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DRIS norms for 'Keitt' mango in the Brazilian semiarid region: diagnosis and validation

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Abstract: Nutritional standards based on long-term data improve the nutritional diagnosis of the crop, as they make norms more precise and establish more refined criteria. This study aimed to evaluate the nutritional status of the mango crop using the DRIS methodology to identify nutritional limitations and validate norms. A database of 202 commercial plots was used, whose leaves were collected in the floral induction period between 2011 and 2018 in the Brazilian semiarid region. The productivity of 'Keitt' mango under the Brazilian semiarid conditions was not related to NBI-DRIS. Nutrient concentration presents positive and significant relationship with the respective DRIS indices, enabling the determination of the balance point, establishing a nutritional standard and enabling the use of foliar diagnosis for the variety. The order of nutrients with the highest frequency of limitations due to lack, in decreasing order, was: Zn > Al > Na > Cu > S > B > Mn > P = K > Fe > Ca > N > Mg, and limitation due to excess, in decreasing order was: Fe > Na > Mg > Al > Cu > B = N > S > Ca > P = K > Zn > Mn.

Index terms: Nutritional diagnosis, Floral induction, *Mangifera indica*.

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Normas DRIS para manga ‘Keitt’ no Semiárido brasileiro: Diagnose e validação

Resumo: Padrões nutricionais com base em dados de longo prazo melhoram o diagnóstico nutricional da cultura, pois tornam as normas mais precisas e estabelecem critérios mais refinados. Objetivou-se avaliar o estado nutricional da cultura da manga utilizando a metodologia DRIS para identificar as limitações nutricionais e para validar as normas. Foi utilizado banco de dados de 202 talhões comerciais, cujas folhas foram coletadas no período de indução floral, entre 2011 e 2018, no Semiárido brasileiro. A produtividade da manga ‘Keitt’, nas condições do Semiárido brasileiro, não foi relacionada com o IBN do DRIS. A concentração dos nutrientes apresenta relação positiva e significativa com os respectivos índices DRIS, possibilitando a determinação do ponto de equilíbrio, estabelecendo um padrão nutricional e viabilizando a utilização da diagnose foliar para a variedade. A ordem de nutrientes com maior frequência de limitações por falta, em ordem decrescente, foi: Zn > Al > Na > Cu > S > B > Mn > P = K > Fe > Ca > N > Mg, e limitantes por excesso, em ordem decrescente, foi: Fe > Na > Mg > Al > Cu > B = N > S > Ca > P = K > Zn > Mn.

Termos para indexação: Diagnose Nutricional, Indução floral, *Mangifera indica*.

Introduction

Productivity variability in perennial crops is mainly affected by plant management and soil fertility conditions. It is necessary to determine the levels of nutrients by diagnostic methods in nutritional composition studies.

Establishing standard reference values for the nutritional status of a crop requires studies that involve variation in soil and climate conditions, so they can be constantly reassessed, generating new information that can be added to the existing data set (PARENT, 2011). Thus, assessing the nutritional status of fruit trees requires better reference standards to be reliable (ROZANE; PRADO, 2020).

Among methods cited in literature, critical level (CL) (ULRICH, 1952), sufficiency range (SR), which uses univariate relationships (DOW; ROBERTS, 1982), diagnosis and recommendation integrated system (DRIS), which uses bivariate relationships (BEAUFILS, 1973) and compositional nutrient diagnosis (CND), which uses multivariate relationships (PARENT; DAFIR, 1992) are widely discussed and applied in different crops.

In mango, Rozane et al. (2007) emphasize that leaf chemical analysis helps in nutritional knowledge and evaluates the result of fertilization based on soil chemical analysis. Wadt and Silva (2020) evaluated the nutritional status of Tommy mangoes using the CND method and reported that it enabled a more efficient fertilization management in commercial orchards.

For this reason, it is necessary to establish nutritional references in specific crops and varieties using tools and methods that compare the results of the foliar contents of samples with adequate nutritional standards obtained in the high-yield population of the crop to be analyzed (FRANCO-HERMIDA et al, 2020).

Thus, with data from the leaf analysis of 'Keitt' mango from commercial plots, the aim was to evaluate the nutritional status of the crop using the DRIS methodology to identify nutritional limitations and validate norms.

Material and Methods

A database of 202 plots was used, whose leaf samples were collected in the floral induction period between 2011 and 2018 from commercial areas in the Brazilian semiarid region, state of Pernambuco. The 'Keitt' mango variety was selected, and leaf samples were collected during the floral induction period. The establishment of the DRIS norms involved the total leaf nutrient contents in $g.kg^{-1}$ for N, P, K, Ca, Mg and S, and in $mg.kg^{-1}$ for B, Cu, Fe, Mn, Zn, Na and Al and crop yield ($Mg.ha^{-1}$).

For the division of the database in reference population or high yield and low yield, Serra et al. (2013) reported that there are several criteria, and in the present study, the yield criterion superior to the average value obtained was established. In order to minimize the flattening effect of data, providing the kurtosis effect, the functions of nutrient ratios were calculated through the logarithm transformation, proposed by Beverly (1987).

The methodology applied to calculate the DRIS indices was the one proposed by Beaufils (1973), which uses all ratios (N/P and P/N):

$$IY = \frac{\sum f\left[\frac{A}{B}\right] - \sum f\left[\frac{A}{B}\right]}{n}$$

Where Y is the nutrient and n is the number of DRIS functions analyzed. To calculate the nutrient balance index - NBI, the sum in modulus of the indices of each nutrient was used:

$$NBI = |IN| + |IP| + |IK| + |ICa| + |IMg| + |IS| + |IB| + |ICu| + |IFe| + |IMn| + |IZn| + |INa| + |IAl|$$

To calculate the average NBI, the criterion proposed by Wadt et al. (1998) was adopted, which uses the sum in modulus of the indices of each nutrient divided by the number of nutrients involved (n):

$$NBI\ mean = \frac{NBI}{n}$$

In order to interpret the NBI, the potential fertilization response (PFR) was used, as established by Wadt (2005), which was defined in 5 classes: (p) positive, (pz) positive or null, (z) null, (nz) negative or null and (n) negative. To facilitate interpretation, classes were grouped according to criteria proposed by Silva et al. (2005) in: (LL) limiting by lack (= p+pz), (NL) non-limiting (= z) and (LE) limiting by excess (= nz+n).

