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Initial growth of forage cactus clones at different potassium fertilization levels

Crescimento inicial de clones de palma forrageira submetidos a níveis de adubação potássica

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Abstract
The objective was to evaluate the effect of different levels of potassium fertilization on the initial growth of forage cactus (*Nopalea cochenillifera* Salm Dyck) clones. The experiment lasted six months, arranged in a randomized block design, in a 5 x 2 factorial scheme, with five levels of potassium fertilization (0, 250, 500, 750, and 1,000 kg of K_2O ha^{-1}) and two forage cactus clones (Little Sweet and Giant Sweet), with four replicates. One cladode was planted per pot (experimental unit) with a capacity of 7 kg of soil (24 x 17 x 23 cm). During the experimental period, the plants' structural characteristics were evaluated, such as plant height and width, length, width, thickness, and perimeter of the cladode, as well as accounting for the number of total cladodes, and in order of appearance. At the end of the experiment, biomass was evaluated to determine the fresh matter (FM) and dry matter (DM) yield of the aerial part and the root system. After determining the DM, the potassium content in the plant tissues was determined. The data were submitted to ANOVA and, if necessary, to the Tukey test at a 5% significance level. The potassium fertilization and the forage palm clones did not exert influences based on the variables evaluated during the experimental conduction. Potassium fertilization does not influence the structural and productive characteristics and the potassium content in the *N. cochenillifera* clones' initial growth.
Keywords: *Nopalea cochenillifera;* potassium; semiarid.

Resumo
Objetivou-se avaliar o efeito de diferentes níveis de adubação potássica no crescimento inicial de clones de palma forrageira (*Nopalea cochenillifera* Salm Dyck). O experimento foi conduzido durante seis meses, disposto em delineamento em blocos ao acaso, em esquema fatorial 5x2, sendo cinco níveis de adubação potássica (0, 250, 500, 750 e 1000 Kg de K_2O ha^{-1}) e dois clones de palma forrageira (Doce Gigante e Doce Miúda), com quatro repetições. Foi plantado um cladódio por vaso (unidade experimental) com capacidade para 7 kg de solo (24 x 17 x 23 cm). Ao longo do período experimental, foram avaliadas as características estruturais das plantas, tais como altura e largura de planta, comprimento, largura, espessura e perímetro de cladódio, bem como contabilização do número de cladódios total e por ordem de surgimento. Ao final do experimento avaliou-se a biomassa, para determinação do rendimento de massa fresca (MV) e seca (MS) da parte aérea e do sistema radicular. Após a determinação de MS, determinou-se o teor potássico nos tecidos vegetais. Os dados foram submetidos a ANOVA e, caso necessário, ao teste de Tukey a 5% de significância. A adubação potássica e os clones de palma forrageira não exerceram influências significativas nas variáveis avaliadas durante a condução experimental. A adubação potássica não influencia as características estruturais, produtivas e teor potássico no crescimento inicial de clones de *Nopalea cochenillifera.*
Palavras-chave: *Nopalea cochenillifera;* potássio; semiárido.

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Introduction

In a semi-arid environment, forage production becomes a major challenge since the climatic characteristics of these regions promote great productive instability, mainly associated with high air temperatures, low rainfall, and spatio-temporal variability[1]. Thus, it is essential to use crops adapted to such conditions and the use of appropriate management (e. g. fertilization) to obtain high productive yields[2–3].

Among the species adapted to the climatic conditions of these regions, the forage cactus stands out due to its ability to adapt through physiological, anatomical, and structural changes when subjected to conditions of severe water deficit[4–6]. This plant has Crassulacean acid physiological metabolism (CAM), tolerating high air temperatures and presenting high water use efficiency[6], in addition to high digestibility and acceptability by animals, with high levels of soluble carbohydrates and high levels of water in their cladodes, serving both as a food and water source[2,4,19].

Fertilization use becomes an indispensable management technique for increasing crop yields since plants extract nutrients from the soil to meet their needs throughout their development[1]. Thus, the adoption of this practice provides a greater possibility of achieving the system's sustainability[7].

