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ESTABLISHMENT OF DRIS NORMS FOR CACTUS PEAR GROWN UNDER ORGANIC FERTILIZATION IN SEMIARID CONDITIONS[1]

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ABSTRACT - The objective of this work was to establish DRIS norms for evaluation of nutritional status of cactos pear of the Gigante cultivar grown under organic fertilization in semiarid conditions. Cladode macro and micronutrient contents and dry matter yield of 72 plots were evaluated. The experiment was conducted in a randomized block design with three replicates, using a 4×3×2 factorial arrangement consisted of four bovine manure rates (0, 30, 60, and 90 Mg ha^{-1} ano^{-1}), three spacings (1.00×0.50, 2.00×0.25, and 3.00×1.00×0.25 m), and two production cycles (600 and 930 days). The data were separated into high-yield population (HYP) and low-yield population (LYP), above and below 19.93 Mg ha^{-1} cycle^{-1}, respectively. The mean, standard deviation, coefficient of variation, variances, and variance ratios of all bivariate relations between nutrients were calculated for the establishment of DRIS norms, considering the direct (A/B) and reverse (B/A) form. The selection of direct and reverse relations between nutrients to compose the DRIS norms was based on the variance ratio between LYP and HYP (S^2_b/S^2_a). The sixty-six relations between cladode nutrient contents that presented the higher ratios between the variances in the LYP and HYP (S^2_b/S^2_a) were chosen. The DRIS norms established make viable the use of leaf diagnosis as an evaluation method of nutritional status of cactos pear of the Gigante cultivar grown under organic fertilization in semiarid conditions.

Keywords: *Opuntia fícus-indica*. Nutritional diagnosis. Fertility. Organic. Gigante cultivar.

ESTABELECIMENTO DE NORMAS DRIS PARA PALMA FORRAGEIRA CULTIVADA COM ADUBAÇÃO ORGÂNICA EM CONDIÇÕES SEMIÁRIDAS

RESUMO - Objetivou-se estabelecer as normas DRIS para avaliação do estado nutricional da palma forrageira ‘Gigante’ cultivada com adubação orgânica em condições semiáridas. Utilizaram-se teores de macro e micronutrientes dos cladódios e produtividades de matéria seca (PMS) de 72 parcelas, de um experimento com quatro doses de esterco bovino (0; 30; 60 e 90 Mg ha^{-1} ano^{-1}), três espaçamentos (1,00 x 0,50; 2,00 x 0,25 e 3,00 x 1,00 x 0,25 m) e dois ciclos de produção (600 e 930 dias após o plantio), dispostos em esquema fatorial 4 x 3 x 2, delineamento em blocos casualizados e três repetições. O banco de dados foi separado em população de alta (PAP) e de baixa produtividade (PBP), acima e abaixo de 19,93 Mg ha^{-1} ciclo^{-1}, respectivamente. Foram calculadas a média, o desvio-padrão, o coeficiente de variação, as variâncias e a razão das variâncias de todas as relações bivariadas entre nutrientes, considerando a relação na forma direta (A/B) ou inversa (B/A). A seleção da relação direta ou inversa dos nutrientes para compor as normas DRIS foi baseada no método da razão das variâncias entre a população de baixa e a de alta produtividade (S^2_b/S^2_a). Foram escolhidas 66 relações entre os teores de nutrientes nos cladódios que apresentaram as maiores razões entre as variâncias da PBP e PAP (S^2_b/S^2_a). As normas DRIS estabelecidas viabilizam a utilização da diagnose foliar como método de avaliação do estado nutricional da palma forrageira ‘Gigante’ cultivada com adubação orgânica em condições semiáridas.

Palavras-chave: *Opuntia*. Diagnose nutricional. Fertilidade. Orgânico. Cultivar Gigante.

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INTRODUCTION

Cactus pear (*Opuntia ficus-indica* (L.) Mill) is a crop plant adapted to the adverse conditions of the Brazilian semiarid region due to its morphological and physiological characteristics, mainly, the crassulacean acid metabolism (DONATO et al., 2014a). The crop represents a viable solution for feeding herds in drought periods because of its good dry matter yield, high non-fiber carbohydrate contents, and good acceptability, digestibility, and energetic value (ALMEIDA, 2012). Cactus pear production in Brazil is 3.58 million Mg; the state of Bahia is responsible for 42% of this production, which makes this crop one of the four most important crops of the state (IBGE, 2017).