The adherence of PFR classes was calculated by the chi-square test (5%), where its validity is verified if there is total significance between rows and columns, with observed (OF) and expected (EF) frequencies, established according to Urano et al. al. (2006):

$$EF\% = \left[\frac{\frac{Total\ No.of\ plots\ evaluated}{Total\ No.of\ nutrients}}{Total\ No.of\ plots\ evaluated}\right] \times 100$$

$$OF\% = \left[\frac{No.\ of\ plots\ in\ which\ the\ nutrient\ was\ (p)}{No.of\ plots\ evaluated}\right] \times 100$$

To determine the ranges of adequate levels of nutrients, regressions between the levels of each nutrient and their respective DRIS indices were obtained. To establish the critical level, sufficiency ranges were established considering deviations from the zero index plus or minus 2/3 of the standard deviation value obtained for each nutrient, as proposed by Serra et al. (2012).

In order to validate the DRIS diagnostic method, the graphical method of the Cate-

Nelson procedure was applied, which principle is the division of the scatterplot into four quadrants, thus maximizing the number of points in the positive quadrants while minimizing the number of negative quadrants (NELSON; ANDERSON, 1977). Each quadrant represents a class of response to the use of the input and means, as mentioned by Parent et al. (2013):

- True Negative (TN): adequate nutritional status, as the high-yield population was correctly identified as balanced.
- False Positive (FP): nutrient consumption by the plant or exceptionally high efficiency of nutrient use, as the high-yield population was incorrectly identified as unbalanced.
- False Negative (FN): nutritional imbalance caused by at least one nutrient, as the low-yield population was correctly identified as unbalanced.
- True Positive (TP): impact of other limiting factors on crop performance, as the low-yield population was incorrectly identified as balanced.

According to Parent et al. (2013), the interpretation of the procedure should be performed as follows:

- Negative Predictive Value (NPV): probability of a balanced diagnosis returning to high performance, calculated as TN / (TN + FN)
- Positive Predictive Value (PPV): probability of an imbalance diagnosis returning to low performance, calculated as TP / (TP + FP)
- Accuracy (Ac.): probability of an observation being correctly identified as balanced or unbalanced, calculated as (TN + VP) / (TN + FN + TP + FP)
- Specificity (Sp.): probability of a high-yield observation being balanced, calculated as TN / (TN + FP)
- Sensitivity (Sens.): probability of a low-performance observation to be unbalanced, calculated as TP / (TP + FN).

Results and Discussion

Analyzing the total of 202 plots, 82 were classified as high-yield or reference subpopulation, totaling 40.6% of the population, and the rest (59.4%) as low-yield subpopulation.

Table 1 shows the mean values, standard deviation and coefficient of variation of the DRIS norm found, using all Beaufils ratios (N/P and P/N) (1973).

Table 1 – Mean, standard deviation and coefficient of variation of logarithms of nutrient ratios of the reference population.

N/	**P**	**K**	**Ca**	**Mg**	**S**	**B**	**Cu**	**Fe**	**Mn**	**Zn**	**Na**	**Al**
Mean	0.96	0.05	-0.20	0.86	1.00	-0.88	0.05	-0.91	-1.55	-0.68	-1.08	-1.10
Standard deviation	0.17	0.13	0.16	0.14	0.21	0.23	0.27	0.19	0.30	0.25	0.22	0.28
CV %	0.03	0.02	0.03	0.02	0.04	0.05	0.07	0.04	0.09	0.06	0.05	0.08
P/	**N**	**K**	**Ca**	**Mg**	**S**	**B**	**Cu**	**Fe**	**Mn**	**Zn**	**Na**	**Al**
Mean	-0.96	-0.91	-1.16	-0.10	0.04	-1.84	-0.92	-1.88	-2.51	-1.64	-2.05	-2.06
Standard deviation	0.17	0.13	0.15	0.17	0.22	0.23	0.28	0.23	0.30	0.25	0.25	0.28
CV %	0.03	0.02	0.02	0.03	0.05	0.05	0.08	0.05	0.09	0.06	0.06	0.08
K/	**N**	**P**	**Ca**	**Mg**	**S**	**B**	**Cu**	**Fe**	**Mn**	**Zn**	**Na**	**Al**
Mean	-0.05	0.91	-0.25	0.81	0.95	-0.93	0.00	-0.96	-1.60	-0.73	-1.13	-1.15
Standard deviation	0.13	0.13	0.16	0.13	0.19	0.22	0.27	0.18	0.30	0.24	0.23	0.28
CV %	0.02	0.02	0.03	0.02	0.03	0.05	0.07	0.03	0.09	0.06	0.05	0.08

(to be continued)

Table 1 – Mean, standard deviation and coefficient of variation of logarithms of nutrient ratios of the reference population (Continuation).

