Acta Scientiarum

http://periodicos.uem.br/ojs
ISSN on-line: 1807-8621
Doi: 10.4025/actasciagron.v43i1.50359

Establishment of leaf nutrient patterns for the nutritional diagnosis of *Urochloa brizantha* pastures in two seasons

André Cayô Cavalcanti[1*], Fábio Luiz Partelli[1], Ivoney Gontijo[1], Jairo Rafael Machado Dias[2], Marta Simone Mendonça Freitas[3] and Almy Júnior Cordeiro de Carvalho[3]

[1]Universidade Federal do Espírito Santo, Rodovia BR-101 Norte, km 60, Bairro Litorâneo, 29932-540, São Mateus, Espírito Santo, Brazil. [2]Universidade Federal de Rondônia, Rolim de Moura, Rondônia, Brazil. [3]Universidade Estadual do Norte Fluminense Darcy Ribeiro, Campos dos Goytacazes, Rio de Janeiro, Brazil. *Author for correspondence. E-mail: andrecavalcanti40@yahoo.com.br

ABSTRACT. To diagnose and monitor the nutritional status of commercial crops, reference standards must be established based on chemical analyses of soils and leaf tissues. Therefore, the objective of this study was to establish sufficiency ranges, DRIS standards and leaf nutritional diagnoses for palisade grass pastures in the rainy and dry seasons. Of a total of 105 sampled pastures, the 20 highest-yielding areas were used to establish reference standards. In the other, low-productivity pastures, the nutritional status was diagnosed in both the rainy and dry seasons for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), boron (B), copper (Cu), iron (Fe), nickel (Ni), molybdenum (Mo), and zinc (Zn). A productivity of 15 tons ha^{-1} year^{-1} was determined as the threshold to separate high-yielding (> 15 tons ha^{-1} year^{-1}) pastures from low-productivity pastures (< 15 tons ha^{-1} year^{-1}). Sufficiency ranges and foliar DRIS standards were established for palisade grass pastures in the rainy and dry seasons, which resulted in the recommendation of region- and season-specific sufficiency ranges and DRIS leaf standards. In the rainy season, in more than 50% of the evaluated pastures, nutritional deficiencies in all nutrients except K, B and Zn were observed, while in the dry season, only N, P, Cu, and Mn were deficient.

Keywords: *Brachiaria*; nutritional sufficiency range; DRIS standards; nutritional diagnosis.

Received on October 14, 2019.
Accepted on March 10, 2020.

Introduction

The agriculture industry, which accounts for approximately 21% of the Brazilian gross domestic product, represents a source of wealth for the country and generates thousands of jobs. Livestock accounts for 30% of this sector (ABIEC, 2016), and 167 million hectares of pasture are used for livestock production (EMBRAPA, 2018).

In Brazil, the area of pastures cultivated with species of the genus *Urochloa* has increased significantly in comparison to that cultivated with other forages. Due to its easy adaptation to moderately fertile soils, the species *U. brizantha,* commonly called palisade grass, is one of the most widely planted and is cultivated in a large part of the pastures in Brazil (Montagner, 2016).

Pasture degradation and the lack of nutrient management are the key problems for livestock farmers that prevent the production potential of many areas destined for use as a pasture from being fully exploited (Dias-Filho, 2019). According to Townsend, Costa, and Pereira (2010), pasture degradation caused by improper management is an evolutionary process of loss of forage vigor and yield that, due to the impossibility of natural recovery under grazing, affects animal production and performance and culminates in the degradation of soil and natural resources.

The impairment of soil fertility maintenance resulting from the lack of replenishment of the nutrients extracted by plants is a major cause of pasture degradation. This problem can be solved, mainly by liming and fertilization to mitigate soil acidity and supply nutrients; these are indispensable practices for increasing productivity (Luengo et al., 2018) but must be based on correct and specific nutritional diagnoses for each crop species.

Chemical analyses of leaf tissues are often used as a key tool for monitoring plant nutritional status in commercial cultivation areas and are useful in determining the sources, quantities and most appropriate timing for liming and fertilizer application by farmers (Balsalobre, 2018; Luengo et al., 2018; Pinto et al., 2017; Prezotti & Martins, 2013). Due to the ease of interpretation of the results, the analysis and evaluation data on the nutritional status of agricultural crops are mainly interpreted by a method known as the sufficiency range (SR) approach (Partelli, Dias, Vieira, Wadt, & Paiva Júnior, 2014). According to Dow and Roberts (1982), sufficiency ranges are the most optimized method for leaf nutrient analysis interpretation; this method establishes a range below which the growth rate or productivity of the crop decreases.

Alternatively, the DRIS (diagnosis and recommendation integrated system) is a method based on the establishment of indices for each nutrient. These indices are normally calculated by functions that express the ratios between the concentrations of one element and other elements (Baldock & Schulte, 1996) in order to simultaneously identify nutrient imbalances, deficiencies and excesses in plant tissues and rank them in order of importance (Walworth & Sumner, 1986), thereby optimizing the efficiency of the nutritional diagnosis (Partelli et al., 2014; 2018).

DRIS standards have been successfully used to interpret leaf analysis results in different annual and perennial crops, such as pine (Sanchéz-Parada, López-López, Gómez-Guerrero, & Pérez-Suàrez, 2018); rubber (Chacón-Pardo, Camacho-Tamayo, & Bernal, 2018); sugarcane (Mccray, Ji, Powell, Montes, & Perdomo, 2010; Santos, Donha, Araújo, Lavres Júnior, & Camacho, 2013); common bean (Partelli et al., 2014), potato (Queiroz, Luz, Oliveira, & Figueiredo, 2014), rice (Wadt et al., 2013), cotton (Serra et al., 2013; Kurihara, Venegas, Neves, Novais, & Staut, 2013), guava (Souza, Rozane, Amorim, & Natale, 2013), mango (Politi et al., 2013), orange (Dias et al., 2013), apple (Xu, Zhang, Wu, & Wang, 2015), and grape (Teixeira, Tecchio, Moura, Terra, & Pires, 2015). However, no studies on *U. brizantha* pastures and their nutritional diagnoses based on DRIS norms are available.