Among the numerous minerals that the plant needs, potassium (K) is considered one of the most important owing to the essential functions it performs, such as participation in the osmotic process, protein synthesis, and pH control, also acting in the process of opening and closing of stomata[8]. Its deficiency causes permanent and irreversible damage, such as reduced plant growth[8].

According to Silva et al.[9], K is the macronutrient most absorbed by forage cactus, being extremely important in its development. According to soil analysis, Santos et al.[10] observed that a nitrogen fertilization with 100 kg N ha^{-1} associated with K application could provide a 100% increase in phytomass production.

In view of the above, the research hypothesis is that choosing the appropriate level of potassium fertilization associated with the forage cactus clone increases the phytomass productivity of the crop. Thus, the objective was to evaluate the effect of different levels of potassium fertilization on the initial growth of *Nopalea cochenillifera* clones in a semi-arid environment.

Material and methods

The experiment was conducted in the field, from June to December 2018, at the Universidade Federal Rural de Pernambuco (UFRPE), in the municipality of Serra Talhada –PE, Brazil (07º 59' 31" S, 38º 17' 54" W, at an elevation of 429 m).

According to the Köppen classification, the climate regime of the region is a BSwh', with the rainy season occurring during the summer, beginning in December and ending in April[11], with minimum and maximum air temperatures ranging from 20.1 to 32.9 ºC, respectively, relative air humidity around 63% and historical average annual rainfall of 642 mm[12].

The soil used in the experiment, classified as an inceptisol, was collected from the surface layer (0 to 20 cm), later crushed and homogenized, then sieved (2 mm mesh), and placed in pots with a capacity of 7 kg of soil (24 x 17 x 23 cm). Soil chemical attributes were determined and are shown in Table 1.

Table 1. Chemical characteristics of an inceptisol, in the municipality of Serra Talhada – PE, Brazil

Depth (m)	Chemical Atributes								
	pH	P	K	Na	Ca	Mg	CTC	OM	V
		mg dm^{-3}	cmol$_c$ dm^{-3}						%
0 – 0.20	7.2	40	0.45	0.06	5.3	1.1	8.14	1.24	84.89

pH - hydrogen potential, P - phosphor, K - potassium, Na - sodium, Ca - calcium, Mg - magnesium, CTC – cation exchange capacity, MO – organic matter, V – base saturation.

The research was carried out in a randomized block design, under a 5 x 2 factorial scheme, with potassium in five doses (0, 250, 500, 750, and 1,000 kg of K_2O ha^{-1}) and two forage cactus clones (Little Sweet and Giant Sweet) of the species *Nopalea cochenillifera* Salm Dyck, with four replications. The cladodes used were taken from the middle third of plants, approximately three years old, from the experimental area of the university. After the cladodes had healed, they were planted on 07/01/2018, with 50% of their length buried in the soil present in the pot (experimental unit). The culture received a fixed irrigation depth, with 1 L/vase being applied, with an interval of two days, throughout the testing period.

On 07/31/2018, 30 days after planting (DAP), potassium levels and a dose of nitrogen (100 kg/ha^{-1}) were applied in all treatments. Nitrogen fertilization was repeated three times, at 60, 90, and 120 DAP, totaling 400 kg of N ha^{-1}. KCl and urea were used as sources of K and N, respectively. It should be noted that no organic fertilizer was used in the test.

During the experimental period, some environmental variables were monitored from the automatic meteorological station belonging to the Instituto Nacional de Meteorologia (INMET, www.inmet.gov.br), located 300 meters from the experimental area, to obtain data on air temperature (°C), relative air humidity (%) and rainfall (mm) (Table 2).

Table 2. Mean monthly meteorological conditions during the experimental period, Serra Talhada – PE, Brazil

Climate Variable	2018							Average
	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Average temperature (°C)	25.4	25.1	25.6	27.1	28.7	28.9	26.9	26.8
Relative humidity (%)	58.4	57.6	48.9	45.1	43.5	43.9	52.5	50.0
Rainfall (mm)	1.2	3.6	0.0	0.0	4.6	49.5	128.0	26.7

Monthly biometric evaluations were carried out, from August to December 2018, on the 5th of each month, in all plants to measure structural characteristics of the culture. Plant height (cm), length, width, and cladode thickness (cm) were obtained, as well as the quantification of the number of cladodes by order and total, following the methodology described by Cavalcante et al.[13] and Pereira et al.[12]. After the harvest on 01/04/2019, the root system length was determined.

