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CROP PRODUCTION

Establishment of DRIS standards and sufficiency range for 'nanica' banana trees in Vale do Ribeira

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ABSTRACT. For a banana tree to reach its productive potential, plants must be nutritionally balanced. Therefore, it is important to use methods that diagnose the nutritional status of plants through chemical leaf analysis, considering the relationships between nutrients and taking advantage of productivity and nutritional monitoring data from orchards. This study aimed to establish norms and ranges of nutrient sufficiency for 'Nanica' banana trees in Vale do Ribeira, São Paulo state, using the Diagnosis and Recommendation Integrated System (DRIS) method. Productivity data and chemical analysis of the leaf tissue of 291 commercial plots of Nanica banana trees, collected between 2015 and 2020 in Vale do Ribeira, were used. The DRIS method was used to establish norms and sufficiency ranges for N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, and Zn. Fruit yield did not correlate with the average nutritional balance index (NBI_a), indicating that its variation was affected by non-nutritional factors. The contents of K, Ca, Mg, S, B, Cu, Fe, Mn, and Zn showed high correlations with their respective nutritional indices. The sufficiency ranges and adequate nutrient contents differed from the values established for bananas in the literature.

Keywords: *Musa* spp.; nutritional balance; leaf diagnosis; bivariate method.

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Introduction

Banana is a fruit of great social and economic importance in many countries, being the most produced in the world, at 125 million tons per year (Food and Agriculture Organization of the United Nations [FAO], 2021). In Brazil, the state of São Paulo has high fruit production, corresponding to 1 million tons or to 26.3% of the total produced in the country (Instituto Brasileiro de Geografia e Estatistica [IBGE], 2022). In this state, the Vale do Ribeira region contributes 72% (768 thousand tons) of fruit production, with an average annual yield of 21.1 t ha^{-1} (Instituto de Economia Agricola [IEA], 2021), being one of the largest and most important producing regions of banana in Brazil.

For the banana tree to reach its productive potential, it is necessary for the plant to be nutritionally balanced, among other factors (Deus et al., 2018; Silva & Carvalho, 2006). Therefore, it is necessary to identify the nutrients that limit the growth, development and production of the crop and provide them in adequate amounts and proportions (Deus et al., 2018; Lima Neto, Natale, Rozane, Deus, & Rodrigues Filho, 2022; Lima Neto, Neves, Martinez, Sousa, & Fernandes, 2020; Silva, Pacheco, & Costa, 2007). Thus, the evaluation of nutritional status using chemical leaf analysis is a useful tool for adjusting the supply of nutrients to the plant, since the leaf is considered the center of physiological activity, reflecting its nutritional status in general (Rozane, Parent, & Natale, 2016).

The interpretation of the results of the leaf chemical analyses can be performed by univariate, bivariate and multivariate methods. Among them, a bivariate method, the Integrated Diagnosis and Recommendation System (DRIS), proposed by Beaufils (1973), stands out for using data from nutritional monitoring (leaf analysis) and the production of commercial orchards, covering the variability of different environmental conditions and management (Rodríguez & Rodríguez, 2000). Another advantage of this method is its consideration of the relationships between pairs of nutrients analyzed in the sample and comparison of them with norms established in high productivity plots, generating indices that may indicate deficiency (negative values), nutritional balance (null values) or excess (positive values) for each nutrient (Guindani, Anghioni, & Nachtigall, 2009).

DRIS standards for banana cultivation have been established over the years, considering different cultivars and locations (Angeles, Sumner, & Lahav, 1993; Lima Neto et al., 2022; Teixeira, Zambrosi, & Bettiol Neto, 2007; Villaseñor, Prado, Silva, Carrilo, & Durango, 2020; Wairegi & Van Asten, 2011). However, research indicates that there is no temporal and/or local universality for standards, and the use of current and specific standards for each producing region is a way to obtain more accurate nutritional diagnoses (Gott et al., 2014; Lima Neto et al., 2022; Silva, Neves, Alvarez, & Leite, 2005; Rocha, Leandro, Rocha, Santana, & Andrade, 2007; Wairegi & Van Asten, 2011).

