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Nutrient reference values for 'Prata-Anã' banana in improved chemical fertility soils

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Abstract – The objective of this work was to establish, through different diagnostic methods, nutrient reference values for 'Prata-Anã' banana in improved fertility soil. The study included a database from an experiment conducted in randomized block design, arranged in a 5 × 6 factorial scheme (five doses of K_2O - 0; 200; 400; 600 and 800 kg ha^{-1}, supplied by cattle manure and rock powder × six evaluations of leaf nutrition and yield – 210; 390; 570; 750; 930 and 1,110 days after planting), with three replicates, totaling 90 samples. The reference values were determined by the Sufficiency Range, Critical Level by the Reduced Normal Distribution, Boundary Line and Mathematical Chance methods. Plots with high yield, ≥ 36.42 t ha^{-1} $cycle^{-1}$, formed the reference population and plots with yield ≥ 45.79 t ha^{-1} formed the reference subpopulation. The methods were efficient in determining the nutrient reference values of 'Prata-Anã' banana. In general, the values established are higher than those reported in the literature, justified by the greater chemical fertility of the soil. Among the diagnostic methods, the Mathematical Chance presented itself as the most accurate for interpreting the nutrient contents in the leaves of 'Prata-Anã' banana under improved soil fertility conditions.

Index terms: *Musa spp.*, nutritional diagnosis, interpretative norms, organic fertilization.

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Valores de referência nutricional para bananeira 'Prata-Anã' em solos de fertilidade química construída

Resumo – O objetivo desse trabalho foi estabelecer, por meio de diferentes métodos diagnósticos, valores de referência nutricional para bananeira 'Prata-Anã' em solo de fertilidade construída. O estudo contemplou um banco de dados de um experimento no delineamento em blocos casualizados, arranjado no esquema fatorial 5 × 6 (cinco doses de K_2O - 0; 200; 400; 600 e 800 kg ha^{-1}, supridas com esterco bovino e farinha de rocha × seis avaliações da nutrição foliar e produtividade - 210; 390; 570; 750; 930 e 1.110 dias após plantio), com três repetições, totalizando 90 amostras. Os valores de referência foram determinados pelos métodos da Faixa de suficiência, do Nível crítico pela distribuição normal reduzida, da Linha de fronteira, e pela Chance Matemática. Parcelas de alta produtividade, ≥ 36,42 t ha^{-1} $ciclo^{-1}$, formaram a população de referência e ≥ 45,79 t ha^{-1} subpopulação de referência. Os métodos foram eficientes na determinação dos valores de referência nutricional da bananeira 'Prata-Anã'. Os valores estabelecidos de forma geral são mais altos comparados à literatura, justificados pela maior fertilidade química do solo. Dentre os métodos diagnósticos, a Chance Matemática apresentou-se como o mais preciso para a interpretação dos teores de nutrientes nas folhas da bananeira 'Prata-Anã' em condições de fertilidade de solo construída.

Termos para indexação: *Musa* spp., diagnose nutricional, normas interpretativas, adubação orgânica.

Introduction

Global demand for inorganic fertilizers has increased by approximately 29% in the last 20 years (FAOSTAT, 2020). Brazil is among the five countries that most use these inputs, and 88% of the primary macronutrients (N, P and K) used nationally are imported. Among these nutrients, potassium is the most required (44%), followed by nitrogen and phosphorus, with 33 and 23%, respectively.

On the other hand, in relation to the use of nutrients, Cunha et al. (2010) estimated that, in general, in Brazilian agriculture, the final levels of utilization of N, P_2O_5 and K_2O are on the order of 72%, 54% and 77%, respectively. That is, considering the data on the use and average utilization of fertilizers in the country, approximately 30% are somehow lost.

