatments N (24.76 g kg^{-1}) and HA+N (36.13 g kg^{-1}) in the S+C substrate. However, for the S+P substrate, only the HA+N treatment (29.10 g kg^{-1}) differed from the control (20.51 g kg^{-1}) (Table 4).

Considering that the gains in leaf dry mass present a limit, the increases in the N content related to its supply were expected. However, these N content increases were less evident in the S+P, due the higher mass accumulation in this substrate; this phenomenon is known as Steenberg's effect (LARCHER, 2003). This way the N use efficiency was higher in S+P than S+C.

In addition, for the S+C substrate, the (N) and (HA+N) treatments reduced simultaneously the Ca and Mg leaf contents, but for the S+P only the Ca presented a significant reduction in relation to the control. The Ca content reduction was from 37.51 g kg^{-1} (C) to 5.83 g kg^{-1} (HA+N) in the S+C substrate, and for the S+P substrate the reduction was 24.17 g kg^{-1} (C) to 7.31 g kg^{-1} (HA+N) (Table 4).

A stronger Ca dilution in S+P was expected since its presented greater mass accumulation; however, the results show the opposite. The Ca dilution in S+P substrate was lower, even accumulating more mass. This result reinforces the hypothesis of the greater nutrients availability in S+P.

In the caudex, on average the P content was lower in the S+C (4.86 g kg^{-1}) than in the S+P substrate (6.97 g kg^{-1}). And among the fertilization treatments, a K contents dilution was observed in the S+C substrate, from 30.92 g kg^{-1} (C) to 11.17 g kg^{-1} (HA+N). However, for the S+P substrate, the K levels variations between (C) and (HA+N) treatments were not significant, indicating sufficient supply of K (Table 5).

Table 5. Nutrients contents of desert rose caudex, cultivated in different substrates and fertilizations.

		N[3]	P	K	Ca	Mg
		---------------------------g kg-1---------------------------				
	C[2]	4.77 b[4]	4.19 b	30.92 ab	7.00 a	1.44 a
	HA	4.77 b	6.80 a	35.39 a	5.59 a	1.05 a
S+C[1]	N	6.23 b	1.94 c	23.77 b	4.72 a	1.39 a
	HA+N	15.76 a	6.52 a	11.17 c	5.91 a	1.43 a
	Average	7.88 A	4.86 B	25.31 A	5.81 A	1.33 A
	C	7.26 ab	7.95 a	36.83 a	5.42 a	1.75 a
	HA	7.67 ab	7.41 ab	14.37 b	7.22 a	1.43 ab
S+P	N	5.29 b	5.46 b	15.08 b	5.49 a	1.11 b
	HA+N	9.74 a	7.05 ab	34.52 a	5.41 a	1.92 a
	Average	7.49 A	6.97 A	25.20 A	5.88 A	1.55 A
	CV(%)	21.20	19.70	19.90	26.40	25.90

[1]Substrates: sand + coconut fiber (S+C); sand + pine powder (S+P). [2]Fertilizations: absent/control (C); Hoagland & Arnon solution (HA); solution of NO_3NH_4 (N); modified Hoagland & Arnon solution (HA+N). [3]Nitrogen (N); phosphor (P); potassium (K); calcium (Ca); magnesium (Mg). [4]The same capital letter between groups and lower-case letters within each group did not differ by the Tukey test at 5% of error probability.

In summary, the highest levels of P and K, associated with the highest mass gains in the S+P substrate, resulted in accumulations significantly higher than those observed in the S+C, for all evaluated nutrients and when the fertilization within each substrate was analyzed, the nutrient accumulations were higher in HA+N treatment in both substrates (Table 6).

In the S+C, the order of accumulated nutrients in HA+N treatment was: N (61.58 mg pot^{-1}) > K (45.04 mg pot^{-1}) > P (20.88 mg pot^{-1}) > Ca (19.20 mg pot^{-1}) > Mg (4.85 mg pot^{-1}). In the S+P, not only the amounts, but also the order of accumulated nutrients was altered, being in the treatment HA+N of: K (202.32 mg pot^{-1}) > N (86.01 mg pot^{-1}) > P (36.53 mg pot^{-1}) > Ca (33.34 mg pot^{-1}) > Mg (11.36 mg pot^{-1}) (Table 6).