The productive potential of cactus pear is maximum when the nutrient relations are adequate and provide normal development of plants. Information on the nutritional balance of plants is important to evaluate their yield potential (SERRA et al., 2010). Leaf diagnosis is used as a complement to soil chemical analysis and visual diagnosis, and shows the dynamics of nutrients in the soil-plant system. This information contributes to a sustainable and economically viable crop production (DONATO et al., 2017b). The leaf nutrient concentration is currently the more relevant, reliable method to assess the plant's nutritional status, since it represents the in -situ condition in a holistic form. Several methods have shown the dynamic nature of nutrient composition in plant tissues (ATTAR; JOOLKA, 2015). The specific combination of nutrient contents to obtain high yields has been considered in some methods, such as the diagnosis and recommendation integrated system (DRIS) (URANO et al., 2006).

The DRIS was developed by Beaufils (1973) as a diagnosis method that uses dual relations between nutrients based on norms (optimal relations), allowing the evaluation of the balance level of nutrients in the plant (GUIMARÃES et al., 2015). It considers the plant as a extractor of nutrients from the soil, allowing a direct evaluation of its nutritional status and an indirect evaluation of soil fertility, based on the fact that the nutrient supplying by the soil is related to the nutrient contents in the plant (BEAUFILS, 1971).

The relation between two nutrients can be determined in two ways: direct (A/B) and reverse (B/A). The ratio between the variances in low-yield (LYP) and high yield (HYP) populations has usually been used to choose the relation form to be used. Different criteria can be used to define the reference population and can result in different norms and efficacies (SERRA et al., 2013).

Few studies determine norms for cactus pear by nutritional diagnosis methods. Blanco-Macías et al. (2009, 2010) determined sufficiency ranges for this crop using the compositional nutrient diagnosis (CND) method and boundary-line analysis for edaphoclimatic conditions in Mexico; Alves et al (2019a, b) established interpretative standards for nutrient contents in cladodes using the mathematical chance method and sufficient range method; and Donato et al. (2017b) evaluate chemical attributes of soils cultivated with cactus pear of the Gigante cultivar using the sufficiency range method and critical level method by reduced normal distribution for semiarid conditions in the state of Bahia, Brazil.

In this context, the objective of this work was to establish DRIS norms for evaluation of nutritional status of Cactus pear of the Gigante cultivar grown under organic fertilization in semiarid conditions.

MATERIAL AND METHODS

The experiment was conducted in a soil classified as Typic Hapludox (typic dystrophic Latossolo Vermelho-Amarelo) with week A horizon and medium texture, from September 2009 and July 2012 (DONATO et al., 2014a; BARROS et al., 2016). The area is in the Instituto Federal Baiano, in Guanambi, BA, Brazil (14°13'30"S, 42°46'53"W, and average altitude of 525 m). The region presents average annual precipitation of 680 mm and average annual temperature of 26°C.

Data of Donato et al. (2014a, b, 2016, 2017a) and Barros et al. (2016) were used in the present study. The macronutrient (N, P, K, S, Ca, and Mg) and micronutrient (B, Cu, Fe, Mn, Zn, and Na) contents and dry matter yield were determined in samples collected from freshly ripe cladodes in 72 plots of an experiment with cactus pear, whose mean dry matter yield was 19.93 Mg ha^{-1} $cycle^{-1}$. The experiment was conducted in a randomized block design with tree replicates, using a 4×3×2 factorial arrangement consisted of four bovine manure rates (0, 30, 60, and 90 Mg ha^{-1} ano^{-1}), three spacings (1.00×0.50, 2.00×0.25, and 3.00×1.00×0.25 m), and two production cycles (600 and 930 days).

According to Donato et al. (2014a, b, 2016, 2017a) and Barros et al. (2016), the organic fertilizer (bovine manure) used presented, on average, in dry basis (65 °C): moisture of 16.72%; 63.73 g kg^{-1} of organic matter; pH of 7.42; density of 0.38 g cm^{-3}; the following macronutrient contents (g kg^{-1}): Ca = 1.7, Mg = 0.2, K = 2.5, N = 5.2, S = 2.3 (EPA 3051 / APHA 3120B), and P = 4.7 (APHA 4500-PC); and the following micronutrient contents (mg kg^{-1}): B = 2.1, Cu = 45.2, Zn = 200.5, Mn = 391.8, and Fe = 1,932.4 (EPA 3051 / APHA 3120B). The description of soil attributes of the experimental area before the palm planting is presented in Donato et al. (2014a, b, 2016, 2017a) and Barros et al. (2016). In the harvests of the first (DONATO et al., 2014a) and second (BARROS et al., 2016) production cycles, three primary cladodes were preserved.