Banana is the most consumed fruit in the world (FAOSTAT, 2020). In addition, banana plants have high nutritional requirements, mainly for potassium and nitrogen (SILVA, 2021). In 'Prata-Anã' banana, fertilizers are one of the main components of the production cost, representing about 15.6% and 18.2% of the average cost per hectare in irrigated perimeters, in the first and second year of implementation, respectively (DONATO et al., 2015). In fact, given the current world scenario of uncertainties, not only good cultural practices, but also constant monitoring of crop nutrition, as well as correct interpretation of the results, are necessary for the better utilization of fertilizers.

Monitoring through leaf analysis is one of the main tools capable of supporting the proper interpretation of the nutritional conditions of the crop. Through reference values it is possible to identify nutrients that limit the growth, development and production of banana (SILVA, 2021). However, accurate nutritional diagnosis requires knowledge of the production system and site-specific conditions.

Reference values for the interpretation of nutritional status can be determined from databases of crops with high yield potential. Among the univariate methods to obtain these values, there are the critical level by the reduced normal distribution (CLz), the sufficiency range (SR), the boundary line (BL) and the mathematical chance (MCh). All stand out for their easy interpretation and decision making, as they cover levels and ranges represented by a single dot or two as a reference. The CLz, developed by Maia et al. (2001), consists of the leaf concentration of the nutrient corresponding to 90% of the plant yield. On the other hand, the SR method, proposed by Martinez et al. (2003), considers a range of adequate values. These two methods, because they are more traditional, are widely used in forage cactus (ALVES et al., 2019), and CLz is used for 'Prata-Anã' banana (CARVALHO JÚNIOR et al., 2019). In the BL method, proposed by Walworth et al. (1986), nutritional contents are related to yield, making it possible to generate a calibration curve at the boundary line. This method was used for pitaya (ALMEIDA et al., 2016) and banana (RODRIGUES FILHO et al., 2021a, 2021c). Finally, the MCh method, developed by Wadt et al. (1998), estimates the nutritional range with the highest probability of response in yield. This methodology has already been used for eucalyptus (WADT et al., 1998), pitaya (ALMEIDA et al., 2016) and forage cactus (ALVES et al., 2019). However, there is no record for the 'Prata-Anã' banana.

For 'Prata-Anã' banana, nutritional reference values were determined in the states of Minas Gerais (SILVA, 2015), Bahia and Ceará (RODRIGUES FILHO et al., 2021a). However, as these studies had different results, Rodrigues Filho et al. (2021a) recommend that specific nutrient reference values, that is, developed for each region and/or cultivar, should be used for foliar diagnosis, because they are more accurate and reduce the effects of climate, management and soil variations.

Among these factors, soil fertility, natural or improved, can also influence the nutrient reference values of banana. The increase in soil fertility over time, through correctives and chemical or organic fertilizers, can increase the production potential of the area due to improvements in the chemical, physical and biological characteristics of the soil. Thus, this new cultivation condition requires new nutritional diagnostic ranges, that is, new reference values.

In view of the above, the objective of this study was to use the univariate methods Sufficiency Range (SR), Critical Level by the Reduced Normal Distribution (CLz), Boundary Line (BL) and Mathematical Chance (MCh), to establish reference values for nutritional diagnosis of 'Prata-Anã' banana cultivated under improved soil fertility conditions and fertilized with organic fertilizers, in the semi-arid region of Bahia, Brazil.

Material and Methods

Experimental conditions

The study was conducted at the Federal Institute Baiano, campus of Guanambi, BA, Brazil (14°17'38"S, 42°41'42"W, average altitude of 525 m). The climate is hot and dry semi-arid, with well-defined dry season in winter and rainy season between October and March. The average annual precipitation is 672 mm (average of 40 years), with average annual temperature of 26 ºC. The meteorological elements recorded during the experimental period are shown in Figure 1.