In most cases, leaf patterns are established for specific regions (Partelli et al., 2014) and may also vary according to the phenological crop stage as well as the time of year (Partelli, Viera, Carvalho, & Mourão Filho, 2007; Partelli et al., 2018; Dias et al., 2013). Given these variations, more specific data could contribute to a more rational use of inputs, improve the plant nutritional balance and, consequently, raise pasture productivity. In this sense, the objective of this study was to establish sufficiency ranges, DRIS standards and a leaf nutritional diagnosis for areas of palisade grass pasture in the rainy and dry seasons.

Material and methods

The experiment was carried out in grazing areas growing commercial palisade grass (*Urochloa brizantha*) in northern Espírito Santo State, Brazil, between the basins of the São Mateus and Itaúnas rivers in the counties of São Mateus, Pinheiros, Boa Esperança, Nova Venécia, Barra de São Francisco, Pedro Canário, Água doce do Norte, and Ecoporanga. Most soils in the region are Latosols and Argisols (Santos et al., 2018).

The regional climate is Aw Tropical, according to Köppen's classification, with two well-defined seasons (dry winters and rainy summers) and an average annual rainfall of 1,500 mm. The rainy season lasts from October to March, and the dry season lasts from April to September. The mean temperature is between 22 and 27°C (Alvares, Stape, Sentelhas, Gonçalves, & Sparovek, 2013).

Of a total of 105 sampled areas, 20 were highly productive pastures, which were used to establish reference standards. In the other, low-productivity pastures, the nutritional status was diagnosed in both the rainy and dry seasons. A productivity limit of 15 tons ha^{-1} year^{-1} was determined to separate high-yielding (> 15 tons ha^{-1} year^{-1}) from low-productivity pasture areas (< 15 tons ha^{-1} year^{-1}), as defined by Euclides (2002).

Leaf samples were collected in the rainy (December 2016 and January 2017) and dry seasons (August and September 2017). Approximately 100 samples of above-ground plant parts (leaves and stems) in each pasture area were sampled by grazing simulation in an attempt to approach the natural conditions of pasture consumption by cattle, as proposed by Penati, Corsi, Dias, and Maya (2001). The samples were then stored in paper bags and labeled.

Each sample was predried at 55°C for 72 hours and stored in a freezer until grinding in a Wiley mill, sieving (1.0 mm mesh), and plant tissue analysis in the laboratory. The leaf concentrations of N, P, K, Ca, Mg, S, B, Cu, Fe, Ni, Mn, Mo, and Zn were quantified according to Detmann, Souza, and Valadares Filho (2012).

The Lilliefors normality test (at 1%) was applied to check the normality of the values for each nutrient concentration in the group of high-yielding pastures for both the rainy and dry seasons. This test is used to study estimated and calculated variances without restrictions for small samples (Dallal & Wilkinson, 1986).

The DRIS norms based on the mean and standard deviation of bivariate relationships were calculated directly and inversely among all evaluated nutrients (Baldock & Schulte, 1996). The sufficiency range (SR) was computed as the amplitude of the interval determined by the mean ± standard deviation of the leaf concentration of each evaluated nutrient. For both calculations, the leaf nutritional concentrations of the high-yielding pasture areas were used. Concomitantly, the level of discrepancy between the reference standards, established by the same method for the rainy and dry seasons, was checked by the F test (at 5%).

To interpret the pasture nutritional status with the SR method, three nutritional classes (low, adequate and high) were established. The pasture nutrient levels were considered adequate when the leaf tissue concentrations were in the range between the maximum and minimum SR contents, low when the nutrient concentrations in the leaf tissue were below the lower SR limit, and high when the nutrient concentrations in the leaf tissue exceeded the upper SR limit.

Nutritional data established by the DRIS method and SRs for palisade grass pastures in the region are scarce. Therefore, studies on pastures in the state of São Paulo (Raij, Cantarella, Quaggio, & Furlani, 1996; Werner et al., 1997) were used to enable comparisons due to the geographical similarity between the two states.

Results and discussion

The patterns observed in the ratios of pairs of nutrients from all the chemically analyzed elements in the leaves of 20 highly productive *Urochloa brizantha* pastures in the rainy and dry seasons represent the variables used for the DRIS diagnosis (Table 1).

Of the 110 observed nutritional relationships, 44 were similar between seasons ($p \leqslant 0.05$), indicating that 60% of the nutritional indices differed between the leaf sampling periods (Table 1). Therefore, the establishment of season-specific DRIS norms is suggested to create adequate indices for the nutritional patterns in pastures.

Table 1. Mean, standard deviation, coefficient of variation (CV) and Student's t-test of the relationships between leaf tissue nutrient contents in high-yielding *U. brizantha* pastures in the rainy and dry seasons in northern Espírito Santo State, Brazil.