After the collection, the samples were sliced and dried in a force-air circulation oven at 60 ºC for

72 hours. They were, then, ground in a Willey mill with a 1 mm mesh sieve, identified, placed in plastic containers, and sent to the laboratory of the Empresa de Pesquisa Agropecuária de Minas Gerais (EPAMIG Norte). The results of the chemical analysis of the plant tissues for N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, Zn, and Na and the yield results were organized in electronic spreadsheets. According to Beaufils (1973), data of high-yield population (above 19.93 Mg ha^{-1} cycle^{-1}) and low-yield population (below 19.93 Mg ha^{-1} cycle^{-1}) were separated for the establishment of the DRIS norms. The criterion used to separate the populations was the mean dry matter yield of the 72 plots.

The mean, standard deviation, coefficient of variation, variances, and variance ratios of all bivariate relations between nutrients were calculated, considering the direct (A/B) and reverse (B/A) relations. These bivariate relations were applied to all nutrients of the database. The selection of direct and reverse relations between nutrients to compose the DRIS norms was based on the variance ratios between low-yield and high-yield populations (S^2_b/S^2_a). The order of relation that presented the higher variance ratio was chosen. Differences between variances of relations in the S^2_a and S^2_b were evaluated using the F test (SILVA; CARVALHO, 2006; SERRA et al., 2014).

RESULTS AND DISCUSSION

The mean yield, coefficient of variation (CV), and cladode nutrient contents for the high-yield population (HYP) and low-yield population (LYP) indicate that concentrations of macro and micronutrients are not always higher in the HYP than in the LYP (Table 1). This could indicate the occurrence of false diagnoses, since the plant may present adequate nutrient contents and nutritional imbalance at the same time. However, the DRIS method based on the evaluation of balance between nutrients contributes to solve this diagnosis problem, since the use of HYP to obtain the DRIS norms considers that the mean value of the relation between two nutrients will be closer to the physiological optimum in this population (SILVA; CARVALHO, 2006).

Table 1. Dry matter yield (DMY), coefficient of variation (CV), and mean nutrient contents in cladodes of high-yield population (HYP) and low-yield population (LYP) of cactus pear (Gigante cultivar) grown under organic fertilization in the semiarid conditions of the state of Bahia, Brazil.

	DMY (Mg ha^{-1} cycle^{-1})	N	P	K	S	Ca	Mg
		g kg^{-1}					
HYP	26.53	15.62	1.46	37.89	1.57	28.03	11.88
LYP	14.65	14.28	1.38	34.49	1.40	29.97	12.15
CV (%)	31.69	16.57	45.13	18.88	29.65	16.89	23.64
	DMY (Mg ha^{-1} cycle^{-1})	B	Cu	Fe	Mn	Zn	Na*
		mg kg^{-1}					
HYP	26.53	27.50	2.89	93.89	383.82	46.18	43.01
LYP	14.65	28.00	2.94	82.03	523.62	51.46	42.19
CV (%)	31.69	19.99	44.44	51.46	74.03	37.88	44.26

*Na is considered a micronutrient for plants with crassulacean acid metabolism (BROADLEY et al., 2012).

Among the nutrients evaluated, Ca, Mg, B, Cu, Mn, and Zn had the highest concentrations in the LYP (Table 1). The HYP was mostly formed (81.25%) by plots treated with the highest rates of bovine manure, 60 and 90 Mg ha^{-1} year^{-1}.

The addition of bovine manure to acid soils increases pH, since organic acids can adsorb H^+ from the soil solution. The decrease in soil acidity slightly increased P availability and decreased the availability of some micronutrients, Cu, Zn, and Mn. Mn presented the highest decrease of absorption due to the increase in soil pH. The formation of organic complexes of humic and fulvic acids, present in the organic matter, with Mn, Cu, and Zn also explains the decrease of the contents of these nutrients in the cladodes (SOUSA; MIRANDA; OLIVEIRA, 2007). The unbalance of Mn, Cu, and Mo in relation to others micronutrients may explain the lower Fe contents found in the LYP (ABREU; LOPES; SANTOS, 2007).