All plants were cut and separated according to the treatment to determine biomass (fresh and dry matter of shoots and root system). After cutting, the plants were weighed to determine the fresh matter (FM). Then, the identification and longitudinal section of all selected cladodes were performed. These were kept under ambient conditions for 48 hours to promote partial dehydration. Subsequently, they were placed in previously marked paper bags and placed in a forced air circulation oven at 65 ºC until a constant mass was recorded, yielding the dry matter (DM) according to the methodology of Detmann et al.[14].

The first and second-order cladodes were weighed, cut transversally, placed in marked paper bags, and then placed in an oven with forced air circulation at 65 ºC until reaching constant weight. Then, they were ground, macerated, and weighed in samples of 100 mg per treatment to determine the potassium content. Next, each sample was placed in a test tube with 10 mL of distilled water and kept in a water bath at 95 ºC for one hour and analyzed for potassium content[15].

All data were submitted to normality, homoscedasticity, and F tests. When significance was found by analysis of variance, potassium doses were compared using regression analysis. For model selection, a significance of 5% was considered for the coefficients of the equations and the coefficient of determination above 0.85. When not significant, the Tukey test was used at a level of 5%, while the forage cactus clones were compared by the F test. The R - project software (version 3.5.3) was used for all analyses. The experimental data were graphed using SigmaPlot 10.0 software.

Results and discussion

Fertilization levels did not significantly influence any of the studied variables. This is due to the initial chemical attributes of the soil used in the experiment (Table 1), since the soil had adequate characteristics for the growth of forage cactus, with high base saturation (84.89%) and potassium (0.45 $cmol_c.dm^{-3}$). According to Dubeux Júnior et al. [17], forage cactus has high demands for soil physicochemical characteristics.

Table 3 shows the values of cladode number (CN), plant height (PH), cladode length (CL), cladode width (CW), cladode thickness (CT), fresh matter (FM), and dry matter (DM) of forage cactus clones. No significant differences were observed for the CT and FM variables for the clones with mean values of 1.7 cm and 859.2 g, respectively. The Little Sweet clone showed the highest values for CN, PH, and DM variables (4.8 units, 47.8 cm, and 110.4 g, respectively). The Giant Sweet clone, with mean values of 27.2 and 12.2 cm, respectively, stood out for the CL and CW variables.

Table 3. Morphological characteristics and phytomass production of forage cactus clones, in Serra Talhada – PE, Brazil

Clone	Variable						
	CN	PH	CL	CW	TC	FM	DM
	(unit.)	(cm)	(cm)	(cm)	(cm)	(g)	(g)
Sweet Giant	3.45b	39.72b	27.2a	12.2a	2.1a	822.8a	83.86b
Sweet Little	4.8a	47.8a	21.7b	8.3b	1.3a	895.5a	110.4a
CV%	35.8	17.7	14.7	11.2	135.1	19.1	17.7

CN: cladodes number; PH: plant height; CL: cladode length; CW: cladode width; CT: cladode thickness; FM: fresh matter; DM: dry matter. Means followed by the same letter in the column do not differ from each other by Tukey's test at 5% probability. CV: coefficient of variation.

The differences found are associated with the morphological characteristics of the evaluated clones. Silva et al.[3] obtained a behavior similar to that observed in the present study when studying different forage cactus clones.

Lucena et al.[20, 21] verified a high variation in the cladode size of Giant Sweet and Little Sweet clones. The authors found a mean length of 22.77 ± 6.83 and 18.77 ± 3.91 cm, width (10.65 ± 3.00 and 7.82 ± 1.68 cm), and cladode thickness (11.28 ± 5.68 and 14.11 ± 5.13 mm.), respectively, for Giant Sweet and Little Sweet.