Ratio	Sampling in the rainy season			Sampling in the dry season			
	Mean	Standard deviation	CV (%)	Mean	Standard deviation	CV (%)	t-test
N/P	21.017	2.5503	12.13	21.182	2.0948	9.89	NS
N/K	2.5821	0.5681	22.00	2.0400	0.3155	15.47	**
N/Ca	1.9473	0.4758	24.44	2.3104	0.3070	13.29	**
N/Mg	9.8288	3.2373	32.94	10.180	1.8650	18.32	NS
N/S	17.162	2.5670	14.96	21.134	3.4392	16.27	**
N/B	0.4174	0.1098	26.31	0.4944	0.0743	15.03	**
N/Cu	3.6612	1.6017	43.75	2.8062	1.3405	47.77	**
N/Fe	0.4541	0.0911	20.05	0.5294	0.2012	38.00	*
N/Mn	0.4068	0.2583	63.49	0.5395	0.4003	74.21	NS
N/Zn	3.4591	1.1164	32.27	2.8420	1.3898	48.90	**
P/N	0.0483	0.0059	12.30	0.0477	0.0047	9.90	NS
P/K	0.1238	0.0275	22.23	0.0965	0.0134	13.85	**
P/Ca	0.0936	0.0240	25.69	0.1097	0.0154	14.01	**
P/Mg	0.4719	0.1587	33.62	0.4822	0.0862	17.87	NS
P/S	0.8258	0.1474	17.84	1.0027	0.1627	16.23	**
P/B	0.0204	0.0066	32.26	0.0235	0.0039	16.59	**
P/Cu	0.1744	0.0738	42.32	0.1320	0.0585	44.37	**
P/Fe	0.0218	0.0049	22.39	0.0250	0.0096	38.45	*
P/Mn	0.0197	0.0131	66.24	0.0254	0.0187	73.69	NS
P/Zn	0.1658	0.0531	32.06	0.1333	0.0617	46.27	**
K/N	0.4070	0.0947	23.26	0.5025	0.0831	16.53	**
K/P	8.4911	1.9554	23.03	10.560	1.4806	14.02	**
K/Ca	0.8084	0.3166	39.17	1.1575	0.2253	19.46	**
K/Mg	4.0690	1.7658	43.40	5.0978	1.1741	23.03	**
K/S	6.9586	1.7468	25.10	10.542	2.0667	19.61	**
K/B	0.1727	0.0702	40.67	0.2469	0.0482	19.51	**
K/Cu	1.4490	0.6104	42.12	1.3712	0.5712	41.66	NS
K/Fe	0.1850	0.0577	31.18	0.2602	0.0956	36.75	**
K/Mn	0.1664	0.1120	67.30	0.2612	0.1757	67.26	**
K/Zn	1.4020	0.5387	38.43	1.3922	0.6384	45.85	NS
Ca/N	0.5431	0.1285	23.66	0.4406	0.0604	13.71	**
Ca/P	11.354	2.7245	24.00	9.2950	1.3279	14.29	**
Ca/K	1.4284	0.5256	36.80	0.8964	0.1771	19.76	**
Ca/Mg	5.0449	1.0423	20.66	4.4461	0.8442	18.99	**
Ca/S	9.2908	2.5039	26.95	9.2571	1.7254	18.64	NS
Ca/B	0.2228	0.0675	30.30	0.2162	0.0344	15.92	NS
Ca/Cu	1.9683	0.9550	48.52	1.2298	0.5945	48.34	**
Ca/Fe	0.2440	0.0684	28.02	0.2310	0.0877	37.95	NS
Ca/Mn	0.2172	0.1338	61.59	0.2344	0.1755	74.86	NS
Ca/Zn	1.8720	0.7451	39.80	1.2539	0.6523	52.02	**
Mg/N	0.1116	0.0326	29.22	0.1016	0.0192	18.86	NS
Mg/P	2.3325	0.6882	29.51	2.1373	0.3691	17.27	NS
Mg/K	0.2943	0.1252	42.56	0.2066	0.0480	23.22	**

Ratio	Sampling in the rainy season			Sampling in the dry season			
	Mean	Standard deviation	CV (%)	Mean	Standard deviation	CV (%)	t-test
Mg/Ca	0.2058	0.0385	18.72	0.2325	0.0414	17.83	**
Mg/S	1.9220	0.6472	33.67	2.1451	0.5110	23.82	NS
Mg/B	0.0458	0.0162	35.44	0.0502	0.0117	23.33	NS
Mg/Cu	0.4152	0.2489	59.95	0.2908	0.1600	55.02	**
Mg/Fe	0.0503	0.0166	33.03	0.0538	0.0252	46.94	NS
Mg/Mn	0.0459	0.0297	64.71	0.0561	0.0432	77.01	NS
Mg/Zn	0.3826	0.1688	44.10	0.2920	0.1566	53.64	**
S/N	0.0600	0.0121	20.11	0.0486	0.0081	16.73	**
S/P	1.2548	0.2606	20.77	1.0249	0.1793	17.49	**
S/K	0.1548	0.0486	31.37	0.0984	0.0192	19.52	**
S/Ca	0.1163	0.0353	30.39	0.1115	0.0198	17.72	NS
S/Mg	0.5922	0.2413	40.75	0.4950	0.1284	25.93	*
S/B	0.0249	0.0074	29.77	0.0238	0.0045	18.94	NS
S/Cu	0.2216	0.1310	59.12	0.1331	0.0578	43.42	**
S/Fe	0.0275	0.0090	32.57	0.0254	0.0099	38.94	NS
S/Mn	0.0247	0.0213	85.99	0.0258	0.0186	71.95	NS
S/Zn	0.2069	0.0819	39.58	0.1348	0.0631	46.78	**
B/N	2.5406	0.5986	23.56	2.0709	0.3343	16.14	**
B/P	54.041	16.666	30.84	43.6891	6.9891	16.00	**
B/K	6.6578	2.4465	36.75	4.1942	0.7662	18.27	**
B/Ca	4.8558	1.3179	27.14	4.7487	0.7981	16.81	NS
B/Mg	24.464	8.1816	33.44	21.1196	5.4834	25.96	*
B/S	43.564	12.518	28.73	43.4463	8.3433	19.20	NS
B/Cu	9.5108	5.1579	54.23	5.6489	2.3440	41.50	**
B/Fe	1.1737	0.4178	35.59	1.0784	0.3868	35.87	NS
B/Mn	1.0400	0.6939	66.72	1.0785	0.6990	64.81	NS
B/Zn	8.7892	3.7036	42.14	5.7507	2.7123	47.16	**
Cu/N	0.3206	0.1259	39.26	0.4170	0.1460	35.01	**
Cu/P	6.6741	2.6868	40.26	8.7510	3.0214	34.53	**
Cu/K	0.8070	0.3133	38.83	0.8338	0.2855	34.24	NS
Cu/Ca	0.6209	0.2986	48.09	0.9594	0.3525	36.74	**
Cu/Mg	3.1907	1.7947	56.25	4.3201	1.8609	43.08	**
Cu/S	5.4841	2.2327	40.71	8.6399	2.9041	33.61	**
Cu/B	0.1371	0.0745	54.38	0.2020	0.0686	33.98	**
Cu/Fe	0.1444	0.0645	44.68	0.2107	0.0933	44.26	**
Cu/Mn	0.1236	0.0811	65.65	0.1992	0.1271	63.78	**
Cu/Zn	1.1289	0.5523	48.92	1.1052	0.6228	56.35	NS
Fe/N	2.3023	0.5304	23.04	2.1518	0.8038	37.36	NS
Fe/P	48.092	10.893	22.65	45.0702	16.4099	36.41	NS
Fe/K	5.9478	1.8953	31.87	4.2909	1.4793	34.48	**
Fe/Ca	4.4271	1.2732	28.76	4.9404	1.9491	39.45	NS
Fe/Mg	22.426	8.4073	37.49	21.7455	8.5394	39.27	NS
Fe/S	39.813	11.778	29.58	44.8841	17.1290	38.16	NS
Fe/B	0.9789	0.3906	39.90	1.0504	0.3970	37.80	NS
Fe/Cu	8.2926	3.6607	44.14	5.6664	2.4355	42.98	**
Fe/Mn	0.9299	0.6008	64.61	1.0832	0.7915	73.07	NS
Fe/Zn	7.9729	3.0632	38.42	5.6744	2.7239	48.00	**
Mn/N	3.5519	2.2940	64.58	2.9539	2.0741	70.22	NS
Mn/P	74.824	49.631	66.33	61.9742	43.7212	70.55	NS
Mn/K	9.2351	6.4507	69.85	5.9100	4.2170	71.35	**
Mn/CA	6.9411	5.0821	73.22	6.6823	4.5379	67.91	NS
Mn/Mg	37.281	34.212	91.77	31.2283	24.564	78.66	NS
Mn/S	60.149	39.254	65.26	62.7916	49.297	78.51	NS
Mn/B	1.5146	1.1339	74.86	1.4564	1.1026	75.71	NS
Mn/Cu	12.515	9.8509	78.71	7.7332	8.0027	103.48	*
Mn/Fe	1.6032	1.0509	65.55	1.4817	1.1674	78.79	NS
Mn/Zn	11.976	8.7446	73.02	7.7950	7.3994	94.93	**
Zn/N	0.3309	0.1424	43.05	0.4562	0.2385	52.29	**
Zn/P	6.9107	3.0525	44.17	9.5170	4.7970	50.40	**
Zn/K	0.8541	0.4297	50.31	0.9102	0.4655	51.14	NS
Zn/Ca	0.6410	0.3109	48.49	1.0498	0.5437	51.79	**
Zn/Mg	3.1856	1.5178	47.64	4.7149	2.7630	58.60	**
Zn/S	5.6438	2.4813	43.96	9.3982	4.6234	49.19	**
Zn/B	0.1369	0.0643	46.94	0.2201	0.1089	49.47	**
Zn/Cu	1.2828	0.9982	77.82	1.1461	0.5062	44.17	NS
Zn/Fe	0.1514	0.0770	50.87	0.2238	0.1132	50.56	**
Zn/Mn	0.1265	0.0754	59.65	0.2120	0.1362	64.24	**