The soil, originally classified as *Latossolo Vermelho-Amarelo Distrófico*, medium texture, with 183 g kg^{-1} and 230 g kg^{-1} of clay at depths of 0.0 – 0.2 and 0.2 – 0.4m, respectively, corresponds to Oxisol (SANTOS et al., 2018). However, after correction, with two decades of applications of organic and

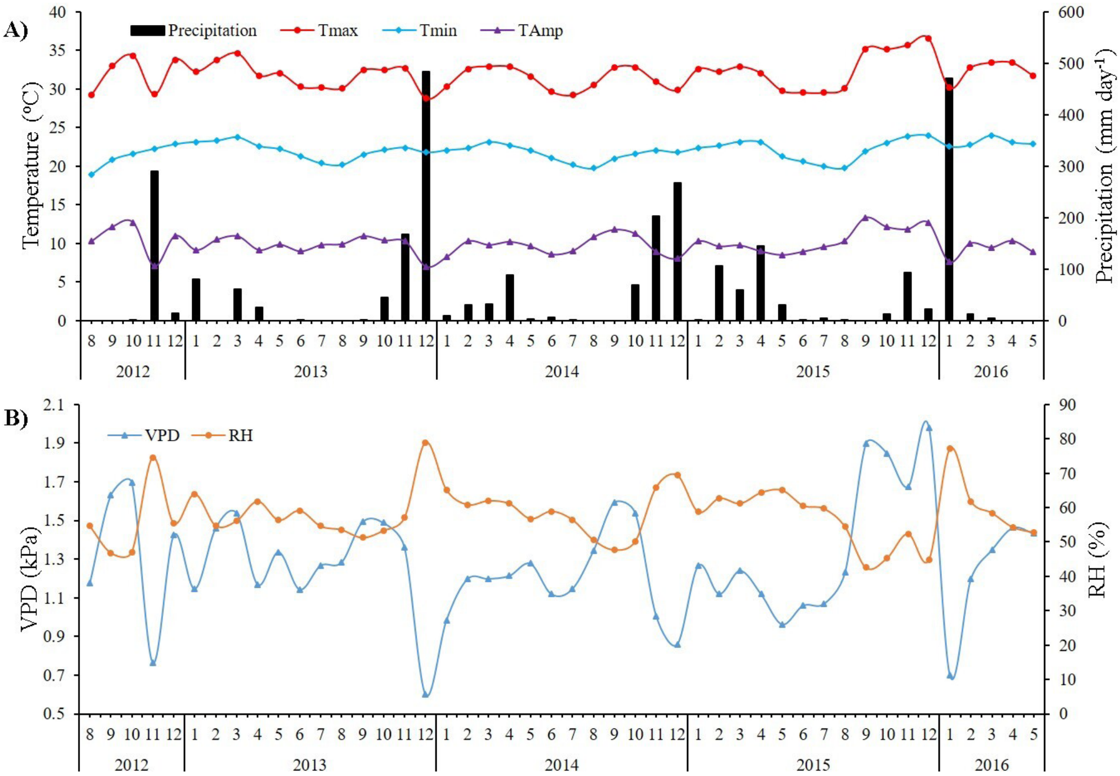

Figure 1 - Average monthly values of meteorological data recorded between 08/01/2012 and 05/31/2016. Guanambi, BA, Brazil.

Note: Maximum temperature (T_{max}), minimum temperature (T_{min}), thermal amplitude (TAmp) and Precipitation (P) – **A**; Average atmospheric vapor pressure deficit (VPD) and average relative humidity of the air (RH) – **B**.

Source: Data collected at the automatic weather station installed in the experimental area of the Federal Institute of Bahia.

chemical fertilizers and incorporation of crop residues, its fertility has been improved (MARQUES et al., 2022) and its nutrient contents and base saturation were changed from a dystrophic to a eutrophic condition. Before the beginning of the experiment, soil samples were collected from each experimental block, whose chemical attributes exhibit high fertility (Table 1).