Ca/	**N**	**P**	**K**	**Mg**	**S**	**B**	**Cu**	**Fe**	**Mn**	**Zn**	**Na**	**Al**
Mean	0.20	1.16	0.25	1.06	1.20	-0.68	0.24	-0.72	-1.35	-0.48	-0.89	-0.90
Standard deviation	0.16	0.15	0.16	0.14	0.22	0.20	0.28	0.21	0.29	0.25	0.22	0.28
CV %	0.03	0.02	0.03	0.02	0.05	0.04	0.08	0.04	0.08	0.06	0.05	0.08
Mg/	**N**	**P**	**K**	**Ca**	**S**	**B**	**Cu**	**Fe**	**Mn**	**Zn**	**Na**	**Al**
Mean	-0.86	0.10	-0.81	-1.06	-0.14	-1.74	-0.82	-1.78	-2.41	-1.54	-1.95	-1.96
Standard deviation	0.14	0.17	0.13	0.14	0.21	0.22	0.29	0.20	0.28	0.26	0.22	0.30
CV %	0.02	0.03	0.02	0.02	0.04	0.05	0.08	0.04	0.08	0.07	0.05	0.09
S/	**N**	**P**	**K**	**Ca**	**Mg**	**B**	**Cu**	**Fe**	**Mn**	**Zn**	**Na**	**Al**
Mean	-1.00	-0.04	-0.95	-1.20	-0.14	-1.88	-0.95	-1.91	-2.55	-1.67	-2.08	-2.10
Standard deviation	0.21	0.22	0.19	0.22	0.21	0.27	0.27	0.24	0.34	0.28	0.27	0.30
CV %	0.04	0.05	0.03	0.05	0.04	0.07	0.07	0.06	0.11	0.08	0.07	0.09
B/	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Cu**	**Fe**	**Mn**	**Zn**	**Na**	**Al**
Mean	0.88	1.84	0.93	0.68	1.74	1.88	0.93	-0.03	-0.67	0.21	-0.20	-0.22
Standard deviation	0.23	0.23	0.22	0.20	0.22	0.27	0.33	0.26	0.32	0.28	0.26	0.28
CV %	0.05	0.05	0.05	0.04	0.05	0.07	0.10	0.07	0.10	0.08	0.07	0.08
Cu/	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**B**	**Fe**	**Mn**	**Zn**	**Na**	**Al**
Mean	-0.05	0.92	0.00	-0.24	0.82	0.95	-0.93	-0.96	-1.60	-0.72	-1.13	-1.15
Standard deviation	0.27	0.28	0.27	0.28	0.29	0.27	0.33	0.28	0.38	0.33	0.35	0.33
CV %	0.07	0.08	0.07	0.08	0.08	0.07	0.10	0.08	0.14	0.11	0.12	0.10
Fe/	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**B**	**Cu**	**Mn**	**Zn**	**Na**	**Al**
Mean	0.91	1.88	0.96	0.72	1.78	1.91	0.03	0.96	0.24	0.24	-0.17	-0.19
Standard deviation	0.19	0.23	0.18	0.21	0.20	0.24	0.26	0.28	0.22	0.22	0.26	0.25
CV %	0.04	0.05	0.03	0.04	0.04	0.06	0.07	0.08	0.05	0.05	0.07	0.06
Mn/	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**B**	**Cu**	**Fe**	**Zn**	**Na**	**Al**
Mean	1.55	2.51	1.60	1.35	2.41	2.55	0.67	1.60	0.63	0.87	0.47	0.45
Standard deviation	0.30	0.30	0.30	0.29	0.28	0.34	0.32	0.38	0.31	0.32	0.33	0.35
CV %	0.09	0.09	0.09	0.08	0.08	0.11	0.10	0.14	0.09	0.10	0.11	0.12
Zn/	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**B**	**Cu**	**Fe**	**Mn**	**Na**	**Al**
Mean	0.68	1.64	0.73	0.48	1.54	1.67	-0.21	0.72	-0.24	-0.87	-0.41	-0.43
Standard deviation	0.25	0.25	0.24	0.25	0.26	0.28	0.28	0.33	0.22	0.32	0.30	0.30
CV %	0.06	0.06	0.06	0.06	0.07	0.08	0.08	0.11	0.05	0.10	0.09	0.09
Na/	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**B**	**Cu**	**Fe**	**Mn**	**Zn**	**Al**
Mean	1.08	2.05	1.13	0.89	1.95	2.08	0.20	1.13	0.17	-0.47	0.41	-0.02
Standard deviation	0.22	0.25	0.23	0.22	0.22	0.27	0.26	0.35	0.26	0.33	0.30	0.30
CV %	0.05	0.06	0.05	0.05	0.05	0.07	0.07	0.12	0.07	0.11	0.09	0.09
Al/	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**B**	**Cu**	**Fe**	**Mn**	**Zn**	**Na**
Mean	1.10	2.06	1.15	0.90	1.96	2.10	0.22	1.15	0.19	-0.45	0.43	0.02
Standard deviation	0.28	0.28	0.28	0.28	0.30	0.30	0.28	0.33	0.25	0.35	0.30	0.30
CV %	0.08	0.08	0.08	0.08	0.09	0.09	0.08	0.10	0.06	0.12	0.09	0.09

Table 2 shows the result of the potential fertilization response, in which it is evident that the highest frequency of positive response (p) was presented by Zn and Al, followed by Cu and S; however, nutrients P and B presented values very close to the others and should not be included in this class. The nutrients that presented low fertilization response (n), that is, found in excess, are: Fe, Cu and Na, respectively.

The chi-square test for nutrient frequencies showed significant effect, indicating that the method was efficient in diagnosing the positive effect of the fertilization response

(TABLE 3). Similar results were found by Politi et al. (2013), applying the test in the mango experiment.

TABLE 2 – Distribution (%), according to criterion established by Wadt (2005), of the potential fertilization response of the 'Keitt' mango crop in the Brazilian semiarid region from the low-yield population.

Nutrient	p[(2)]	pz	z	nz	n
N	6.6	3.3	68.6	14.9	6.6
P	7.4	10.7	65.3	12.4	4.1
K	6.6	11.6	65.3	12.4	4.1
Ca	5.0	6.6	69.4	14.0	5.0
Mg	2.5	6.6	64.5	19.0	7.4
S	10.7	13.2	56.2	11.6	8.3
B	7.4	15.7	55.4	15.7	5.8
Cu	10.7	14.9	50.4	9.1	14.9
Fe	4.1	13.2	48.8	14.0	19.8
Mn	3.3	19.0	69.4	6.6	1.7
Zn	14.0	19.8	53.7	5.8	6.6
Na	7.4	19.8	44.6	15.7	12.4
Al	14.0	18.2	43.0	21.5	3.3

(2) p: positive, with high probability; pz: positive, with low probability; z: null; nz: negative, with low probability; n: negative, with high probability, according to Wadt (2005).