NS - non significant; **and * - significant at 1 and 5% probability, respectively. Macronutrients are expressed in g kg^{-1} and micronutrients are expressed in mg kg^{-1}.

Satisfactory results from DRIS have been reported for different crops, e.g., pine (Sanchéz-Parada et al., 2018), rubber (Chacón-Pardo et al., 2018), sugarcane (Mccray, et al., 2010; Santos et al., 2013), common bean (Partelli et al., 2014), potato (Queiroz et al., 2014), rice (Wadt et al., 2013), cotton (Serra et al., 2013; Kurihara et al., 2013), guava (Souza et al., 2013), mango (Politi et al., 2013), orange (Dias et al., 2013), apple (Xu et al., 2015), and grape (Teixeira et al., 2015).

Batista and Batista (2010) studied the effects of nutrient supply on the nutrient contents of various types of forage grass to determine an adequate nutrient supply for the grass. When grass is fertilized, the contents of one particular nutrient may be increased, but there may also be side effects of this application, resulting in increasing or decreasing levels of other nutrients. Thus, the application of one nutrient can benefit or hamper the content and action of another, reinforcing the importance of an adequate nutritional balance (Whitehead, 2000).

One of the major challenges cattle producers must overcome in most regions in Brazil is the climatic seasonality and the consequent seasonality of the productivity of the pastures that feed their animals. Based on this information, Table 2 shows the sufficiency ranges and mean nutritional concentrations in 20 highly productive *U. brizantha* pastures in the dry and rainy seasons.

Table 2. Sufficiency range, mean, standard deviation, coefficient of variation (CV) and F-test results of the leaf contents of high-yielding *U. brizantha* pastures in the rainy and dry seasons in northern Espírito Santo State, Brazil.

	Rainy season				Dry season				
Nutrient	Sufficiency range	Mean	Standard deviation	CV	Sufficiency range	Mean	Standard deviation	CV	t-test
N (g kg^{-1})	21,2 – 31,4	25.22	5.32	21.11	19.2 – 29.7	18.48	6.39	34.58	*
P (g kg^{-1})	2.5 – 5.1	2.90	0.88	30.50	1.6 – 3.8	2.38	0.50	20.89	NS
K (g kg^{-1})	24.3 – 34.2	24.82	6.08	24.49	19.6 – 30.8	23.57	5.74	24.35	NS
Ca (g kg^{-1})	2.6 – 5.9	4.05	1.05	25.87	1.9 – 5.9	3.73	1.01	27.01	NS
Mg (g kg^{-1})	4.1 – 9.1	4.63	1.64	35.45	2.5 – 3.5	3.99	1.24	31.17	NS
S (g kg^{-1})	1.1 – 2.4	1.69	0.36	21.32	1.2 – 1.6	1.36	0.34	24.75	NS
B (mg kg^{-1})	2.2 – 4.0	8.26	8.13	25.37	1.1 – 2.4	7.24	5.60	37.40	NS
Cu (mg kg^{-1})	5.7 – 11.1	17.56	7.81	28.33	3.9 – 9.6	6.28	1.71	27.26	*
Fe (mg kg^{-1})	179.7 – 270.0	194.00	115.68	20.75	86.1 – 290.0	150.96	81.0	43.36	*
Ni (mg kg^{-1})	0.29 – 0.83	0.26	0.13	31.13	0.2 – 0.4	0.37	0.20	43.1	NS
Mn (mg kg^{-1})	173.2 – 371.0	198.00	76.73	47.32	23.4 – 128.0	62.89	31.26	39.71	*
Mo (mg kg^{-1})	0.6 – 1.2	0.43	0.25	39.31	0.17 – 1.1	0.52	0.25	38.64	NS
Zn (mg kg^{-1})	14.0 – 30.2	20.56	7.81	28.33	9.25– 15.6	10.25	8.26	29.24	*

NS - non significant; * - significant at 5% probability.