The LYP (S^2_b) and HYP (S^2_a) were composed using 32 and 40 samples, respectively, to establish the DRIS norms; 132 relations between nutrients were calculated and the 66 relations that presented the highest S^2_b to S^2_a ratio (S^2_b/S^2_a) were selected (Table 2). Among these 66 relations, 27 presented significant differences between S^2_b/S^2_a. The method of ratios between variances favors the choice of relations with lower variance in the HYP (SERRA et al., 2013). These relations included Cu (8 relations), P (7 relations), Mn and S (6 relations), Ca and Zn (5 relations), K and Mg (4 relations), Na (2 relations), and N (1 relation). No relation with iron presented significant difference.

Table 2. Norms (mean; standard deviation - SD), coefficient of variation (CV), variance (S^2), and variance ratios (S^2_b/S^2_a) of high-yield population (HYP) and low-yield population (LYP), and selected relations (SR) for nutrient concentrations in cladodes of cactus pear (Gigante cultivar) grown under organic fertilization in the semiarid conditions of the state of Bahia, Brazil.

	HYP				LYP					
	Mean	SD	CV %	S^2_a	Mean	SD	CV %	S^2_b	S^2_b/S^2_a	SR
N/P	13.23	6.97	52.65	48.55	13.54	7.67	56.61	58.80	1.21^{ns}	X
P/N	0.10	0.05	51.42	0.00	0.10	0.05	52.49	0.00	1.04^{ns}	-
N/K	0.43	0.13	30.37	0.02	0.43	0.11	24.95	0.01	0.67^{ns}	-
K/N	2.50	0.67	26.80	0.45	2.46	0.58	23.50	0.33	0.74^{ns}	X
N/Ca	0.58	0.15	26.31	0.02	0.50	0.13	26.60	0.02	0.76^{ns}	-
Ca/N	1.85	0.48	25.99	0.23	2.16	0.59	27.35	0.35	1.50^{ns}	X
N/Mg	1.37	0.36	26.44	0.13	1.22	0.31	25.38	0.10	0.72^{ns}	X
Mg/N	0.78	0.20	25.50	0.04	0.86	0.16	19.14	0.03	0.69^{ns}	-
N/S	11.49	5.60	48.76	31.42	11.38	4.72	41.53	22.32	0.71^{ns}	X
S/N	0.11	0.04	42.21	0.00	0.10	0.04	36.26	0.00	0.68^{ns}	-
N/B	0.59	0.18	29.81	0.03	0.54	0.17	32.43	0.03	0.97^{ns}	-
B/N	1.84	0.58	31.54	0.34	2.05	0.65	31.63	0.42	1.25^{ns}	X
N/Cu	7.33	4.77	65.09	22.77	7.36	8.53	115.91	72.71	3.19**	X
Cu/N	0.20	0.11	57.87	0.01	0.22	0.13	60.71	0.02	1.38^{ns}	-
N/Fe	0.21	0.09	46.25	0.01	0.20	0.08	39.98	0.01	0.68^{ns}	X
Fe/N	6.02	3.10	51.47	9.60	5.79	1.94	33.43	3.74	0.39**	-
N/Mn	0.08	0.07	83.06	0.00	0.04	0.04	93.90	0.00	0.35**	-
Mn/N	27.33	24.09	88.13	580.28	40.13	24.91	62.07	620.40	1.07^{ns}	X
N/Zn	0.41	0.20	49.31	0.04	0.33	0.16	48.98	0.03	0.62^{ns}	-