Table 6. Nutrients accumulation in the shoot of desert rose cultivated in different substrates and fertilizations.

		N[3]	P	K	Ca	Mg
		---------------------------mg pot-1[1]---------------------------				
	C[2]	3.27 c[4]	2.40 c	16.82 b	5.57 c	0.92 c
	HA	16.61 c	10.28 b	55.85 a	14.62 b	2.65 b
S+C[1]	N	20.40 b	5.27 c	57.12 a	13.75 b	3.61 b
	HA+N	61.58 a	20.88 a	45.04 a	19.20 a	4.85 a
	Average	25.46 B	9.71 B	43.71 B	13.28 B	3.01 B
	C	18.43 c	15.21 c	71.89 c	16.73 c	3.66 c
	HA	17.81 c	12.80 c	32.20 d	16.42 c	2.88 c
S+P	N	37.65 b	26.01 b	93.58 b	28.96 b	6.40 b
	HA+N	86.01 a	36.53 a	202.32 a	33.34 a	11.36 a
	Average	39.97 A	22.64 A	100.00 A	23.86 A	6.08 A
	CV(%)	20.30	22.60	25.50	16.90	22.40

[1]Substrates: sand + coconut fiber (S+C); sand + pine powder (S+P). [2]Fertilizations: absent/control (C); Hoagland & Arnon solution (H); solution of NO_3NH_4 (N); modified Hoagland & Arnon solution (H+N). [3]Nitrogen (N); phosphor (P); potassium (K); calcium (Ca); magnesium (Mg). [4]The same capital letter between groups and lower-case letters within each group did not differ by the Tukey test at 5% of error probability.

The K and N inversion is the result of the interaction between fertilization and substrate, been this interaction already observed in the literature. For McBride et al. (2014) N is more accumulated than K, the inverse was reported by Colombo, et al. (2016). Our results indicated that, the K is the most demanded nutrient for a rapid rose desert growth.

The pH of the substrates varied between 5.31 (HA+N) to 5.83 (C) in the S+C and 5.95 (HA+N) to 6.76 (C) in the S+P. When seen the fertilization effects in S+P, was observed pH reductions, these reductions in the (N) and (HA+N) treatments, allowed fitting its pH in zone considered adequate for nutrient absorption. The ideal pH must be between at 5.0 to 6.5 in which there is a higher availability of most nutrients (Kämpf, 2000). Only the control on the S+P was out of this ideal pH zone (Table 7).

Table 7. Hydrogenionic potential (pH) and electrical conductivity (EC) of the distinct substrates of desert rose cultivated in different fertilizations after 150 days.

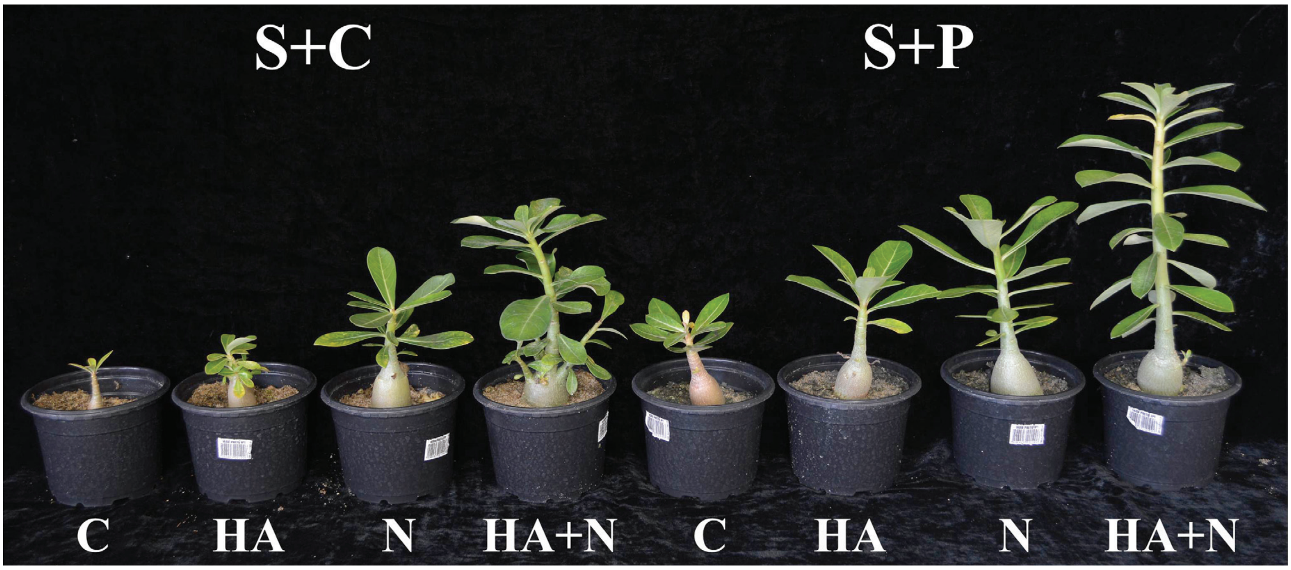
		[3]pH	EC (mS cm-1)
	C[2]	5.83 [4]a	1.92 a
	HA	5.66 a	2.15 a
S+C[1]	N	5.58 a	2.31 a
	HA+N	5.31 a	2.33 a
	Average	5.6 B	2.18 A
	C	6.76 a	1.06 b
	HA	6.49 a	1.54 a
S+P	N	6.02 b	1.87 a
	HA+N	5.95 b	2.01 a
	Average	6.31 A	1.62 B
	CV(%)	12.9	16.52