It is worth emphasizing that a large amount of nutrient content data for *U. brizantha* pastures was compiled in studies conducted in the states of São Paulo and Minas Gerais and in the Central-West Region of Brazil (Raij et al., 1996; Marques, Schulze, Curi, & Mertzman, 2004; Wilcke & Lilienfien, 2004), where the climatic conditions are different from those in northern Espírito Santo. Therefore, no studies with surveys and sufficiency ranges of nutritional contents or nutrient availability in pastures in this region during the dry and rainy seasons are available.

A comparison of the mean nutrient concentrations of *U. brizantha* leaves in this study (Table 2) with those found by Raij et al. (1996) and Werner et al. (1997) in the state of São Paulo showed that the contents of N, Mg and Cu were higher than, and those of B and Zn were below, those recommended by the sufficiency ranges suggested by these authors. This reinforces the importance of establishing region-specific norms and ranges, as also stated by Serra et al. (2010), Camacho, Silveira, Camargo, and Natale (2012) and Partelli et al. (2014).

The mean leaf concentrations of the nutrients N, Cu, Fe, Mn, and Zn were higher in the rainy season than in the dry season, while the other evaluated nutrients did not differ (Table 2).

Nitrogen application to pastures intensifies the dry matter production, forage availability and, consequently, the stocking rate in the area, especially in the hot and rainy seasons, when the yield response to N fertilization is higher. This fact might explain the lower values of this nutrient in the dry season than in the rainy season (Table 2).

According to Silva, Costa, Lana, and Lana (2011), interactions between Cu and soil organic matter may influence the availability of Cu in forages. According to Carvalho, Barbosa, and McDowell (2003), palisade grasses are Zn-poor, rarely reaching dry matter contents of 22 mg Zn kg^{-1}, with low levels in dry pasture compared to moist pasture and lower levels in mature pasture than in younger pasture; similar observations were made in this study (Table 2).

In contrast to B and Zn, Mn is the second most abundant micronutrient after Fe in tropical soils. Manganese availability in the soil depends mainly on pH, oxidation potential, organic matter and equilibrium with other cations such as Fe, Ca, and Mg (Malavolta, 2006).

For iron, Silva et al. (2011) reported several factors that may affect the availability of Fe in forage plants, e.g., the particular conditions of iron oxide-rich soils, the imbalance of Fe with other metals, an excess of soil phosphorus, and the effects of high pH (excessive liming), waterlogging and cold. Flooding increases Fe availability by tending to reduce Fe from +3 to +2, increasing its mobility and availability. Waterlogging damages the plants due to the lack of oxygenation.

The differences between the mean leaf concentrations of the pastures in the two sampled seasons (Table 2) show the importance of establishing region- and season-specific norms and ranges for the dry and rainy seasons. Differences in mineral concentrations in different sampling seasons were also observed by Santos et al. (2013) in commercial sugarcane (*Saccharum* sp.) and by Silva et al. (2011) when evaluating the micronutrient uptake of *Urochloa decumbens*, indicating that reference values should also be season-specific.

Table 3 shows the nutritional diagnosis of 85 *U. brizantha* pastures sampled during the dry and rainy seasons based on the ranges and nutritional patterns found in Table 2. Except for K, B, and Zn, the nutritional concentrations of all other evaluated nutrients were below the recommended ranges (Table 2) in more than 50% of the pastures evaluated during the rainy season (Table 3). The same trend was not observed in the dry season, as only N, P, Cu, and Mn were below the recommended ranges (Table 2) in more than half of the evaluated pastures (Table 3). These differences once again demonstrate the important effects of climate seasonality and its influence on nutrient uptake in tropical forage plants, thus reinforcing the importance of adopting specific norms and ranges for each season.

According to Martha Júnior, Alves, and Contini (2012), and Dias Filho (2013) tropical pastures do not have the same productivity and nutritional value throughout the year. During the rainy and hot months, they grow rapidly and have considerable nutritional value. In the dry months and at milder or cold temperatures, pasture growth and nutritional quality are significantly lower.

Table 3. Percentage of nutrients in *U. brizantha* pastures sampled in northern Espírito Santo State, Brazil, in the rainy and dry seasons in which nutrients were below, within and above the sufficiency range (< critical range, ADQ, > critical range, respectively).

	Pastures sampled in the rainy season (%)												
	N	P	K	Ca	Mg	S	B	Zn	Mo	Cu	Fe	Ni	Mn
< FC	77.6	77.6	31.8	63.5	87.0	54.1	14.2	34.1	82.4	63.5	71.8	53.0	90.6
ADQ	21.2	21.2	62.3	36.5	13.0	45.9	32.9	61.2	15.3	35.3	20.0	34.1	9.4
> FC	1.2	1.2	5.9	0.0	0.0	0.0	52.9	4.7	2.3	1.2	8.2	12.9	0.0
	Pastures sampled in the dry season (%)												
< FC	69.4	51.4	15.3	7.1	29.5	35.3	1.2	1.2	22.4	51.4	37.7	34.2	51.0
ADQ	30.6	45.1	80.0	88.2	43.5	52.9	20.0	97.6	70.6	45.1	58.8	47.0	36.0
> FC	0.0	3.5	4.7	4.7	27.0	11.8	78.8	1.2	7.0	3.5	3.5	18.8	13.0

According to Dias Filho (2011; 2013), livestock production has historically been used in the occupation of agricultural frontier areas in Brazil because it is the least expensive and most efficient means of occupying and maintaining the possession of large areas of land. This strategy, while beneficial on the one hand for acquiring land at a low price, has contributed on the other hand to the traditionally low levels of investment in technology and inputs in the establishment and management of much of the Brazilian pasture area to date, as shown by a diagnosis of *U. brizantha* pastures in northern Espírito Santo State (Table 3). The main consequence of this situation is a high incidence of degraded pastures in Brazil and the stigmatization of pasture-based livestock as an unproductive activity that is essentially harmful to the environment.