Zn/N	3.15	1.65	52.30	2.72	3.83	1.77	46.19	3.13	1.15^{ns}	X
N/Na	0.56	0.51	90.51	0.26	0.45	0.34	75.32	0.12	0.45**	-
Na/N	2.87	1.49	52.05	2.23	3.08	1.52	49.28	2.30	1.03^{ns}	X
P/K	0.04	0.02	39.81	0.00	0.04	0.01	37.52	0.00	0.90^{ns}	-
K/P	29.44	9.69	32.92	93.90	30.11	12.23	40.63	149.65	1.59^{ns}	X
P/Ca	0.05	0.03	48.90	0.00	0.05	0.02	50.48	0.00	0.82^{ns}	-
Ca/P	22.44	8.98	40.02	80.61	27.34	13.22	48.37	174.87	2.17*	X
P/Mg	0.13	0.07	53.82	0.00	0.12	0.06	51.68	0.00	0.75^{ns}	-
Mg/P	9.61	4.19	43.62	17.58	11.26	6.11	54.28	37.34	2.12*	X
P/S	0.92	0.25	27.41	0.06	0.94	0.29	30.34	0.08	1.28^{ns}	-
S/P	1.15	0.25	22.03	0.06	1.16	0.34	29.60	0.12	1.83*	X
P/B	0.05	0.02	42.51	0.00	0.05	0.03	60.09	0.00	1.87*	-
B/P	21.98	9.38	42.66	87.96	26.61	15.65	58.82	244.95	2.78**	X
P/Cu	0.55	0.17	31.74	0.03	0.54	0.30	55.35	0.09	2.96**	-
Cu/P	2.00	0.59	29.47	0.35	2.48	1.57	63.18	2.45	7.06**	X
P/Fe	0.02	0.01	59.03	0.00	0.02	0.01	54.77	0.00	0.78^{ns}	-
Fe/P	76.53	51.94	67.87	2698.15	76.07	50.75	66.72	2576.00	0.95^{ns}	X
P/Mn	0.01	0.00	62.87	0.00	0.00	0.00	78.17	0.00	0.62^{ns}	-
Mn/P	243.98	140.53	57.60	19748.16	503.16	410.93	81.67	168862.30	8.55**	X
P/Zn	0.03	0.01	34.65	0.00	0.03	0.01	38.13	0.00	0.81^{ns}	-
Zn/P	33.54	11.13	33.18	123.83	43.52	18.51	42.52	342.45	2.77**	X
P/Na	0.05	0.03	66.04	0.00	0.04	0.02	46.52	0.00	0.31**	-
Na/P	34.32	23.15	67.46	535.87	37.01	27.73	74.92	768.94	1.43^{ns}	X
K/Ca	1.36	0.26	19.01	0.07	1.19	0.32	26.52	0.10	1.48^{ns}	-
Ca/K	0.76	0.13	16.95	0.02	0.90	0.26	28.98	0.07	4.19**	X
K/Mg	3.28	0.74	22.40	0.54	2.91	0.66	22.64	0.44	0.80^{ns}	-
Mg/K	0.32	0.08	25.59	0.01	0.36	0.09	23.84	0.01	1.10^{ns}	X
K/S	25.54	5.79	22.69	33.56	25.75	5.33	20.71	28.44	0.85^{ns}	-
S/K	0.04	0.01	21.66	0.00	0.04	0.01	20.52	0.00	0.87^{ns}	X
K/B	1.40	0.31	22.11	0.10	1.29	0.41	31.91	0.17	1.76^{ns}	-
B/K	0.75	0.16	21.88	0.03	0.86	0.28	33.04	0.08	3.01**	X
K/Cu	15.94	6.88	43.16	47.33	16.05	14.87	92.66	221.25	28.30**	X
Cu/K	0.08	0.03	42.98	0.00	0.09	0.05	59.97	0.00	2.74**	-
K/Fe	0.49	0.19	38.77	0.04	0.47	0.17	36.81	0.03	0.84^{ns}	X
Fe/K	2.49	1.30	52.30	1.70	2.45	0.98	40.18	0.97	0.57*	-
K/Mn	0.18	0.12	69.19	0.01	0.10	0.09	85.71	0.01	0.49*	-
Mn/K	9.67	6.89	71.23	47.43	16.25	9.51	58.54	90.52	1.91*	X

** = significant at 1% and * = significant at 5% by the F test; ns = not significant.

Table 2. Continuation.