Table 3 – Calculation of the chi-square distribution of the frequency of 'Keitt' mango leaf samples from the low-yield population [(1)].

Nutrient	OF [(3)]	FE	$(OF\text{-}EF)^2/EF$
N	6.6	7.7	0.2
P	7.4	7.7	0.0
K	6.6	7.7	0.2
Ca	5.0	7.7	1.0
Mg	2.5	7.7	3.5
S	10.7	7.7	1.2
B	7.4	7.7	0.0
Cu	10.7	7.7	1.2
Fe	4.1	7.7	1.6
Mn	3.3	7.7	2.5
Zn	14.0	7.7	5.3
Na	7.4	7.7	0.0
Al	14.0	7.7	5.3
	Chi-square		**21.91 ****

(1) With response potential to positive and very likely fertilization (p), according to Wadt (2005). (3) OF and EF correspond to observed and expected frequencies, respectively. ** Significant at 1%.

The analysis of nutritional class found the following nutrients limiting due to lack, in decreasing order of frequency: Zn > Al > Na > Cu > S > B > Mn > P = K > Fe > Ca > N > Mg, and limiting due to excess, in decreasing order: Fe > Na > Mg > Al > Cu > B = N > S > Ca > P = K > Zn > Mn (TABLE 4). Fe excess result corroborates findings by Silva et al. (2004) in 'Tommy Atkins' mango. Similarly, Raj and Rao (2006), in a long-term experiment with mango, found that the most limiting nutrients by the DRIS method were Fe and Zn.

Table 4 – Frequency distribution of 'Keitt' mango leaf samples into nutritional classes defined by the DRIS method, from the low-yield population.

Nutrient	LL[(1)]	NL	LE	Total
N	9.9	68.6	21.5	100
P	18.2	65.3	16.5	100
K	18.2	65.3	16.5	100
Ca	11.6	69.4	19.0	100
Mg	9.1	64.5	26.4	100
S	24.0	56.2	19.8	100
B	23.1	55.4	21.5	100
Cu	25.6	50.4	24.0	100
Fe	17.4	48.8	33.9	100
Mn	22.3	69.4	8.3	100
Zn	33.9	53.7	12.4	100
Na	27.3	44.6	28.1	100
Al	32.2	43.0	24.8	100

(1) LL- limiting due to lack; NL- non-limiting; LE- limiting due to excess.

Figure 1 shows the graph of the relationship between average NBI and yield, showing linear equation, significant at 1%, with determination coefficient equal to 5% (R^2=0.059). Similar result (R^2=0.003) was found by Santos (2016) for atemoya crop, whereas Souza et al. (2013) obtained determination coefficient of 42% for guava crop.

In view of the above, it is clear that the average NBI mean did not provide the necessary information to determine whether crop production is significantly associated with the nutritional balance index calculated by the

DRIS method. Even if plots are managed in a uniform way, as they belong to a single company, there was variation according to the years under analysis.

However, when relating the DRIS index with the concentrations of the respective nutrients, determination coefficients above 53% for macronutrients were observed, being 76% for S (FIGURE 2) and above 65% for micronutrients, being 76% for Zn and Fe (FIGURE 3).

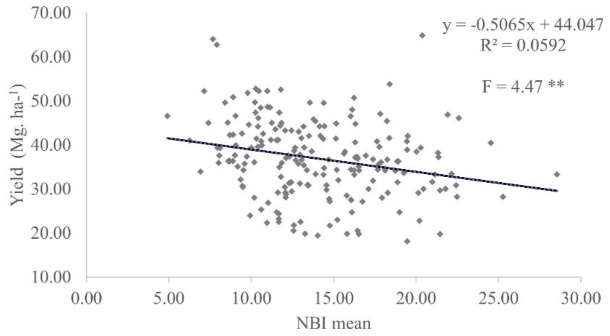

Figure 1 – Relationship between average NBI mean values and yield of 'Keitt' mango orchards in the Brazilian semiarid region.
** Significant at 1%.