[1]Substrates: sand + coconut fiber (S+C); sand + pine powder (S+P). [2]Fertilizations: absent/control (C); Hoagland & Arnon solution (HA); solution of NO_3NH_4 (N); modified Hoagland and Arnon solution (HA+N). [3]Hydrogenionic potential (pH) and electrical conductivity (EC) of the distinct substrates of desert rose cultivated in different fertilizations after 150 days. [4]The same capital letter between groups and lower-case letters within each group did not differ by the Tukey test at 5% of error probability.

The electrical conductivity in the substrate S+C presented an average value of 2.18 mS cm^{-1}, higher than the 1.62 mS cm^{-1} found in S+P. Among the treatments, no significant differences were observed within of each substrate. Although values above 1.75 mS cm^{-1} been considered high salinity (TAKANE et al., 2013), in all evaluated treatments the plants grew without show any substrate salinization signs, such as the death of shoots, necrosis at the tip or edges of the leaves (Table 7).

Considering the lack of nutrients in the arid origin center of desert rose (Sahel regions of Africa) (McLAUGHLIN and GAROFALO, 2002), was expect less fertilization response, due its adaptability to these environments. However, the plants were highly responsive to fertilization. Thus, the adequate use of fertilizers and substrates is an important strategy to obtain high-quality plants in a shorter time.

The use of S+P was better than S+C as the substrate. The S+P resulted in better growth, with higher: height, number of shoots, mass and nutrients accumulation, in which its use combined with (HA+N) or (N) fertilizations, is suitable for the initial growth of desert rose. However, for S+C, the (HA+N) fertilization is necessary to increase the growth (Figure 1).



[2]Fertilizations: absent/control (C); Hoagland and Arnon solution (HA); solution of NO_3NH_4 (N); modified Hoagland and Arnon solution (HA+N). Substrates: sand + coconut fiber (S+C); sand + composted Lupa pine powder (S+L);

Figure 1. Initial growth of the seedlings, cultivated in different fertilizations and distinct substrates after 150 days.

4. CONCLUSIONS

The use of the sand + pine powder substrate (1:1 v v^{-1}) and the fertilization with the Hoagland & Arnon solution combined with the ammonium nitrate solution (590 g L^{-1}) are recommended for the initial growth of desert rose.

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AUTHORS CONTRIBUTIONS

G.A.C.A.: Creation of the idea, experiment installation and conduction at the greenhouse, laboratory analysis and data collection, statistical analysis of data, manuscript preparation. **R.T.H.:** Experiment installation and conduction at the greenhouse, laboratory analysis and data collection. **D.J.B.:** Laboratory analysis and data collection, manuscript preparation. **A.B.P.S.:** Laboratory analysis and data collection, manuscript preparation. **R.C.C.:** Orientation of the work, important suggestions incorporated to the work. **R.T.F.:** Orientation of the work, important suggestions incorporated to the work.

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