	HYP				LYP					
	Mean	SD	CV %	S^2_a	Mean	SD	CV %	S^2_b	S^2_b/S^2_a	SR
K/Zn	0.92	0.27	29.40	0.07	0.75	0.27	35.87	0.07	1.00^{ns}	-
Zn/K	1.21	0.46	37.71	0.21	1.56	0.72	46.36	0.52	2.49**	X
K/Na	1.28	0.97	76.11	0.94	1.00	0.52	51.98	0.27	0.29**	-
Na/K	1.18	0.67	57.00	0.45	1.26	0.71	56.48	0.51	1.12^{ns}	X
Ca/Mg	2.42	0.39	16.14	0.15	2.53	0.55	21.77	0.30	2.00*	X
Mg/Ca	0.43	0.08	17.96	0.01	0.41	0.09	22.79	0.01	1.52^{ns}	-
Ca/S	19.33	5.62	29.09	31.63	23.15	7.25	31.31	52.56	1.66^{ns}	X
S/Ca	0.06	0.02	27.92	0.00	0.05	0.02	33.49	0.00	1.06^{ns}	-
Ca/B	1.04	0.22	20.79	0.05	1.11	0.33	29.41	0.11	2.27**	X
B/Ca	1.00	0.21	20.62	0.04	0.97	0.24	24.86	0.06	1.36^{ns}	-
Ca/Cu	12.00	5.66	47.18	32.05	13.62	11.42	83.84	130.43	4.07**	X
Cu/Ca	0.10	0.04	41.67	0.00	0.10	0.05	48.41	0.00	1.29^{ns}	-
Ca/Fe	0.36	0.14	39.58	0.02	0.41	0.14	33.47	0.02	0.89^{ns}	X
Fe/Ca	3.34	1.71	51.11	2.91	2.77	0.99	35.89	0.99	0.34*	-
Ca/Mn	0.13	0.10	71.88	0.01	0.08	0.07	85.81	0.01	0.56*	-
Mn/Ca	13.25	9.68	73.10	93.78	18.15	10.31	56.82	106.34	1.13^{ns}	X
Ca/Zn	0.68	0.21	30.59	0.04	0.64	0.20	32.04	0.04	0.96^{ns}	X
Zn/Ca	1.62	0.55	33.92	0.30	1.73	0.53	30.99	0.29	0.95^{ns}	-
Ca/Na	0.96	0.79	82.54	0.63	0.87	0.45	51.79	0.20	0.32**	-
Na/Ca	1.56	0.80	51.42	0.64	1.42	0.66	46.96	0.44	0.69^{ns}	X
Mg/S	8.30	3.06	36.91	9.39	9.40	3.28	34.91	10.76	1.15^{ns}	X
S/Mg	0.14	0.05	34.05	0.00	0.12	0.04	32.36	0.00	0.69^{ns}	-
Mg/B	0.44	0.13	28.18	0.02	0.46	0.16	34.98	0.03	1.65^{ns}	-
B/Mg	2.41	0.61	25.28	0.37	2.46	0.88	35.66	0.77	2.07*	X
Mg/Cu	5.23	2.82	53.86	7.94	5.67	4.65	82.03	21.63	2.72**	X
Cu/Mg	0.25	0.12	49.03	0.02	0.25	0.14	55.83	0.02	1.33^{ns}	-
Mg/Fe	0.15	0.06	38.45	0.00	0.16	0.05	29.54	0.00	0.66^{ns}	-
Fe/Mg	0.02	0.01	47.69	0.00	0.02	0.01	41.83	0.00	0.68^{ns}	X
Mg/Mn	0.06	0.05	79.42	0.00	0.04	0.03	86.28	0.00	0.41**	-
Mn/Mg	33.51	26.67	79.57	711.09	46.60	28.84	61.88	831.55	1.17^{ns}	X
Mg/Zn	0.30	0.12	40.48	0.01	0.27	0.11	42.45	0.01	0.90^{ns}	-
Zn/Mg	4.00	1.72	42.92	2.95	4.44	1.89	42.53	3.57	1.21^{ns}	X
Mg/Na	0.43	0.41	94.71	0.17	0.36	0.21	59.07	0.04	0.27**	-
Na/Mg	3.83	2.00	52.17	3.98	3.53	1.64	46.54	2.70	0.68^{ns}	X
S/B	0.06	0.01	26.31	0.00	0.05	0.02	36.16	0.00	1.58^{ns}	-
B/S	18.95	5.78	30.49	33.37	22.17	9.07	40.92	82.34	2.47**	X
S/Cu	0.61	0.18	30.09	0.03	0.59	0.36	61.05	0.13	3.79**	X
Cu/S	1.80	0.59	32.97	0.35	2.16	1.14	52.95	1.31	3.71**	-
S/Fe	0.02	0.01	47.69	0.00	0.02	0.01	41.83	0.00	0.68^{ns}	-
Fe/S	64.44	37.44	58.10	1401.62	63.65	32.37	50.87	1048.06	0.75^{ns}	X
S/Mn	0.01	0.00	67.50	0.00	0.00	0.00	83.13	0.00	0.52*	-
Mn/S	222.08	130.88	58.93	17128.37	413.86	267.83	64.71	71731.56	4.19**	X
S/Zn	0.04	0.01	27.23	0.00	0.03	0.01	31.97	0.00	0.89^{ns}	-
Zn/S	29.66	8.72	29.40	76.03	38.43	14.56	37.88	211.89	2.79**	X
S/Na	0.05	0.04	71.14	0.00	0.04	0.01	38.87	0.00	0.17**	-
Na/S	30.27	19.84	65.54	393.67	30.81	14.65	47.53	214.49	0.54*	X
B/Cu	11.88	6.07	51.03	36.79	13.71	16.12	117.56	259.74	7.06**	X
Cu/B	0.10	0.05	45.52	0.00	0.11	0.05	43.80	0.00	0.97^{ns}	-
B/Fe	0.37	0.16	44.70	0.03	0.40	0.19	48.16	0.04	1.39^{ns}	X
Fe/B	3.60	2.45	68.24	6.02	3.12	1.46	46.70	2.12	0.35**	-
B/Mn	0.34	0.29	86.79	0.09	0.08	0.07	86.01	0.00	0.05**	-
Mn/B	13.36	10.23	76.57	104.67	18.70	9.33	49.89	87.09	0.83^{ns}	X
B/Zn	0.68	0.24	35.75	0.06	0.62	0.27	44.09	0.07	1.25^{ns}	X
Zn/B	1.68	0.69	40.89	0.47	1.88	0.67	35.76	0.45	0.95^{ns}	-
B/Na	0.92	0.67	72.85	0.45	0.86	0.57	66.70	0.33	0.72^{ns}	X
Na/B	1.63	0.99	60.62	0.98	1.57	0.81	51.28	0.65	0.67^{ns}	-
Cu/Fe	0.04	0.02	65.02	0.00	0.04	0.03	67.88	0.00	1.30^{ns}	-
Fe/Cu	39.22	22.68	57.83	514.34	37.21	28.34	76.15	802.98	1.56^{ns}	X
Cu/Mn	0.01	0.01	77.24	0.00	0.01	0.01	75.22	0.00	0.40**	-
Mn/Cu	125.54	63.37	50.48	4016.24	259.45	434.10	167.32	188443.31	46.92**	X