The Little Sweet clone is superior to Giant Sweet in CN and PH due to the emission of higher- order cladodes, thus promoting greater plant height.

The average biometric PH, CW, CT, and CN data of forage cactus, regardless of the clone, taking into account only the levels of fertilization used, are shown in Table 4. When the different levels of potassium were evaluated, it was found that there was no significant difference between treatments when tested by the F test at 5% probability. The mean values of PH, CW, CT, and CN variables are equal at 43.7 cm, 10.2 cm, 1.7 cm, and 4.1 units, respectively.

Table 4. Biometric variables of forage cactus under different levels of potassium fertilization in a semi-arid environment, Serra Talhada – PE, Brazil

	Potassium fertilization level (kg of K_2O ha^{-1})					
Variable	0	250	500	750	1000	CV%
PH (cm)	43.7	44.3	45.339.4		45.8	17.7
CW (cm)	9.9	10	10.310.4		10.5	35.8
CT (cm)	1.2	1.3	3.21.2		1.6	11.2
CN (unit.)	4.0	4.5	4.03.9		4.3	135.09

PH: plant height; CW: cladode width; CT: cladode thickness; CN: cladodes number. CV: coefficient of variation. Means followed by the same letter on the line do not differ from each other by Tukey's test at 5% probability.

The lack of effect of potassium fertilization can be explained by the chemical conditions of the soil before the application of the treatments, since the soil presented adequate conditions for the growth and development of the crop. However, Dubeux Júnior et al.[18] also observed that potassium did not influence the forage cactus cladodes number.

Other factors must be considered in the absence of fertilization influence, such as the experimental period in which the culture was evaluated (150 days), considered short, not covering the full development of the plant, and influencing the non-significant result of fertilization.

It was observed that both the levels of fertilization and the clones used showed no significant difference in the yield of fresh (FM) and dry (DM) matter (Figure 1). The mean values for FM and DM were 0.859 and 0.113 kg/plant^{-1}, respectively. The soil already had a satisfactory amount of the nutrient, so that the treatments with the lowest dosages were able to obtain statistically similar values to the other treatments, through the absorption of sufficient amounts of potassium.

Leite et al.[22] evaluated 1,018 cladodes of *N. cochenillifera*, and observed high dispersion in cladode weight. The authors found tertiary cladodes weighing 5.0 g and secondary cladodes weighing 530.0 g.

According to Cavalcante et al.[16], the Little Sweet clone has smaller and lighter cladodes, however, with higher dry matter contents than those obtained by the Giant Sweet clone, consequently higher dry weight.

The forage cactus clones did not show significant differences in terms of length and dry matter of the root system, with average values of 46.2 cm and 44.8 g/plant^{-1}, respectively (Figure 2). It was observed that the values obtained for the two clones, regardless of the level of potassium fertilization used, were very similar, reinforcing the idea that this lack of response may be a function of the K content (0.45 $cmol_c$ dm^{-3}) present in the soil, that is, the natural fertility of this soil in relation to nutrient K must meet the nutritional requirement of the clones evaluated in the period of implantation of the culture, in its initial growth, corroborating with Dubeux Júnior et al.[18].

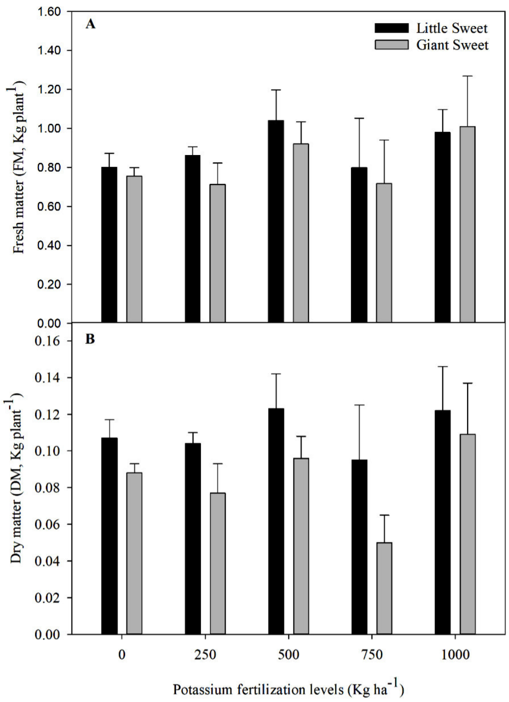

Figure 1. Fresh (A) and dry matter (B) yield (kg/plant^{-1}) of different forage cactus clones submitted to potassium fertilization levels.