The establishment of norms and specific nutritional ranges for 'Nanica' banana trees in the Vale do Ribeira will enable the producer to be more accurate in diagnosing the nutritional status of the crop, considering the management characteristics, cultivar, soil and climate of the region. Thus, the aim of the study was to establish DRIS norms and nutrient sufficiency ranges for Nanica banana trees in Vale do Ribeira.

Material and methods

This study was carried out with data from 291 plots collected between 2015 and 2020 in commercial non-irrigated areas of Nanica banana production in the Vale do Ribeira region, state of São Paulo, Brazil. The climate in this region is Af or tropical humid without a dry season, according to the Köppen Classification System (Alvares, Stape, Sentelhas, Gonçalves, & Sparovek, 2013).

In each sampling unit (plots), leaf sampling was carried out following the recommendations proposed by the International Reference Sampling Method (MEIR). The third leaf (f3) was collected from the apex when the inflorescence presented all female bunches without bracts and with two or three open male bunches; a central strip 0.10 m wide was removed and the midrib and peripheral halves were removed (Martin-Prével, 1984).

Leaves were gently washed successively with distilled water, detergent solution (0.1%), hydrochloric acid solution (0.3%), and deionized water to reduce surface contamination by dust and fungicides. The samples were oven-dried at 65°C for 48–96h and ground to less than 0.841 mm (20 mesh). Nitrogen (N) was analyzed using the micro-Kjeldahl method. Phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), boron (B), copper (Cu), zinc (Zn), manganese (Mn), and iron (Fe) were quantified using a Perkin Elmer AA400 Atomic Absorption Spectrophotometer after acid digestion according to the methodology described by Bataglia, Teixeira, Furlani, Furlani, and Gallo (1983).

The soils that predominate in the region (Rossi, 2017) are classified as Haplic Cambisols eutrophic and have CEC ranging from 57 to 192 $mmol_c\ dm^{-3}$ compared to 70 - 880 $mmol_c\ dm^{-3}$ for eutrophic Argisols, indicating a great variation in the clay and organic matter content (Gotardo, Pereira, Kaufmann, Torres, & Piazza, 2020; Soares & Alleoni, 2008).

To establish the DRIS norms, yield data ($Mg\ ha^{-1}$) and leaf content of N, P, K Ca, Mg, and S ($g\ kg^{-1}$) and B, Cu, Fe, Mn, and Zn ($mg\ kg^{-1}$) were used. The database was divided into high population (reference population) and low yield using the average yield of the database, as used by Santos and Rozane (2017).

The mean and standard deviation (DRIS norms) of the dual logarithmic ratios of the reference population were calculated, as proposed by Beverly (1987), using the equation proposed by Beaufils (1973):

$$I_x = \frac{\sum f\left[\frac{X}{Y}\right] - \sum f\left[\frac{Y}{X}\right]}{n + m}$$

where I_x – nutritional index of nutrient x; $f\left[\frac{X}{Y}\right]$ – direct function of the ratio between two nutrients; $f\left[\frac{Y}{X}\right]$ – inverse function of the ratio between two nutrients; n – number of direct relationships evaluated; m – number of inverse relations evaluated.

The average nutritional balance index (NBI_a) was obtained by the quotient of the sum in the module of the indices of each nutrient and the total number of nutrients analyzed:

$$NBI_a = \frac{|I_N| + |I_P| + |I_K| + |I_{Ca}| + \cdots + |I_{Zn}|}{n}$$

A mathematical model was adjusted between yield and NBI_a to generate the coefficient of determination (R^2), which determined how much yield was explained by nutritional factors (Souza, Rozane, Amorim, & Natale, 2013; Teixeira et al., 2007).