** = significant at 1% and * = significant at 5% by the F test; ns = not significant.

Table 2. Continuation.

	HYP				LYP					
	Mean	SD	CV %	S^2_a	Mean	SD	CV %	S^2_b	S^2_b/S^2_a	SR
Cu/Zn	0.06	0.02	27.25	0.00	0.06	0.02	34.70	0.00	1.36^{ns}	-
Zn/Cu	17.34	5.03	29.01	25.30	20.77	13.37	64.36	178.76	7.07^{**}	X
Cu/Na	0.08	0.05	56.30	0.00	0.08	0.04	54.11	0.00	0.83^{ns}	-
Na/Cu	17.40	11.66	67.00	135.93	17.21	10.82	62.89	117.09	0.86^{ns}	X
Fe/Mn	0.53	0.53	101.06	0.28	0.25	0.25	98.80	0.06	0.21^{**}	-
Mn/Fe	5.43	4.79	88.27	22.96	7.63	5.26	68.85	27.62	1.20^{ns}	X
Fe/Zn	2.33	1.41	60.76	2.00	1.83	1.01	55.47	1.03	0.51^{*}	-
Zn/Fe	0.61	0.36	58.75	0.13	0.72	0.37	51.32	0.14	1.07^{ns}	X
Fe/Na	3.00	2.54	84.76	6.47	2.48	1.85	74.33	3.41	0.53^{*}	-
Na/Fe	0.54	0.32	59.55	0.10	0.58	0.36	61.96	0.13	1.25^{ns}	X
Mn/Zn	7.53	4.20	55.75	17.60	10.72	6.36	59.30	40.39	2.29^{**}	X
Zn/Mn	0.18	0.10	56.43	0.01	0.13	0.08	59.79	0.01	0.55^{*}	-
Mn/Na	10.69	8.00	74.79	63.92	16.13	14.29	88.62	204.29	3.20^{**}	X
Na/Mn	0.22	0.28	126.98	0.08	0.12	0.12	98.61	0.01	0.18^{**}	-
Zn/Na	1.40	0.85	60.94	0.73	1.42	0.61	43.30	0.38	0.52^{*}	-
Na/Zn	1.04	0.70	66.65	0.48	0.89	0.55	62.04	0.30	0.62^{ns}	X