Minerals are known to be indispensable for the good development of vital functions in cattle, which reinforces the importance of knowing the concentrations of these elements in pastures. Animals raised on tropical grass pastures can produce much more than animals raised on other forages. However, less than half of the production potential of these pastures is exploited due to management errors that are mainly related to the lack of knowledge about the nutritional composition of the pastures and the nutritional requirements of the animals (Deblitz, 2012). In this context, the mineral requirements for beef and dairy cattle based on NRC (2016) and NRC (2001) are shown in Table 4.

The mean concentrations of nearly all minerals found in the high-yielding *U. brizantha* pastures in the two evaluated periods (Table 2) were within the nutritional requirement ranges recommended by NRC (2016) for beef cattle (Table 4). The only exception was Zn in the dry period (mean of 10.25 mg Zn kg^{-1}), which was below the recommended requirement range.

Table 4. Daily mineral nutritional requirements for cattle, as recommended by NRC (2001)[2] and NRC (2016)[1].

Nutrient	Beef cattle	Dairy cattle
	Nutritional requirement range[1]	Nutritional requirement range[2]
P (g kg^{-1})	1.7 – 5.9	3.2 – 4.4
K (g kg^{-1})	5.0 – 7.0	1.0 – 1.07
Ca (g kg^{-1})	1.7 – 15.3	5.3 – 6.7
Mg (g kg^{-1})	0.5 – 2.5	2.4 – 2.9
S (g kg^{-1})	0.8 – 1.5	2.0
Cu (mg kg-^{1})	4.0 – 10.0	9.0 – 11.0
Fe (mg kg^{1})	50.0 – 100.0	12.3 – 40.0
Mn (mg kg^{-1})	20.0 – 50.0	12.0 – 14.0
Mo (mg kg^{-1})	< 6.0	< 6.0
Zn (mg kg^{-1})	20.0 – 40.0	43.0 – 54.0

For dairy cattle, the highly productive *U. brizantha* pastures (Table 2) did not meet the mineral requirements recommended by the NRC (2001) for P, Ca, S, Zn in both evaluated seasons and for Cu in the dry season.

To ensure the vital, productive and reproductive functions of cattle, the nutrient quantity and quality they receive must be compatible with their body weight, physiological status, and production level as well as with the environmental factors to which they are exposed (Malafaia, Cabral, Vieira, Magnoli, & Carvalho, 2003). Of all ruminants, the category with the highest nutritional requirements is lactating dairy cattle, a fact that certainly influenced the differences in this study when the different categories, i.e., beef and dairy cattle, were evaluated.

According to Embrapa (2017), the risk of mineral deficiency in animals fed a varied diet with high concentrations of specific nutrients from certain plants is lower than that in cattle grazing on a single grass species, where mineral deficiencies are aggravated by the increased requirements for that single grass species.

In the pastures used for diagnosis (Table 3), their inability to meet the requirements for beef or dairy cattle was evident; in more than half of the evaluated pastures, the nutritional ranges were below those recommended for highly productive pastures (Table 2). These results reinforce the need for mineral supplementation with increasingly region-specific mineral formulations that meet the requirements of the respective animal category.

Diagnoses as established in this study are important for the evolution of livestock husbandry in the central Cerrado to support the correction of nutrient imbalances and deficiencies by mineral supplementation (EMBRAPA, 2017); this also reinforces their importance for northern Espírito Santo State.

This understanding was confirmed by Malafaia et al. (2003), who reported that although extensive areas in Brazil are deficient in one or more mineral elements, there may be no mineral deficiency in others. In northwestern Rio de Janeiro State, Brazil, mainly along the Paraíba do Sul and Pomba rivers, the same researchers found only sodium deficiency, and they found only copper deficiency in the microregion of Itaguaí and Seropédica; mineral supplementation with complete mixtures would therefore represent a huge financial waste for the farmers in these regions.

Conclusion

DRIS standards and sufficiency ranges were established for highly productive *U. brizantha* pastures in the rainy and dry seasons. The results suggest that region- and season-specific sufficiency ranges and standards should be used.

With the exception of K, B, and Zn, the nutritional concentrations of all evaluated nutrients were below the recommended ranges in more than 50% of the diagnosed pastures in the rainy season.

In the dry season, the levels of N, P, Cu, and Mn were below the recommended ranges in more than half of the diagnosed pastures.

High-yielding *U. brizantha* pastures in both evaluated periods met the mineral requirements recommended by the NRC (2016) for beef cattle, except for Zn in the dry period.

The high-yielding *U. brizantha* pastures did not meet the recommended mineral requirements of NRC (2001) for dairy cattle for P, Ca, S, Zn in either evaluated season and for Cu in the dry season.

Acknowledgements

We gratefully acknowledge the support of the Federal University of Espírito Santo (UFES), Cooperativa Veneza, the Foundation for Support of Research and Innovation of the State of Espirito Santo (FAPES), and the Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES).

References

Associação Brasileira das Indústrias Exportadoras de Carnes [ABIEC]. (2016). *Perfil da Agropecuária no Brasil.* Retrieved on Aug. 8, 2019 from http://abiec.com.br/Sumario.aspx

Alvares, C. A., Stape, J. L., Sentelhas, P. C., Gonçalves, J. L. M., & Sparovek, G. (2013). Koppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, *22*(1), 11-28. DOI: 10.1127/0941-2948/2013/0507

Baldock, J. O., & Schulte, E. E. (1996). Plant analysis with standardized scores combines DRIS and sufficiency range approaches for corn. *Agronomy Journal*, *88*(3), 448-456. DOI: 10.2134/agronj1996.00021962008800030015x

Balsalobre, M. A. A. (2018). *Análise foliar em plantas forrageiras*. Retrieved on Aug. 8, 2019 from https://www.milkpoint.com.br/artigos/producao/analise-foliar-em-plantas-forrageiras.