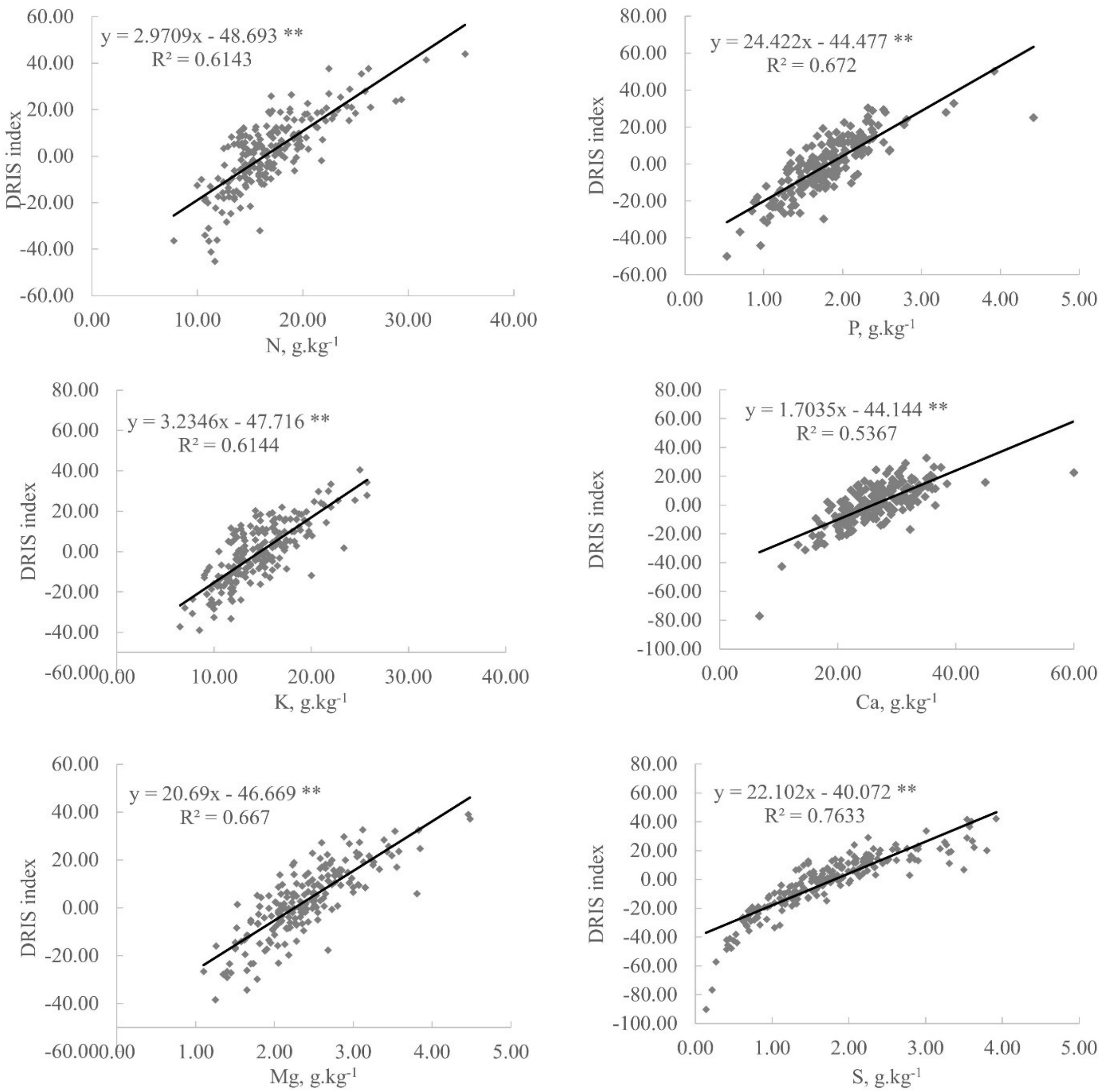

Figure 2 – Relationship between DRIS indices and the concentration of macronutrients in 'Keitt' mango leaves.
** Significant at 1%.

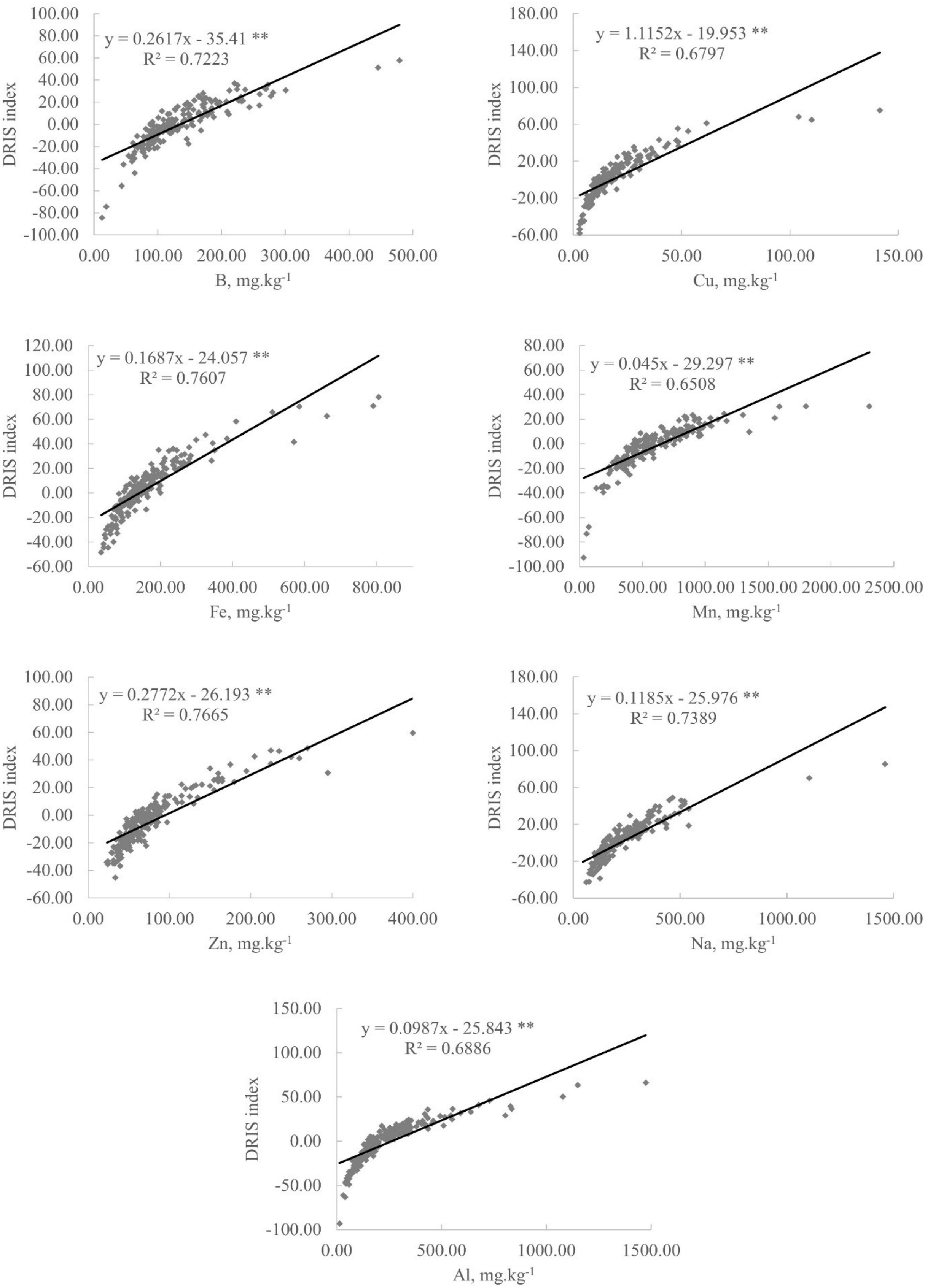

Figure 3 – Relationship between DRIS indices and the concentration of micronutrients in 'Keitt' mango leaves.
** Significant at 1%.