Dataset

The database used contained contents of nutrients (N, P, K, S, Ca, Mg, B, Cu, Fe, Mn, Zn) and Na in the leaves and bunch yields (BY) from an experiment with ‘Prata-Anã’ banana (AAB), planted at 2.5 m x 2.0 m spacing (2.000 plants ha^{-1}), irrigated by microsprinkler, conducted during four produc-

Table 1. - Means and standard deviations of the chemical attributes of the soil with improved fertility, cultivated with ‘Prata-Anã’ banana, prior to transplanting, at sampling depths of 0.0-0.2 and 0.2-0.4 m. Guanambi, BA, Brazil.

Sampling	pH[1]	OM[2]	P[3]	K[3]	Na[3]	Ca[4]	Mg[4]	Al[4]	H+Al[5]	SB
		g kg^{-1}	----mg dm^{-3}----		----------cmol$_c$ dm^{-3}----------					
0.0-0.2	7.4±0.2	12.3±2.5	468.3±32.2	493.0±46.8	0.1±0	4.6±0.5	1.7±0.1	0	0.8±0	7.6±0.4
0.2-0.4	7.3±0.1	1.7±0.6	229.1±67.5	372.0±61.5	0.1±0	3.5±0.3	1.1±0.2	0	0.8±0.1	5.7±0.4
Sampling	**T**	**V**	**m**	**B[6]**	**Cu[3]**	**Fe[3]**	**Mn[3]**	**Zn[3]**	**Prem[7]**	**EC**
	cmol$_c$ dm^{-3}	--------%--------		----------mg dm^{-3}----------					mg L^{-1}	ds m^{-1}
0.0-0.2	8.4±0.5	91±0	0	0.9±0.3	2.2±0.3	22.3±6.2	46.5±1.3	40.8±11.8	43.6±1.0	1.5±0.2
0.2-0.4	6.5±0.4	89±0.6	0	1.0±0.1	1.2±0.1	26.8±7.6	27.7±1.1	8.7±2.4	42.2±2.5	1.3±0.2

Source: Marques et al. (2022) modified. [1]pH in water; [2]colorimetry; [3]Mehlich-1 extraction; [4]1 mol L^{-1} KCl; [5]pH SMP (Shoemaker-McLean-Pratt method); [6]$BaCl_2$ extractant; [7]equilibrium solution of P; OM - organic matter; SB - sum of bases; T - cation exchange capacity at pH 7; V - base saturation; m - aluminum saturation; Prem - remaining phosphorus; EC - electrical conductivity; mg dm^{-1} = ppm; cmol$_c$ dm^{-3} = meq 100cm^{-3}.

tion cycles, with average yield of 36.42 ± 8.4 t ha^{-1} (MARQUES et al., 2022). The sampled population consisted of 90 plots (n=90) arranged in a randomized block design in a 5 × 6 factorial scheme, corresponding to five annual doses of K_2O (0; 200; 400; 600 and 800 kg ha^{-1}), supplied with cattle manure and rock powder (0.00-0.00; 40.00-3.25; 80.00-6.50; 120.00-9.75; and 160.00-13.00 t ha^{-1} for manure and rock powder), six leaf sampling times (210; 390; 570; 750; 930 and 1.110 days after planting) and three replicates, in plots with six usable plants and complete border.

Leaf tissue was sampled according to Rodrigues et al. (2010). Nutrient contents were determined and yields were estimated in t ha^{-1} $cycle^{-1}$ by weighing the bunches during the harvests of each plot. The results of leaf and yield analyses were organized and processed in a Microsoft Excel® spreadsheet.

According to Marques et al. (2022), the bovine manure used contained, on a dry basis at 65 °C, on average, moisture of 16.72%, organic matter of 637.3 g kg^{-1}, pH of 7.42, density of 0.38 g cm^{-3} and the following contents of macronutrients (g kg^{-1}): Ca = 1.7, Mg = 0.2, K = 2.5, N = 5.2, S = 2.3 and P = 4.7; and micronutrients (mg kg^{-1}): B = 2.1; Cu = 45.2; Zn = 200.5; Mn = 391.8 and Fe = 1,932.4. The rock powder, natural earth from Ipirá, Naturalplus® from Terra Produtiva Mineradora Ltda., contained 30.0 g kg^{-1} of K_2O (total), 10.0 g kg^{-1} of P_2O_5, 52.0 g kg^{-1} of CaO, 30.0 g kg^{-1} of MgO, 63.0 g kg^{-1} of Fe_2O_3, 1.5 g kg^{-1} of MnO, 630 g kg^{-1} of SiO_2, 69 mg kg^{-1} of Zn, 127 mg kg^{-1} of Cu and 5 mg kg^{-1} of MO.