The nutritional indices obtained were interpreted by the Fertilizer Response Potential (FRP), as proposed by Wadt (2005), in five classes: positive (p), positive or null (nz), null (z), negative or null (nz), and negative (n). The observed frequencies (FO) of each nutrient in each FRP class were obtained by counting the number of observations of their occurrences in relation to the index values obtained for all nutrients. The expected frequencies (FE) of each nutrient in each class were obtained by the quotient between the total number of plots and the number of evaluated nutrients. FO and FE were submitted to the chi-square test at 5% probability, with n−1 degrees of freedom.

The levels and sufficiency ranges of nutrients considered adequate for N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, and Zn were determined as recommended by Lima Neto et al. (2022), Rodrigues, Silva, Rozane, Natale, and Silva (2022), Rozane et al. (2020), and Souza et al. (2015). The contents of each nutrient were related to their respective indices, and subsequently, regression equations were adjusted that best represented the relationship between the data. To establish adequate nutritional levels, the indices (y-axis) were equal to zero, and the content of each nutrient was calculated under the conditions of nutritional balance (index zero). The lower (LI) and upper (LS) limits of the sufficiency ranges were determined by the appropriate level value ± 2⁄3 of the standard deviation of the total population.

Results and discussion

Descriptive statistics (minimum, maximum, mean, standard deviation and coefficient of variation) of the nutrient content evaluated in the subpopulations of high and low yields are presented in Table 1. K was the macronutrient with the greatest variability, both in the high-yield (29.2%) and low-yield populations (26.9%). This variation, in part, was attributed to differences in the management of potassium fertilization adopted by producers at different doses and times of the year. With regard to micronutrients, Mn had the highest coefficient of variation in the high-yield (58.2%) and low-yield populations (64.0%), which can also be related to pesticide management, as demonstrated by Rozane, Mattos, Parent, Natale, and Parent (2015) and Yamane et al. (2022).

Table 1. Minimum (min.), maximum (max.), mean ($\bar{m}$), standard deviation (s) and coefficient of variation (CV) values of leaf nutrient content and yield obtained from high and low yield plots of 'Nanica' banana trees in the Vale do Ribeira, São Paulo State, Brazil.

High-Yield Subpopulation (n = 126)						
Variable	N	P	K	Ca	Mg	S
	g kg^{-1}					
min.	18.9	1.6	16.3	2.0	1.6	1.4
max.	39.3	2.7	82.5	14.3	4.5	3.6
$\bar{m}$	26.4	2.1	34.8	7.5	2.9	2.1
s	3.3	0.2	10.1	1.7	0.5	0.4
CV (%)	12.3	10.7	29.2	23.1	15.9	19.5
	B	Cu	Fe	Mn	Zn	Yield
	mg kg^{-1}					Mg ha^{-1}
mín.	4.1	4.0	40.0	27.0	10.0	34.6
máx.	46.0	27.0	250.0	950.0	32.0	65.9
$\bar{m}$	12.5	9.2	123.2	319.1	20.6	42.2
s	4.4	2.7	35.4	185.8	3.6	4.2
CV (%)	35.0	28.8	28.7	58.2	17.5	9.8
Low-Yield Subpopulation (n = 165)						
	N	P	K	Ca	Mg	S
	g kg^{-1}					
min.	18.9	1.6	15.8	2.0	1.4	1.3
max.	38.2	2.7	49.9	12.8	4.9	3.3
$\bar{m}$	26.8	2.2	33.9	7.6	3.0	2.1
s	3.3	0.2	9.1	1.9	0.6	0.4
CV (%)	12.4	11.1	26.9	25.1	19.1	20.2
	B	Cu	Fe	Mn	Zn	Yield
	mg kg^{-1}					Mg ha^{-1}
min.	3.7	3.3	10.0	32.0	11.0	13.1
max.	80.0	16.0	670.0	1454.0	30.0	32.6
$\bar{m}$	13.1	8.4	124.0	279.5	20.2	25.4
s	8.0	2.0	75.9	178.9	3.4	5.1
CV (%)	61.0	24.1	61.2	64.0	17.0	20.0

The order of variation observed in the mean leaf nutrient content in the low-yield population was Mn>Fe>B>K>Ca>Cu>S>Mg>Zn>N>P. In general, micronutrients showed greater variability, with Mn and Zn showing the highest and lowest values, respectively. The greatest variation for micronutrients corroborates that found by Lima Neto et al. (2022) on ‘Prata’ banana leaves in Ceará.