Considering that the plant is in nutritional balance when the DRIS index value approaches zero (WALWORTH; SUMMER, 1987), a DRIS nutritional balance point was determined, equating the graph equation to zero (TABLE 5).

Table 5 - DRIS nutritional balance point for nutrients of the 'Keitt' mango crop in the Brazilian semiarid region.

Nutrient	DRIS nutritional balance point (1)
N ($g.kg^{-1}$)	16.4
P ($g.kg^{-1}$)	1.8
K ($g.kg^{-1}$)	14.8
Ca ($g.kg^{-1}$)	25.9
Mg ($g.kg^{-1}$)	2.3
S ($g.kg^{-1}$)	1.8
B ($mg.kg^{-1}$)	135.3
Cu ($mg.kg^{-1}$)	17.9
Fe ($mg.kg^{-1}$)	142.6
Mn ($mg.kg^{-1}$)	651.0
Zn ($mg.kg^{-1}$)	94.5
Na ($mg.kg^{-1}$)	219.2
Al ($mg.kg^{-1}$)	261.8

(1) Nutrient concentration in leaves of nutritionally balanced 'Keitt' mango plants.

The sufficiency range and adequate content of DRIS results were compared with literature data, and it was observed that there was a difference in amplitudes (TABLE 6). The results show smaller amplitude of the DRIS sufficiency range for K, Ca, Mg, Cu, and Zn when compared to literature. Analyzing the appropriate content, only Mn, B and K, DRIS had its highest values, the others being very close to those of literature.

Data referring to Al and Na are not reported in diagnostic studies, although Al is considered a toxic element for plants, some biochemical mechanisms can give plants the ability to inactivate or store aluminum in leaves in non-toxic forms (SILVA et al., 1984). In regions such as the semiarid, Na is frequently analyzed in order to detect the occurrence of the soil salinization process. The excess of salts severely limits agricultural production, especially in arid and semiarid regions, where about 25% of the irrigated area is salinized (FAO, 2011).

In Figure 4, the result of the application of the Cate-Nelson procedure is presented, where the general nutritional balance indices are related to the entire sample set of the 'Keitt' mango crop yield.

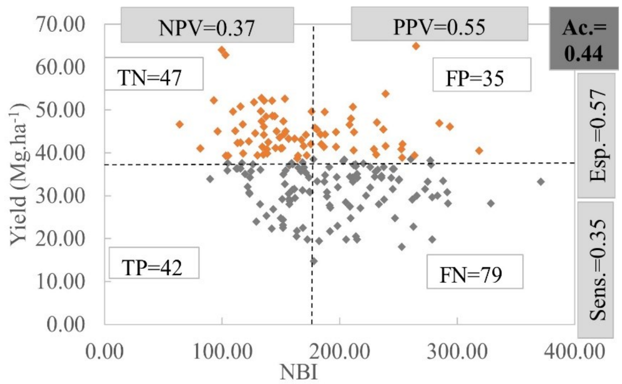

Figure 4 – Cate-Nelson partitioning for the relationship between NBI and yield for the 202 'Keitt' mango plots. NPV = Negative Predictive Value; PPV = Positive Predictive Value; TN = True Negative; FP = False Positive; TP = True Positive; FN = False Negative; Ac. = Accuracy; Esp. = Specificity; Sens. = Sensitivity.

Accuracy, which represents the probability level of the observation being correctly identified as balanced or unbalanced, presented value of 44% (FIGURE 4). Parent et al. (2013) found values of 92% for mango crop using CND. In literature, ideal values above 50% (BEVERLY; HALLMARK, 1992) or above 68% (WADT; LEMOS, 2010) are reported.

As for specificity and sensitivity, the values obtained were 57 and 34%, respectively (FIGURE 4). In the work developed by Meneses et al. (2017) with sweet corn crop, specificity of 95% and sensitivity of 45% were obtained.

Table 6 – Nutrient distribution range in "Keitt" mango leaves established by the DRIS norm calculation and literature.