** = significant at 1% and * = significant at 5% by the F test; ns = not significant.

Considering the 110 dual relations, the CV varied from 16.14% (Ca/Mg) to 126.98% (Na/Mn) in the HYP, and up to 167.32% (Mn/Cu) in the LYP. All relations that presented CV higher than 50% involved micronutrients, except B and Zn. Despite the high variability, the norms generated in the present work were adequate for the crop evaluated, since micronutrients commonly present high CV in dual relations (SILVA; CARVALHO, 2006). This is due to the higher interference of factors in their dynamics in the soil-plant system. In all the cases of the present study, the highest CV of dual relations included micronutrients, especially Mn and Na. This result is due to the fact that the micronutrient availability is affect by soil pH, organic matter content, clay content, mineral material, and, in the cases of Fe and Mn availabilities, by redox potential; these factors may affect the contact of ions with roots (ABREU; LOPES; SANTOS, 2007) and, consequently, their absorption and contents in tissues of cladodes of cactos pear.

In most cases, the soil pH is the most important factor for Mn availability to plants (ABREU; LOPES; SANTOS, 2007). The present study considered an experimental area with organic fertilization (bovine manure) at variable rates, whose soil presented negative charges as the manure rate was increased, which increases Mn adsorption. Donato et al. (2016) found lower Mn contents in cladodes of cactus pear of the Gigante cultivar as the pH was increased from 5.4 (before planting) to 6.0, 6.1, and 6.2 after addition of 30, 60, and 90 Mg ha^{-1} year^{-1} of bovine manure, respectively. Silva et al. (2012) evaluated mineral fertilization and found 2,006.0 mg kg^{-1} of Mn, well above the sufficiency range (260.0 to 507.7 mg kg^{-1}) (DONATO et al., 2017b). Silva et al. (2016) found 3-fold the Mn exported by the plant, using ammonium sulfate as N source, which reduces the pH and, thus, increases the solubility and absorption of Mn^{2+}. This was observed by the pH decrease from 5.3 (before planting) to 4.3 (harvest time), when using ammonium sulfate as N source. This shows the influence of pH in Mn availability and explains the high variability in tissues of forage palm in experiments with variable fertilizer rates, as in the present work.

The results found in the literature for Na are controversial; it is described as a beneficial and toxic element. Despite it is not essential for all species, Broadley et al. (2012) reported that Na is a micronutrient for plants with crassulacean acid metabolism, such as *Opuntia* spp., because it is essential for the regeneration of phosphoenolpyruvate, which is a substrate of the first carboxylation in this route**.** Na deficiency causes chlorosis and necrosis in tissues and problems to flower formation.

Sumner and Beaufils (1975) supported the universal application of DRIS norms, however, the crop development is dependent on soil fertility, climate, water availability conditions, and cultivar used. In perennial crops, nutritional disorders can have cumulative effects on plants over time. Moreover, the occurrences of pests and diseases affect the nutrition of plants and alter their responses to fertilization. Therefore, DRIS norms are more reliable when locally defined (CARNEIRO et al., 2015).

No studies on nutritional relations and DRIS norms for cactus pear were found. The establishment of DRIS norms makes viable the use of leaf diagnosis as a method to evaluate the nutritional status of cactus pear of the Gigante cultivar, allowing the diagnosis of cactus pear crops, either for nutrient sufficiency, deficiency, or excess (GUINDANI; ANGHINONI; NACHTIGALL, 2009).

CONCLUSIONS

DRIS norms were established for cactus pear of the Gigante cultivar grown in the semiarid conditions of the southwestern state of Bahia, Brazil, with 66 relations between nutrients.

The DRIS norms established make viable the use of leaf diagnosis as a method to evaluated the nutritional status of cactus pear plants of the Gigante cultivar grown under organic fertilization in the semiarid conditions of the state of Bahia, Brazil.

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