Fertilizer doses were divided into six applications every 60 days. Foliar applications of B and Zn were also performed until the flowering of the first production cycle; from the second cycle onwards, B, Zn and Cu were applied via rhizome of the thinned shoot, according to the methodology presented by Rodrigues et al. (2007), and Mg in the soil (MARQUES et al., 2022).

The methods used to determine the reference values were: Sufficiency Range (SR), Critical Level by the Reduced Normal Distribution (CLz), Boundary Line (BL) and Mathematical Chance (MCh). The data set was separated into low-yielding population (LYP) and high-yielding population (HYP), below and above the average, 36.42 t ha^{-1} $cycle^{-1}$. As used by Alves et al. (2019), the HYP was considered for SR and CLz. For MCh, the mean HYP of 43.21 t ha^{-1} $cycle^{-1}$ (n= 45) was subdivided into a reference subpopulation, based on the mean + 0.5 standard deviation, greater than or equal to 45.79 t ha^{-1} $cycle^{-1}$ (n=14).

Determination of reference values and sufficiency ranges by the Sufficiency Range (SR) method

The SR method, described by Martinez et al. (2003), can determine the reference values according to the following equation: SR = $\bar{x} \pm kS\bar{x}$, where, $\bar{x}$ = average content of each nutrient in the leaf; $S\bar{x}$ = standard deviation of the mean; and k = correction factor to adjust the sufficiency ranges, avoiding very wide intervals, as used by Alves et al. (2019). The values of k considered the coefficient of variation (CV) of each nutrient: k = 1.0 for nutrients with CV below 20%; k = 0.8 for CV between 20.01 and 40%; k = 0.6 for CV between 40.01 and 80%; and k = 0.4 for CV greater than 80%. Thus, five interpretative classes were adjusted for the nutrient contents in banana leaves: deficient (DEF), < ($\bar{x}$ - 2k$S\bar{x}$); tending to sufficient (TSF), ≥ ($\bar{x}$ - 2k$S\bar{x}$) and < ($\bar{x}$ - k$S\bar{x}$); sufficient (SUF), SR ≥ ($\bar{x}$ - k$S\bar{x}$) and < ($\bar{x}$ + k$S\bar{x}$); high (H), ≥ ($\bar{x}$ + k$S\bar{x}$) and < ($\bar{x}$ + 2k$S\bar{x}$) and tending to excessive (TEX), ≥ $\bar{x}$ + 2k$S\bar{x}$).

Determination of critical levels by the reduced normal distribution (CLz) method

The CLz method, developed by Maia et al. (2001), can be used according to the following equation: CLz(i) = (1.281552 × $S\bar{x}1$ + $\bar{x}1$) / (1.281552 × $S\bar{x}2$ + $\bar{x}2$); where, CLz(i) is the critical level of nutrient i; $S\bar{x}1$ and $\bar{x}1$ are the standard deviation and the mean of BY; and

$S\bar{x}2$ and $\bar{x}2$ are standard deviation and mean of Q, which is defined as the ratio between BY and n(i) (Q = BY /n(i)); where n(i) is the nutrient content used.

Determination of potential nutrient-response curves, reference values and sufficiency ranges by the Boundary Line (BL) method

To apply the BL method, BY values were related to the nutrient contents in the leaf, through scatter plots. Data points located at the top edge of the scatter plot (X, Y) were selected, forming a boundary line. Each data point on the line represents the highest yield at a corresponding nutrient concentration. A regression equation fitted to the potential nutrient-response curve (RODRIGUES FILHO et al., 2021a) was used to determine the reference values.