The greatest variations in the micronutrient content in the leaf, in part, are attributed to their great variation in the soil, as also observed by Guimarães and Deus (2021). The authors also attributed this to the variability that occurs depending on the period in which the collection takes place, as observed by Costa et al. (2019) when evaluating the variation in nutrient content in diagnostic banana leaves in winter and summer, as well as by cultural practices, especially phytosanitary practices (Rozane et al., 2015; Yamane et al., 2022).

The observed variation in productivity may be a result of the variability in the physical and chemical characteristics of the soil in the study region (Gotardo et al., 2020; Rossi, 2017; Soares & Alleoni, 2008). Another likely explanation can be found in Rozane, Natale, Prado, and Barbosa (2009), who indicated that water is a means of transporting nutrients to plants and a vehicle for greater nutritional stabilization. Machado, Prata Neto, and Coelho (2004) reported an even greater concentration of root volume and an increase in the number of rootlets in the irrigated area of citrus orchards managed with localized irrigation; thus, a more constant and uniform absorption may occur over time in irrigated areas, whereas in non-irrigated areas, such as the one in the present study, this would not occur. It adds to the different management employed by different products at the most diverse technological levels.

The average yield obtained was 32.7 Mg ha^{-1}, and of the 291 plots evaluated, 126 plots (43.3%) were classified as a high-yield subpopulation (reference population) and 165 plots (56.7%) as low yield. The cut-off point obtained was lower than the 45.0 Mg ha^{-1} found by Teixeira et al. (2007) when establishing DRIS standards for bananas from the Cavendish subgroup grown in Planalto Paulista and Vale do Ribeira; however, the authors did not describe the methodology used to obtain the cut-off point.

Subsequently, the mean and standard deviation of the dual logarithmic ratios between the nutrients, which correspond to the DRIS norms, of the high-yield population were calculated (Table 2).

Table 2. Mean (m̄) and standard deviation (s) (DRIS norms) of the dual logarithmic relationships between leaf nutrient contents obtained from high-yield plots (n = 126) of Nanica banana trees in Vale do Ribeira, São Paulo State, Brazil.