Batista, K., & Batista, F. A. (2010). Variações nos teores de potássio, cálcio e magnésio em capim-marandu adubado com doses de nitrogênio e de enxofre. *Revista Brasileira de Ciência de Solo*, *34*(1), 151-161. DOI: 10.1590/S0100-06832010000100016

Camacho, M. A., Silveira, M. V., Camargo, R. A., & Natale, W. (2012). Faixas normais de nutrientes pelos métodos ChM, DRIS e CND e nível crítico pelo método de distribuição normal reduzida para laranjeira-pera. *Revista Brasileira de Ciência do Solo*, *31*(1), 193-200. DOI: 10.1590/S0100-06832012000100020

Carvalho, F. A. N., Barbosa, F. A., & McDowell, L. R. (2003). *Nutrição de bovinos a pasto*. Belo Horizonte, MG: PapelForm.

Chacón-Pardo, E., Camacho-Tamayo, J. H., & Bernal, J. H. (2018). DRIS norms for rubber clone FX3864 in the easterns plans of Colômbia. *Revista U.D.C.A Actualidad & Divulgación Científica*, *16*(1), 13-120. DOI: 10.1590/S0100-06832011000600023

Dallal, G. E., & Wilkinson, L. (1986). An analytic approximation to the distribution of 'Lilliefors' test for normality. *The American Statistic*, *40*(2), 94-96. DOI: 10.1080/01621459.1967.10482916

Deblitz, C. (2012). *Beef and Sheep Report: understanding agriculture worldwide.agribenchmark.* Retrieved on Aug. 8, 2019 from https://bitlybr.com/jenHKhOl

Detmann, E, Souza, M. A., Valadares Filho, S. C. (2012). *Métodos para análise de alimentos*. Visconde do Rio Branco, MG: Universidade Federal de Viçosa.

Dias, J. R. M., Tucci, C. A. F., Wadt, P. G. S., Partelli, F. L., Perez, D. V., Espíndola, M. C., & Tomio, D. B. (2013). Antecipação do período de diagnose foliar em laranjeira 'Pêra' no Amazonas. *Pesquisa Agropecuária Brasileira*, *48*(7), 757-764. DOI: 10.5747/ca.2017.v13.nesp.000194

Dias-filho, M. B. (2019). *Breve histórico das pesquisas em recuperação de pastagens degradas na Amazônia*. Brasília, DF: Embrapa.

Dias-filho, M. B. (2013). *Recuperação de pastagens e segurança alimentar: uma abordagem histórica da pecuária na Amazônia*. Bebedouro, SP: Editora Scot Consultoria.

Dias-filho, M. B. (2011). Os desafios da produção animal em pastagens na fronteira agrícola brasileira. *Revista Brasileira de Zootecnia*, *40*(1), 243-252. DOI: 10.5216/cab.v14i1.16785

Dow, A. I., & Roberts, S. (1982). Proposal: critical nutrient ranges for crop diagnosis. *Agronomy Journal*, *74*(1), 401-403. DOI: 10.2134/agronj1982.00021962007400020033x

Empresa Brasileira de Pesquisa Agropecuária [EMBRAPA]. (2017). *Pastagem*. Retrieved on Aug. 8, 2019 from https://bitlybr.com/nIxFB5lC

Kurihara, C. H., Venegas, V. H. A., Neves, J. C. L., Novais, R. F., & Staut, L. A. (2013). Faixas de suficiência para teores foliares de nutrientes em algodão e em soja, definidas em função de índices DRIS. *Revista Ceres, 60*(3), 412-419. DOI: 10.1590/S0034-737X2013000300015

Luengo, R. F. A., Butruille, N. M. S., Melo, R. A. C., Silva, J., Maldonade, I. R., & Costa Júnior, A. D. (2018). Determination of soil mineral content and analyses of collards leaves grown in Brasília. *Brazilian Journal Food and Technology*, *21*(1), 1-9. DOI: 10.1590/1981-6723.14117

Malafaia, P., Cabral, L. S., Vieira, R. A. M., Costa, R. M., & Carvalho, C. A. B. (2003). Suplementação protéico-energética para bovinos criados em pastagens: aspectos teóricos e principais resultados publicados no Brasil. *Livestock Research for Rural Development*, *15*(12), 1-33.

Malavolta, E. (2006). *Manual de nutrição mineral de plantas.* São Paulo, SP: Agronômica Ceres.

Marques J. J., Schulze, D. G., Curi, N., & Mertzman, S. A. (2004). Trace element geochemistry in Brazilian Cerrado soils. *Geoderma*, 121(1), 31-43. DOI: 10.1016/j.geoderma.2003.10.003

Martha Junior, G. B., Alves, E., & Contini, E. (2012). Land-saving approaches and beef production growth in Brazil. *Agricultural Systems*, *110*(1), 173-177. DOI: 10.1016/j.agsy.2012.03.001

Mccray, J. M., Ji, S., Powell, G., Montes, G., & Perdomo, R. (2010). Sugarcane response to DRIS-based fertilizer supplements in Florida. *Journal of Agronomy and Crop Science*, *196*(1), 66-75.

Montagner, D. B. (2016). *Manejo de pastos de Urochloa brizantha*. Retrieved on Aug. 8, 2019 from https://bitlybr.com/lVmc3

National Research Council [NRC]. (2016). *Nutrient Requirements of Beef Cattle* (8th ed.). Washington, DC: The National Academies Press.

National Research Council [NRC]. (2001). *Nutrient requirements of beef cattle. Minerals* (7th ed.). Washington, DC: National Academies Press.

Partelli, F. L., Oliveira, M. G., Covre, A. M., Vieira, H. D., Dias, J. R. M., & Braun, H. (2018). Nutritional standards and nutritional diagnosis of the Conilon coffee plants in phenological growth stages. *Journal of Plant Nutrition*, *41*(19), 1-11. DOI: 10.1080/01904167.2018.1510513

Partelli, F. L., Viera, H. D., Carvalho, V. B., & Mourão Filho, F. A. A. (2007). Diagnosis and recommendation integrated system norms, sufficiency range, and nutritional evaluation of Arabian coffee in two sampling periods. *Journal of Plant Nutrition*, *30*(1), 1651-1667. DOI: 10.1080/01904167.2018.1510513

Partelli, F. L., Dias, J. R. M., Vieira, H. D., Wadt, P. G. S., & Paiva Júnior, E. (2014). Avaliação nutricional de feijoeiro irrigado pelos métodos CND, DRIS e faixas de suficiência. *Revista Brasileira de Ciência do Solo*, *38*(1), 858-866. DOI: 10.1590/S0100-06832014000300017

Pinto, L. E. V., Creste, J. E., Martins, F. B., Alves, A. M., Silva, A. P. L., & Loosli, F. S. (2017). Utilização do software de diagnose da composição nutricional (CND) para avaliação do estado nutricional de citros. *Colloquium Agrariae*, *13*(1), 203-209. DOI: 10.5747/ca.2017.v13.nesp.000194

Prezotti, L. C., & Martins, A. G. (2013). *Guia de interpretação de análise de solo e foliar.* Vitória, ES: Incaper.