Then, the BL equations were derived and the first derivative was equaled to zero to obtain the optimal levels by the BL method (OL_{BL}) of the leaf contents of each nutrient corresponding to the maximum point on the BL curve. These values were replaced in the respective equations to estimate the maximum values of bunch yield (BY_{MP}) on the 'y' axis, and multiplied by 0.7 and 0.9 to obtain the 'y' values corresponding to 70% and 90% of yield, which were then used to estimate the reference ranges for each nutrient. The lower (LL) and upper (UL) limits were determined based on the following interpretative categories: deficient (BY < 70%, to the left of the maximum), tending to sufficient (70% ≤ BY < 90%, to the left of the maximum), sufficient (90%, to the left of the maximum, ≤ BY >90%, to the right of the maximum), high (90% > BY ≥ 70%, to the right of the maximum), and tending to excessive (BY < 70%, to the right of the maximum).

Determination of sufficiency ranges, critical levels and optimal nutrient levels by the Mathematical Chance (MCh) method

The adjustment of classes by MCh, a method developed by Wadt et al. (1998), followed Alves et al. (2019). For each nutrient under study, leaf contents were classified in ascending order and distributed in number of classes (i), corresponding to the square root of the number of observations (n), whose intervals of each class were calculated by dividing the amplitude of the nutrient contents by the number of predefined classes. In each class, the mathematical chance (MCh) was calculated by the equation: $MCh(i) = [(MCh(A(i)/A) \times MCh(A(i)/C(i))]^{0.5}$, where: MCh(i) = mathematical chance in class "i"; MCh (A(i)/A) = P(A(i)/A) × BY(i); P(A(i)/A) = frequency of high-yielding plots in class "i", relative to the overall total of high-yielding plots; BY(i)= average yield of high-yielding plots in class "i" (t ha^{-1}); MCh (A(i)/C(i)) = P(A(i)/C(i)) × BY(i); and P(A(i)/C(i)) = frequency of high-yielding plots of class "i", relative to the overall total of plots in class "i".

The optimal ranges for each nutrient were located between the lower (LL(i)) and upper (UL(i)) limits of the classes with the highest MCh. As also adopted by Alves et al. (2019), the highest total frequency of plots in class "i" and the highest frequency of plots with highest BY (≥ 45.79 t ha^{-1}) in class "i" were also considered. Subsequently, the optimal levels (OL_{MCh}) of the nutrients were estimated by the median of the threshold values of the selected classes.

The methods were compared with the literature data and with each other through the amplitudes, the limits (lower and upper) and the positions of the sufficiency ranges and the critical and optimal levels.

Results and Discussion

The chemical attributes of the soil in the experimental area before planting (Table 1), in general, highlight fertile conditions, with 'high' levels of base saturation (V%), average of 88.7% in the subsurface layer (0.2 – 0.4 m). This value is well above the V% recommended for banana in the surface layer (0.0 – 0.2 m), which is 70% (SILVA, 2021). The contents of macro and micronutrients were, on average, in the 'high and very high' levels. Therefore, these results show the high fertility of the soil improved over 20 years (MARQUES et al., 2022). The organic matter contents in the soil surface layer (0.0 – 0.2 m) are 'low', thus justifying fertilization with sources of organic matter.

However, the contribution of organic matter to plant yield and nutritional contents depends on current soil fertility conditions and can therefore influence the values and amplitudes of adjusted interpretative norms, which justifies their non-universality (RODRIGUES FILHO et al., 2021b). Marques et al. (2022) observed that in improved fertility soils the application of cattle manure and rock powder did not increase the yields of 'Prata-Anã' and 'BRS Platina' banana over four production cycles, but increased the N, P, K and S contents in the leaves, which may characterize luxury consumption. Damatto Junior et al. (2011b) found that organic compost doses did not influence the contents of most macronutrients in the leaves of 'Prata-Anã' banana. On the other hand, in the study conducted by Damatto Junior et al. (2006) the use of composting promoted increments in pH, organic matter, phosphorus and calcium contents, sum of bases, as well as CEC and base saturation.