N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
m̄	1.09	−0.10	0.56	0.96	1.09	0.34	0.47	−0.65	−1.00	0.11
s	0.06	0.14	0.11	0.09	0.10	0.14	0.11	0.13	0.30	0.09
P	N	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
m̄	−1.09	−1.20	−0.54	−0.13	0.002	−0.75	−0.63	−1.75	−2.10	−0.98
s	0.06	0.14	0.11	0.08	0.08	0.14	0.11	0.13	0.30	0.09
K	N	P	Ca	Mg	S	B	Cu	Fe	Mn	Zn
m̄	0.10	1.20	0.66	1.07	1.20	0.45	0.57	−0.55	−0.90	0.22
s	0.14	0.14	0.17	0.15	0.16	0.18	0.17	0.19	0.32	0.15
Ca	N	P	K	Mg	S	B	Cu	Fe	Mn	Zn
m̄	−0.56	0.54	−0.66	0.41	0.54	−0.21	−0.09	−1.21	−1.56	−0.44
s	0.11	0.11	0.17	0.11	0.13	0.16	0.17	0.16	0.33	0.14
Mg	N	P	K	Ca	S	B	Cu	Fe	Mn	Zn
m̄	−0.96	0.13	−1.07	−0.41	0.13	−0.62	−0.49	−1.62	−1.96	−0.85
s	0.09	0.08	0.15	0.11	0.10	0.14	0.13	0.13	0.29	0.10
S	N	P	K	Ca	Mg	B	Cu	Fe	Mn	Zn
m̄	−1.09	−0.002	−1.20	−0.54	−0.13	−0.75	−0.63	−1.75	−2.10	−0.98
s	0.10	0.08	0.16	0.13	0.10	0.16	0.12	0.15	0.30	0.10
B	N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn
m̄	−0.34	0.75	−0.45	0.21	0.62	0.75	0.13	−1.00	−1.34	−0.23
s	0.14	0.14	0.18	0.16	0.14	0.16	0.18	0.17	0.33	0.14
Cu	N	P	K	Ca	Mg	S	B	Fe	Mn	Zn
m̄	−0.47	0.63	−0.57	0.09	0.49	0.63	−0.13	−1.12	−1.47	−0.36
s	0.11	0.11	0.17	0.17	0.13	0.12	0.18	0.15	0.29	0.11
Fe	N	P	K	Ca	Mg	S	B	Cu	Mn	Zn
m̄	0.65	1.75	0.55	1.21	1.62	1.75	1.00	1.12	−0.35	0.77
s	0.13	0.13	0.19	0.16	0.13	0.15	0.17	0.15	0.31	0.13
Mn	N	P	K	Ca	Mg	S	B	Cu	Fe	Zn
m̄	1.00	2.10	0.90	1.56	1.96	2.10	1.34	1.47	0.35	1.11
s	0.30	0.30	0.32	0.33	0.29	0.30	0.33	0.29	0.31	0.30
Zn	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn
m̄	−0.11	0.98	−0.22	0.44	0.85	0.98	0.23	0.36	−0.77	−1.11
s	0.09	0.09	0.15	0.14	0.10	0.10	0.14	0.11	0.13	0.30

DRIS - Integrated Diagnosis and Recommendation System.

The relationship between yield and the average nutritional balance index (NBI_a) is shown in Figure 1. The coefficient of determination (R^2) obtained was 0.0097, indicating that the variation in yield was not associated with the nutritional status of the banana plant. Low R^2 values were also observed when relating yield to NBI_a for atemoya (Santos & Rozane, 2017), banana (Silva & Carvalho, 2006; Villaseñor et al., 2020), and mango (Tullio & Rozane, 2022).

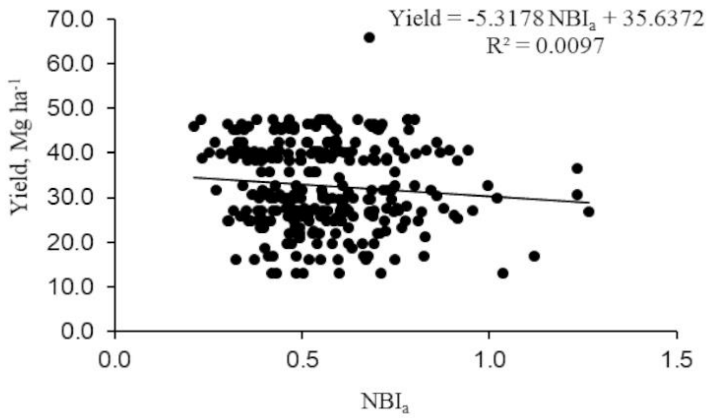

Figure 1. Relationship between yield and the average nutritional balance index (NBI_a) of commercial stands of 'Nanica' banana trees in Vale do Ribeira, São Paulo State, Brazil.

Although there was no relationship between yield and NBI_a, the statistical models obtained from the relationship between the K, Ca, Mg, S, B, Cu, Fe, Mn, and Zn content in leaf tissue and their respective DRIS indices (Table 3) presented an R^2 greater than 0.70. Only N and P had R^2 values lower than 0.50. Lima Neto et al. (2022), Teixeira et al. (2007), and Villaseñor et al. (2020) also observed low R^2 values for these nutrients when establishing DRIS norms for banana.

Table 3. Statistical models obtained between nutrient content and respective DRIS indices in leaf samples of 'Nanica' banana trees in Vale do Ribeira, São Paulo State, Brazil.