Nutrient	Method	Adequate range	Adequate content
N	DRIS	13.7 - 19.1	16.4
	Quaggio et al. (1996)	12.0 - 14.0	-
	Medeiros et al. (2005)	-	12.9
	Araújo (2010)	-	13.8
P	DRIS	1.5 - 2.1	1.8
	Quaggio et al. (1996)	0.8 - 1.6	-
	Medeiros et al. (2005)	-	1.2
	Araújo (2010)	-	1.0
K	DRIS	12.4 - 17.2	14.8
	Quaggio et al. (1996)	5.0 - 10.0	-
	Medeiros et al. (2005)	-	6.9
	Araújo (2010)	-	8.5
Ca	DRIS	21.8 - 30.0	25.9
	Quaggio et al. (1996)	20 - 35	-
	Medeiros et al. (2005)	-	41.4
	Araújo (2010)	-	23.4
Mg	DRIS	1.9 - 2.7	2.3
	Quaggio et al. (1996)	2.5 - 5.0	-
	Medeiros et al. (2005)	-	4.0
	Araújo (2010)	-	2.4
S	DRIS	1.3 - 2.3	1.8
	Quaggio et al. (1996)	0.8 - 1.8	-
	Medeiros et al. (2005)	-	-
	Araújo (2010)	-	0.7
B	DRIS	93.2 - 177.4	135.3
	Quaggio et al. (1996)	50.0 - 100.0	-
	Medeiros et al. (2005)	-	-
	Araújo (2010)	-	82.7
Cu	DRIS	7.1 - 28.7	17.9
	Quaggio et al. (1996)	10.0 - 50.0	-
	Medeiros et al. (2005)	-	78.0
	Araújo (2010)	-	12.3
Fe	DRIS	68.4 - 216.8	142.6
	Quaggio et al. (1996)	50.0 - 200.0	-
	Medeiros et al. (2005)	-	114.0
	Araújo (2010)	-	84.5
Mn	DRIS	451.1 - 850.9	651.0
	Quaggio et al. (1996)	50.0 - 100.0	-
	Medeiros et al. (2005)	-	189.0
	Araújo (2010)	-	174.1
Zn	DRIS	53.0 - 136.0	94.5
	Quaggio et al. (1996)	20.0 - 40.0	-
	Medeiros et al. (2005)	-	96.0
	Araújo (2010)	-	28.6
Na	DRIS	116.5 - 321.9	219.2
	Quaggio et al. (1996)	-	-
	Medeiros et al. (2005)	-	-
	Araújo (2010)	-	-
Al	DRIS	132.4 - 391.2	261.8
	Quaggio et al. (1996)	-	-
	Medeiros et al. (2005)	-	-
	Araújo (2010)	-	-

DRIS, floral induction phase; Quaggio et al. (1996), flowering phase; Medeiros et al. (2005), pre-flowering phase; Araújo (2010), pre-flowering phase.

For the high-yield population (82 plots), 47 were correctly identified with adequate nutritional status (TN) and 35 were incorrectly identified (FP). As for the low-yield population (121 stands), 41 were correctly identified as unbalanced (TP), where at least one nutrient is affecting yield, while 79 were impacted by other factors limiting crop performance, not nutritional (FN) (FIGURE 4).

Conclusions

The yield of 'Keitt' mango under the Brazilian semiarid conditions was not related to NBI-DRIS.

Nutrient concentration has positive and significant relationship with the respective DRIS indices, enabling the determination of the balance point, establishing a nutritional standard and enabling the use of foliar diagnosis for the variety.

The order of nutrients with the highest frequency of limitations due to lack, in decreasing order was: Zn > Al > Na > Cu > S > B > Mn > P = K > Fe > Ca > N > Mg, and due to excess in decreasing order was: Fe > Na > Mg > Al > Cu > B = N > S > Ca > P = K > Zn > Mn.

References

ARAÚJO, J.J.de. **Avaliação do estado nutricional da mangueira Tommy Atkins irrigada no Vale do Açu em diferentes épocas de amostragem foliar**. 2010. (Mestrado em Irrigação e Drenagem) - Universidade Federal Rural do Semi-Árido, Mossoró, 2010.

BEAUFILS, E.R. Diagnosis and recommendation integrated system (DRIS). A general scheme for experimentation and calibration based on principles developed from research in plant nutrition. **Soil Science Bulletin**, Pietermararitzburg, v 1, p.132, 1973.

BEVERLY, R.B. Comparison of DRIS and alternative nutrient diagnostic methods for soybean. **Journal of Plant Nutrition**, Abingdon, v.10, p.901-920, 1987.

BEVERLY, R.B.; HALLMARK, W.B. Prescient diagnostic analysis: a proposed new approach to evaluating plant nutrient diagnostic methods. **Communications in Soil Science and Plant Analysis**, Basingstoke, v.23, p.2633-2640, 1992.

DOW, A.I.; ROBERTS, S. Proposal: critical nutrient ranges for crop diagnosis. **Agronomy Journal**, Madison, v.74, p.401–403.1982.

FAO - Food and Agriculture Organization of the United Nations. **The state of the world’s land and water resources for food and agriculture**. Roma, 2011.

FRANCO-HERMIDA, J.J.; QUINTERO-CASTELLANOS, M.F.; GUZMÁN, A.I.; GUZMÁN, M.; CABRERA, R.I. Validating integrative nutrient diagnostic norms for greenhouse cut-roses. **Scientia Horticulturae**, New York, v.264, n.109094, 2020.

MEDEIROS, A.A; AMORIM, J.R.A.de; SILVA, D.J; GUEDES, F.X; GUERRA, A.G; DANTAS, J.A. **Composição mineral de folhas e exportação de nutrientes pelos frutos de mangueira, em cultivo irrigado, no Rio Grande do Norte**. Natal: Emparn, 2005. 13 p.(Boletim de Pesquisa e Desenvolvimento, 30).

MENESES, N.B. **Diagnóstico do estado nutricional do milho-doce**. 2017. Tese (Doutorado em Agronomia) - Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista, Jaboticabal, 2017.

NELSON, L.A.; ANDERSON, R.L. Partitioning of soil test-crop response probability. *In*: PECK T.R.; COPE-JUNIOR, J.T.; WHITNEY, D.A. (ed.). **Soil testing**: correlating and interpreting the analytical results. Madison: American Society of Agronomy, Crop Science Society of America, 1977.

PARENT, L.E. Diagnosis of the nutrient compositional space of fruit crops. **Revista Brasileira de Fruticultura**, Jaboticabal, v.33, n.1, p.321-334, 2011.

PARENT, S.E.; PARENT, L.E.; ROZANE, D.E.; NATALE, W. Plant ionome diagnosis using sound balances: case study with mango (*Mangifera indica*). **Frontiers in Plant Science**, Lausanne, v.4, n.39, p.1-10, 2013.

PARENT, L.E.; DAFIR, M. A theoretical concept of compositional nutrient diagnosis. **Journal of the American Society for Horticultural Science**, Alexandria, v.117, p.239-242, 1992.