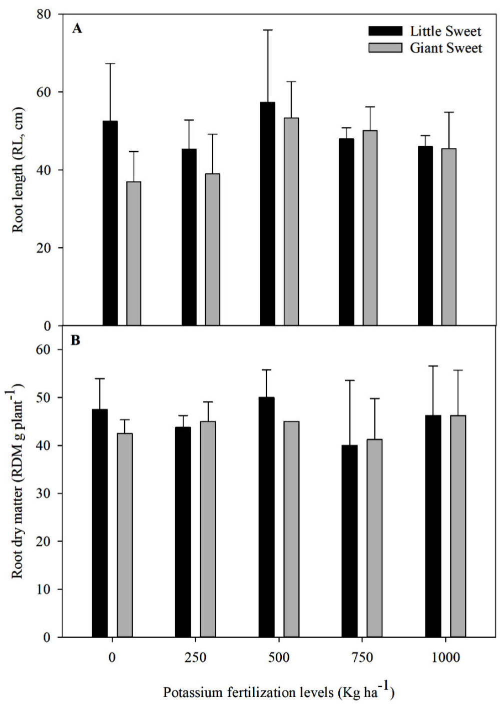

Figure 2. Length (A) and root dry matter (B) of different forage cactus clones submitted to different potassium fertilization levels.

Figure 3 shows the potassium content of forage cactus clones cladodes under different potassium fertilization levels. It was found that the treatments did not significantly influence the uptake of potassium by the plant, with an average value of 2.9 g/plant^{-1}. This is an indication that, when the soil presents satisfactory levels in relation to the need of the crop in the initial growth and implantation phase, the management of potassium fertilization can be planned in the long term, from the second growth cycle of the crop.

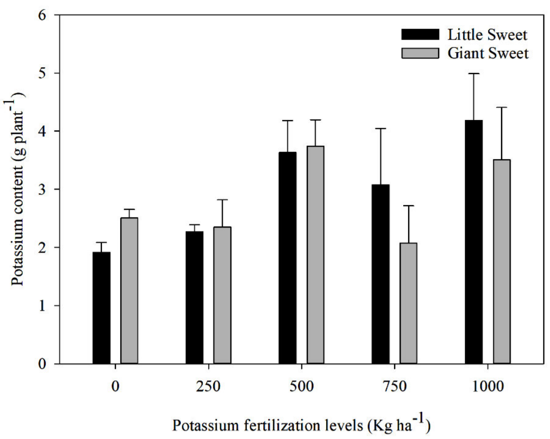

Figure 3. Potassium content in forage cactus clones cladodes subjected to different potassium fertilization levels.

Conclusion

The potassium fertilization levels do not influence in the initial growth period the morphological and productive parameters and the potassium content of forage cactus (*Nopalea cochenillifera*).

Additional research is suggested considering a longer period of cactus evaluation, encompassing different growth cycles, different cactus production systems, other clones, soils with different potassium contents, and potassium different sources.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: M.L.M.V. Leite; *Data curation*: B.C. Junior; *Formal analysis*: B.C. Junior, M.L.M.V. Leite; *Funding acquisition*: M.L.M.V. Leite; *Investigation*: B.C. Junior, F. E. da Silva, C. P. Alves, D. S. Eugênio; *Methodology*: B.C. Junior, M.L.M.V. Leite, A. C. de Oliveira; *Project administration*: B.C. Junior; *Resources*: M.L.M.V. Leite, A.C. de Oliveira; *Writing (original draft and review & editing):* B.C. Junior, M.L.M.V. Leite, F. E. da Silva, C. P. Alves, A.C. de Oliveira D. S. Eugênio.

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