Nutrients	Equations	R^2
N	$IN = 0.1244\ N - 3.2314$	0.50
P	$IP = 1.4155\ P - 2.9591$	0.40
K	$IK = -0.0010\ K^2 + 0.1530\ K - 3.9642$	0.88
Ca	$ICa = 2.8236\ \ln(Ca) - 5.5778$	0.87
Mg	$IMg = 0.9642\ Mg - 2.8763$	0.72
S	$IS = 1.4000\ S - 2.9897$	0.76
B	$IB = 2.5729\ \ln(B) - 6.3463$	0.91
Cu	$ICu = -0.0084\ Cu^2 + 0.4480\ Cu - 3.3633$	0.87
Fe	$IFe = 2.6505\ \ln(Fe) - 12.6292$	0.93
Mn	$IMn = 1.3912\ \ln(Mn) - 7.7443$	0.98
Zn	$IZn = -0.0054\ Zn^2 + 0.3721\ Zn - 5.2554$	0.71

R^2 – coefficient of determination.

DRIS indices were interpreted using the Fertilizer Response Potential (FRP) method, according to Wadt (2005). The frequencies at which the nutrients behaved in terms of classes p, pz, z, nz, and n in the subpopulation of low yield are shown in Table 4. A high frequency of plots had a positive response to fertilization (p) for K (18.8%), Mn (13.3%), and Fe (12.7%). The plots that showed a low response to fertilization (n) were for K (13.3%), Ca (12.7%), and Mn (12.7%) nutrients. Thus, it was observed that for the low-yield population, there were plots that may or may not respond to K fertilization. This nutrient is the most demanded by the plant and is directly linked to fruit yield and quality (Deus et al., 2020; Ratke, Santos, Pereira, Souza, & Carneiro, 2012).

Table 5 presents the observed (FO) and expected (FE) frequencies of the nutrients in the five classes of the FRP, as well as the calculation of the chi-square ($\mathcal{X}^2$) for subpopulations with high and low yields. Distribution analysis rejected the hypothesis that the FO for the nutrients was statistically similar to the FE because the $\mathcal{X}^2$ value calculated was below the $\mathcal{X}^2$ tabulated (p = 0.05), indicating that FRP was not a sensitive interpretation method for interpreting the DRIS indices for Nanica banana trees in Vale do Ribeira.

Table 4. Observed frequency (%) of nutrients considering the five classes of Fertilizer Response Potential (FRP) in the subpopulation of low yield for 'Nanica' banana trees in Vale do Ribeira, São Paulo State, Brazil.

FRP	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
						%					
p	1.2	4.2	18.8	10.3	1.8	10.9	9.7	9.1	12.7	13.3	7.9
pz	9.1	6.1	10.3	5.5	12.7	12.1	8.5	20.0	15.2	18.2	12.1
z	68.5	64.2	45.5	57.6	61.8	62.4	60.0	62.4	52.7	47.3	61.8
nz	10.9	17.6	12.1	13.9	12.1	10.3	12.1	5.5	9.7	8.5	13.3
n	10.3	7.9	13.3	12.7	11.5	4.2	9.7	3.0	9.7	12.7	4.8

p – positive; pz – positive or null; z – null; nz – negative or null; n – negative.

Table 5. Frequencies of nutrients considering the five classes of Fertilizer Response Potential (FRP) and chi-square values ($\mathcal{X}^2$) for subpopulations with high and low yields of 'Nanica' banana trees in Vale do Ribeira, São Paulo State, Brazil.