POLITI, L.S.; FLORES, R.A.; SILVA, J.A.S.; WADT, P.G.S.; PINTO, P.A.C.; PRADO, R.M. Estado nutricional de mangueiras determinado pelos métodos DRIS e CND. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v.17, p.11-18, 2013.

QUAGGIO, J.A.Adubação e calagem para a mangueira e qualidade dos frutos. *In*: SÃO JOSÉ, A.R.; SOUZA, I.V.B.; MARTINS FILHO, J.; MORAIS, O.M. (ed.) **Manga**: tecnologia de produção e mercado.Vitória da Conquista: UESB, 1996. p.106-135.

RAJ.G.B.; RAO.A.P. Identificação de nutrientes limitadores de rendimento em manga através de índices DRIS. **Communications in Soil Science and Plant Analysis**, Basingstoke, v.37, p.1761-1774, 2006.

ROZANE, D.E.; NATALE, W.; PRADO, R.DE.M.; BARBOSA, J.C. Amostragem para diagnose do estado nutricional de mangueiras. **Revista Brasileira de Fruticultura**, Jaboticabal, v.29, n.2, p.371-376, 2007.

ROZANE, D.E.; PRADO, R. de M. **Fruit crops**: diagnosis and management of nutrient constraints. Amsterdam: Elsevier. 2020. Disponível em: https://books.google.com.br/books?id=1RbB-DwAAQBAJ&pg=PA143&lpg=PA143&dq=diagnose+da+composi%C3%A7%C3%A3o+nutricional+da+manga&source=bl&ots=cmlSFfEW4T&sig=ACfU3U12UOXRbsG7ju-IyPCFNkRw1dZEt4A&hl=ptBR&sa=X#v=onepage&q&f=false. Acesso em: 03 abr 2020.

SANTOS, E.M.H dos. **Diagnose da composição nutricional (CND) para a cultura da Atemoia**. 2016. Dissertação (Mestrado em Ciência do Solo) - Universidade Federal do Paraná, Curitiba, 2016.

SERRA, A.P.; MARCHETTI, M.E.; ROJAS, E.P.; VITORINO, A.C.T. Beaufils ranges to assess the cotton nutrient status in the southern region Mato Grosso. **Revista Brasileira de Ciência do Solo**, Viçosa, MG, v.36, p.171-181, 2012.

SERRA, A.P.; MARCHETTI, M.E.; ROJAS, E.P.; MORAIS, H.S.de.; CONRAD, V.D.A.; GUIMARÃES, F.C.N. Estabelecimento de normas DRIS para o algodoeiro com diferentes critérios de seleção da população de referência. **Pesquisa Agropecuária Brasileira,** Brasília, DF, v.48, p.1472-1480, 2013.

SILVA, D.R.; PEREIRA, R.; MOUCO, M.A.; ALBUQUERQUE, A.S. de.; RAIJ, B.; SILVA, C.A. **Nutrição mineral e adubação da mangueira em condições irrigadas**. Petrolina: Embrapa Semiárido, 2004. 13 p. (Circular Técnica, 77).

SILVA, G.G.C., NEVES, J.C.L.; ALVAREZ, V.H. Avaliação da universalidade das normas DRIS, M- DRIS e CND. **Revista Brasileira de Ciência do Solo**, MG, Viçosa, v.29, p.755-761, 2005.

SILVA, J.B.C.; NOVAIS, R.F.; SEDIYAMA, C.S. Identificação de genótipos de sorgo tolerantes a toxicidade de alumínio. **Revista Brasileira de Ciência do Solo**, Viçosa, MG, v.8, p.77-83, 1984.

SOUZA, H.A.; ROZANE, D.E.; AMORIM, D.A de.; NATELE, W. Normas preliminares DRIS e faixas de suficiência para goiabeira ‘Paluma’. **Revista Brasileira de Fruticultura**, Jaboticabal, v.35, n.1, p.282-291, 2013.

ULRICH, A. Physiological bases for assessing the nutritional requirements of plants. **Annual Review of Plant Physiology**, Palo Alto, v 3, p.207–228.1952.

URANO, EM.O.; KURIHARA, C.H.; MAEDA, S.; VITORINO, A.C.T.; GONÇALVES, M.C.; MARCHETTI, M.C. Avaliação do estado nutricional da soja. **Pesquisa Agropecuária Brasileira**, Brasília, DF, v.41, p.1421-1428, 2006.

WADT, P.G.S.; NOVAIS, R.F.; ALVAREZ, V.H.; FONSECA, S.; BARROS, N.F.; DIAS, L.E. Três métodos de cálculo do DRIS para avaliar o potencial de resposta à adubação de árvores de eucalipto. **Revista Brasileira de Ciência do Solo**, Viçosa, MG, v.22, p.661-666, 1998.

WADT, P.G.S. Relationships between soil class and nutritional status of coffee plantations. **Revista Brasileira de Ciência do Solo**, Viçosa, MG, v.29, p.227-234, 2005.

WADT, P.G.S.; LEMOS, C.O. Medidas de acurácia para diagnósticos nutricionais e seu impacto no manejo das adubações. *In*: PRADO, R. de M.; CECÍLIO FILHO, A.B.; CORREIA, M.A.R.; PUGA, A.P. (ed.). **Nutrição de plantas**: diagnose foliar em hortaliças. Jaboticabal: Funep, 2010. p.213-236.

WADT, P.G.S.; SILVA, D.J. **Normas multivariadas para avaliação do estado nutricional de mangueiras cultivar Tommy Atkins, pelo método da composição da diagnose nutricional**. Rondônia: EMBRAPA, 2020. (Comunicado Técnico, 412)

WALWORTH, J.L.; SUMNER, M.E. The diagnosis and recommendation integrated system (DRIS). **Advances in Soil Science**, New York, v.6, p.150-188, 1987.