Politi, L. S., Flores, R. A., Silva, J. A. S., Wadt, P. G. S., Pinto, P. A. C., & Prado, R. M. (2013). Estado nutricional de mangueiras determinado pelos métodos DRIS e CND. *Revista Brasileira de Engenharia Agrícola e Ambiental*, *17*(1), 11-18. DOI: 10.1590/S1415-43662013000100002

Queiroz, A. A., Luz, J. M. Q., Oliveira, R. C., & Figueiredo, F. C. (2014). Productivity and establishment of DRIS indices for tubers of the potato cultivar 'Agata'. *Revista Ciência Agronômica*, *45*(2), 351-360. DOI: 10.1590/S1806-66902014000200017

Raij, B. V., Cantarella, H., Quaggio, J. A., & Furlani, A. M. C. (1996). *Recomendações de adubação e calagem para o Estado de São Paulo.* Campinas, SP: Instituto Agronômico/Fundação IAC.

Sánchez-Parada, A., López-López, M. Á., Gómez-Guerrero, A., & Pérez-Suàrez, M. (2018). Critical Nutrient Concentrations and DRIS Norms for *Pinus patula*. *Preprints*, *1*(1), 1-13. DOI: 10.20944/preprints201801.0011.v1

Santos, H. G., Jacomine, P. K. T., Anjos, L. H. C., Oliveira, V. A., Lumbreras, J. F., Coelho, M. R. ... Cunha, T. J. F. (2018). *Sistema Brasileiro de Classificação de Solos.* Brasília, DF: Embrapa.

Santos, E. F., Donha, R. M. A., Araújo, C. M. M., Lavres Júnior, J., & Camacho, M. A. (2013). Faixas normais de nutrientes em cana-de-açúcar pelos métodos CHM, DRIS e CND e nível crítico pela distribuição normal reduzida. *Revista Brasileira de Ciência do Solo*, *37*(6), 1651-1658. DOI: 10.1590/S0100-06832013000600021

Serra, A. P., Marchetti, M. E., Rojas, E. P., Morais, H. S., Conrad, V. A., & Guimarães, F. C. M. (2013). Estabelecimento de normas DRIS para o algodoeiro com diferentes critérios de seleção da população de referência. *Pesquisa Agropecuária Brasileira*, *48*(11), 1472-1480. DOI: 10.1590/S0100-204X2013001100008

Silva, A. A., Costa, A. M., Lana, R. M. Q., & Lana, A. M. Q. (2011). Absorção de micronutrientes em pastagem de *Brachiaria decumbens*, após aplicação de cama de peru e fontes minerais na fertilização. *Bioscience Journal*, *27*(1), 41-48. DOI: 10.11606/9788566404227

Souza, H. A., Rozane, D. E., Amorim, D. A., & Natale, W. (2013). Normas preliminares Dris e faixas de suficiência para goiabeira 'paluma'. *Revista Brasileira de Fruticultura*, *35*(1), 282-291. DOI: 10.1590/S0100-29452013000100033

Teixeira, L. A. J., Tecchio, M. A., Moura, M. F., Terra, M. M., & Pires, E. J. P. (2015). Dris norms and critical leaf nutrient levels for 'Niagara rosada' grape in Jundiaí region, São Paulo (Brasil). *Revista Brasileira de Fruticultura*, *37*(1), 247-255. DOI: 10.1590/0100-2945-409/13

Townsend, C. R., Costa, N. L., & Pereira, R. G. A. (2010). Aspectos econômicos da recuperação de pastagens na Amazônia brasileira. *Amazônia: Ciência e Desenvolvimento*, *5*(10), 27-49.

Wadt, P. G. S., Anghinoni, I., Guindani, R. H. P., Lima, A. S. T., Puga, A. P., Silva, G. S., & Prado, R. M. (2013). Padrões nutricionais para lavouras arrozeiras irrigadas por inundação pelos métodos da CND e chance matemática. *Revista Brasileira de Ciência do Solo*, *37*(1)145-156. DOI: 10.1590/S0100-06832013000100015

Wadt, P. G. S., Dias, J. R. M., Perez, D. V., & Lemos, C. O. (2012). Interpretação de Índices Dris para a cultura do cupuaçu. *Revista Brasileira Ciência do Solo*, *36*(1)125-135. DOI: 10.1590/S0100-06832012000100014

Walworth, J. L., Sumner, M. E. (1987) The diagnosis and Recommendation Integrated System (DRIS). In B. A. Stewart (Ed.), *Advances in Soil Science* (p. 149-188). New York, NY: Springer. DOI: 10.1007/978-1-4612-4682-4_4

Whitehead, D. C. (2000). *Nutrient elements in grassland soil–plant–animal relationships.* New York, US: CABI Publishing.

Wilcke, W., & Lilienfein, J. (2004). Element storage in native, agri, and silvicultural ecosystems of the Brazilian savanna. II. Metals. *Plant and Soil*, *258*(1), 31-41. DOI: 10.1023/B:PLSO.0000016503.59527.ea

Werner, J. C. (1997). *Recomendações de adubação e calagem para o Estado de São Paulo* (2a. ed.). Campinas, SP: Instituto Agronômico de Campinas.

Xu, M., Zhang, J., Wu, F., & Wang, X. (2015). Nutritional Diagnosis for Apple by DRIS, CND and DOP. *Advance Journal of Food Science and Technology*, *7*(4), 266-273. DOI: 10.19026/ajfst.7.1306