The pH of all plots was classified as 'high' to 'very high', with a 'low' standard deviation, indicating high data homogeneity (Table 1). The main problem related to high pH values is the decrease in the availability, solubility and absorption of micronutrients (Cu, Zn, Fe and Mn) by plants (DECHEN et al., 2018). On the other hand, in banana crop, the addition of organic matter and the elevation of soil pH to the highest possible level, close to neutrality, without affecting plant growth, become interesting, as they can mitigate the severity of Fusarium wilt (ORR; NELSON, 2018), the main disease of the banana crop, which affects the absorption of water and nutrients.

Regarding the leaf nutrient contents of banana, from the plots under study, it can be noticed that the coefficients of variation (CV) of N, P, K, Mg, S and Zn were lower than 20%, demonstrating adequate homogeneity of the data set (Table 2); however, the nutrients Ca, B, Cu, Fe and Mn and Na showed CV higher than 20%, and those with the highest variation were Na (46%), Fe (37%) and Mn (36%). The greater homogeneity in the data set of some nutrients can be explained by their high mobility and patterns of accumulation in the plant, being easily redistributed among the organs, such as leaves and fruits

Table 2. Reference values estimated using the Sufficiency Range (SR) technique for interpreting leaf nutrient contents of 'Prata-Anã' banana in improved fertility soil. Guanambi, BA, Brazil.

Nut	Reference values					$\bar{x}$[1]	$S\bar{x}$[1]	CV[1]
	DEF	TSF	SUF	H	TEX			
	g kg^{-1}							%
N	<22.6	22.6 - 25.9	25.9 - 32.5	32.5 - 35.8	>35.8	29.2	3.3	11.28
P	<1.6	1.6 - 1.9	1.9 - 2.4	2.4 - 2.7	>2.7	2.2	0.3	12.60
K	<28.2	28.2 - 30.2	30.2 - 34.4	34.4 - 36.4	>36.4	32.3	2.1	6.40
Ca	<3.6	3.6 - 5.0	5.0 - 7.8	7.8 - 9.2	>9.2	6.4	1.7	27.12
Mg	<3.1	3.1 - 3.8	3.8 - 5.1	5.1 - 5.7	>5.7	4.4	0.7	14.75
S	<1.5	1.5 - 1.9	1.9 - 2.7	2.7 - 3.1	>3.1	2.3	0.4	17.48
	mg kg^{-1}							%
B	<13.8	13.8 - 20.4	20.4 - 33.8	33.8 - 40.5	>40.5	27.1	8.4	30.83
Cu	<4.0	4.0 - 5.5	5.5 - 8.5	8.5 - 10.0	>10.0	7.0	1.9	26.80
Fe	<41.3	41.3 - 72.1	72.1 - 133.7	133.7 - 164.5	>164.5	102.9	38.5	37.40
Mn	<32.5	32.5 - 54.8	54.8 - 99.4	99.4 - 121.7	>121.7	77.1	27.9	36.14
Zn	<12.7	12.7 - 15.5	15.5 - 21.1	21.1 - 24.0	>24.0	18.3	2.8	15.35
Na	<13.4	13.4 - 21.6	21.6 - 37.9	37.9 - 46.1	>46.1	29.7	13.6	45.71

Nut: Nutrients and Na; [1]$\bar{x}$: Mean, $S\bar{x}$: standard deviation and CV: coefficient of variation; DEF: Deficient; TSF: Tending to sufficient; SUF: Sufficient; H: High; and TEX: Tending to excessive. n=45.

(DEUS et al., 2020). According to Marschner (2012), the nutrients N, P, K, Mg and S have high mobility in the phloem, that is, they are easily redistributed among the organs (source/sink). On the other hand, Ca, B, Cu, Fe and Mn have lower mobility and, therefore, greater variability in plant tissues, also justified by their dynamics in the soil-plant system, with greater influence of pH, organic matter, clay content and redox conditions.