Nutrients	(FE-FO)²/FE					
	n	nz	z	pz	p	($\mathcal{X}^2$)
N	0.3	16.2	102.8	20.0	11.3	150.5^{ns}
P	0.3	5.7	82.7	27.2	4.3	120.1^{ns}
K	3.3	13.9	20.0	17.4	17.1	71.6^{ns}
Ca	2.4	10.8	55.6	28.8	0.3	97.8^{ns}
Mg	1.1	13.9	72.2	12.8	9.6	109.6^{ns}
S	4.3	17.4	74.8	13.9	0.6	110.9^{ns}
B	0.1	13.9	64.8	21.4	0.1	100.2^{ns}
Cu	6.7	28.8	74.8	3.2	0.0	113.4^{ns}
Fe	0.1	18.7	39.2	8.9	2.4	69.2^{ns}
Mn	2.4	21.4	24.2	5.0	3.3	56.2^{ns}
Zn	3.3	11.8	72.2	13.9	0.3	101.4^{ns}
($\mathcal{X}^2$)	24.0^{ns}	172.3^{ns}	683.1^{ns}	172.5^{ns}	49.1^{ns}	-
($\mathcal{X}^2$)	-	-	-	-	-	1101.0^{ns}

FE – expected frequency; FO – observed frequency; p – positive; pz – positive or null; z – null; nz – negative or null; n – negative; ^{ns}not significant at 5% probability.

The ($\mathcal{X}^2$) test indicated divergence between the comparison of the proportions of observed and expected occurrences, that is, in areas of high productivity for all response classes (p, pz, z, nz, and n) and nutrients evaluated, the frequency with which the PRF method indicated the probability of the crop's response to fertilization was not confirmed significantly. Santos and Rozane (2017) also noted the inefficiency of the method for growing atemoya. A possible explanation may be associated with the indications by Hahn et al. (2022) and Yamane et al. (2022), who attributed the need for the sum of numerous other production factors to nutritional analysis for more reliable answers. This can be aggravated when the assessment of nutritional status is not carried out using a multivariate method (Parent et al., 2013) and/or there is high variation in the productive environment given the characteristics of the soil (Gotardo et al., 2020; Rossi, 2017; Soares & Alleoni, 2008) and that the crop is under non-irrigated management (Rozane et al., 2009). Marschner (2012) showed that methods evaluating the concentration of a single nutrient have low efficacy in predicting productivity in crops, which may also be the case for banana. Furthermore, the results demonstrated that PRF was dependent not only on the concentrations of a given nutrient within the plant diagnosed by leaf analysis but especially on the relationships between nutrients (Marschner, 2012; Rozane et al., 2016).

The sufficiency ranges and adequate leaf nutrient contents obtained by the DRIS method, as well as the ranges established for the crop by other authors, are shown in Table 6.

Differences were observed between the sufficiency ranges and adequate nutrient content established by the DRIS method for bananas in the present study with those indicated for banana trees in Ceará State (Lima Neto et al., 2022), Santa Catarina State (Guimarães et al., 2020), Planalto Paulista and Vale do Ribeira, São Paulo State, Brazil (Teixeira et al., 2007). The upper limits of the established ranges were higher for P, S, and Cu, while the lower limits were lower for K compared to these authors. However, the nutritional ranges established in the present study remained within those recommended for the state of São Paulo (Cantarella et al., 2022), which has a greater range of values.

These observations demonstrate the importance of establishing and using specific norms and values for each region according to the cultivar, technological level used by producer, management and edaphoclimatic conditions (Lima Neto et al., 2022). This makes it possible to improve the accuracy of the interpretation of the results, reducing the probability of mistaken interpretations regarding the deficiency, sufficiency or excess of one or more nutrients (Carvalho Júnior et al., 2019; Kurihara, Alvares, Neves, Novais, & Staut, 2013; Partelli, Deus, Vieira, Wadt, & Paiva Júnior, 2014).

Table 6. Sufficiency ranges and adequate nutrient contents for banana trees obtained by the DRIS methodology and found in the literature.

Nutrients		Sufficiency ranges	Adequate contents
N (g kg^{-1})	DRIS – Banana	23.8–28.2	26.0
	Cantarella, Quaggio, Mattos Júnior, Boaretto, and Raij (2022)	25.0–30.0	-
	Lima Neto et al. (2022)	19.7–21.8	20.7
	Guimarães, Deus, and Rozane (2020)	21.0–24.0	-
	Teixeira et al. (2007)	27.6–29.4	28.5
P (g kg^{-1})	DRIS – Banana	1.9–2.2	2.1
	Cantarella et al. (2022)	1.7–2.1	-
	Lima Neto et al. (2022)	1.4–1.7	1.6
	Guimarães et al. (2020)	1.9–2.2	-
	Teixeira et al. (2007)	1.65–1.75	1.7
K (g kg^{-1})	DRIS – Banana	26.7–39.4	33.0
	Cantarella et al. (2022)	30.0–40.0	-
	Lima Neto et al. (2022)	28.1–35.8	3.0
	Guimarães et al. (2020)	37.0–54.0	-
	Teixeira et al. (2007)	27.0–28.8	27.9
Ca (g kg^{-1})	DRIS – Banana	6.0–8.4	7.2
	Cantarella et al. (2022)	3.0–12.0	-
	Lima Neto et al. (2022)	5.8–7.4	6.6
	Guimarães et al. (2020)	6.0–8.0	-
	Teixeira et al. (2007)	10.4–11.2	10.8
Mg (g kg^{-1})	DRIS – Banana	2.6–3.3	3.0
	Cantarella et al. (2022)	2.0-5.0	-
	Lima Neto et al. (2022)	1.9–2.4	2.2
	Guimarães et al. (2020)	2.9–3.4	-
	Teixeira et al. (2007)	3.5–3.7	3.6
S (g kg^{-1})	DRIS – Banana	1.9–2.4	2.1
	Cantarella et al. (2022)	1.8–2.5	-
	Lima Neto et al. (2022)	1.2–1.7	1.4
	Guimarães et al. (2020)	1.5–2.0	-
	Teixeira et al. (2007)	–	-
B (mg kg^{-1})	DRIS – Banana	7.3–16.2	11.8
	Cantarella et al. (2022)	10.0–25.0	-
	Lima Neto et al. (2022)	7.1–12.1	9.6
	Guimarães et al. (2020)	12.0–19.0	-
	Teixeira et al. (2007)	17.1–18.3	17.7
Cu (mg kg^{-1})	DRIS – Banana	7.5–10.6	9.0
	Cantarella et al. (2022)	7.0–20.0	-
	Lima Neto et al. (2022)	3.9–6.4	5.2
	Guimarães et al. (2020)	6.0–9.0	-
	Teixeira et al. (2007)	9.1–9.9	9.5
Fe (mg kg^{-1})	DRIS – Banana	76.2–158.4	117.3
	Cantarella et al. (2022)	80.0–200.0	-
	Lima Neto et al. (2022)	55.7–70.2	63.0
	Guimarães et al. (2020)	120.0–207.0	-
	Teixeira et al. (2007)	82.3–92.3	87.3
Mn (mg kg^{-1})	DRIS – Banana	139.8–383.3	261.6
	Cantarella et al. (2022)	220.0–1000.0	-
	Lima Neto et al. (2022)	112.4–233.2	172.7
	Guimarães et al. (2020)	148.0–460.0	-
	Teixeira et al. (2007)	419.9–453.1	436.5
Zn (mg kg^{-1})	DRIS – Banana	17.5–22.2	19.8
	Cantarella et al. (2022)	15.0–30.0	-
	Lima Neto et al. (2022)	13.5–18.0	15.8
	Guimarães et al. (2020)	18.0–23.0	-
	Teixeira et al. (2007)	16.7–17.9	17.3

Conclusion

The variation in yield of Nanica banana trees in Vale do Ribeira was not explained by the nutritional status of the orchards affected by non-nutritional factors. However, the content of K, Ca, Mg, S, B, Cu, Fe, Mn, and Zn presented a positive correlation with their respective nutritional indexes obtained by the DRIS method.

Nutritional norms established by the DRIS method and the nutritional ranges obtained in the present study can be used by banana producers in Vale do Ribeira, allowing greater accuracy in the nutritional diagnosis of the crop for the edaphoclimatic conditions of the region.

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