According to Deus et al. (2020), banana has an ideal pattern of partitioning of nutrients as a function of the different yields. In other words, lower yield will result in lower values of critical levels (CARVALHO JÚNIOR et al., 2019). However, N and P are less sensitive to these differences (DEUS et al., 2020). Marques et al. (2022) found that the levels of N, P, K, S and Cu in banana crop increased with doses of organic fertilizer.

The nutrient reference values between the Sufficiency Range (SR) and Boundary Line (BL) methods (Tables 2 and 3, respectively) showed similarities, in at least one of the diagnostic nutritional ranges ('Deficient', 'Tending to sufficient', 'Sufficient', 'High' and 'Tending to excessive'). Between these methods, P and B were the nutrients that showed the highest similarity between the limit contents (lower and upper) of all ranges. N and Zn, on the other hand, showed higher values in all diagnostic ranges, in relation to SR. However, still between these two methods, the nutrients N, P, S, B and Zn had practically the same maximum amplitudes as the reference values (difference between the upper limit of the 'Tending to excessive' range and the lower limit of the 'Deficient' range). These relationships are possibly due to the decomposition of organic matter, which, according to Lucena et al. (2021), in lime-corrected soils, increases microbial activity and the release mainly of N, P, S and B in the soil solution, with consequent absorption by the plant and higher contents in the tissues, as evidenced by Marques et al. (2022). Specifically for B there was continuous supply in all experimental plots, which contributes to justifying the high values.

The nutrient reference values for 'Prata-Anã' banana determined by Rodrigues Filho et al. (2021a) by the BL method differed

Table 3. Reference values estimated using the Boundary Line (BL) method for interpreting leaf nutrient contents of 'Prata-Anã' banana in improved fertility soil. Guanambi, BA, Brazil.

Nut	BY_{MP}	OL_{BL}	Reference values				
			DEF	TSF	SUF	H	TEX
			BY< 70%	70% ≤ BY< 90%	90%≤BY>90%	90%>BY≥70%	BY<70%
	t ha^{-1} cycle^{-1}	------------------ g kg^{-1} ------------------					
N	57.1	30.6	< 24.1	24.1 - 26.9	26.9 - 34.4	34.4 - 37.1	> 37.1
P	57.8	2.2	< 1.6	1.6 - 1.9	1.9 - 2.5	2.5 - 2.7	> 2.7
K	58.0	32.2	< 28.8	28.8 - 30.2	30.2 - 34.2	34.2 - 35.6	> 35.6
Ca	56.7	7.4	< 3.3	3.3 - 5.0	5.0 - 9.8	9.8 - 11.5	> 11.5
Mg	53.2	4.6	< 3.1	3.1 - 3.7	3.7 - 5.4	5.4 - 6.1	> 6.1
S	55.3	2.4	< 1.5	1.5 - 1.9	1.9 - 2.9	2.9 - 3.3	> 3.3
	t ha^{-1} cycle^{-1}	------------------ mg kg^{-1} ------------------					
B	56.6	26.9	< 13.3	13.3 - 19.1	19.1 - 34.8	34.8 - 40.6	> 40.6
Cu	56.0	6.7	< 1.2	1.2 - 3.5	3.5 - 9.9	9.9 - 12.2	> 12.2
Fe	52.7	120.0	< 35.5	35.5 - 71.2	71.2 - 168.8	168.8 - 204.5	> 204.5
Mn	55.4	82.7	< 21.7	21.7 - 47.5	47.5 - 117.9	117.9 - 143.6	> 143.6
Zn	56.6	21.1	< 14.8	14.8 - 17.5	17.5 - 24.7	24.7 - 27.3	> 27.3
Na	52.3	25.0	< 2.7	2.7 - 12.1	12.1 - 38.0	38.0 - 47.4	> 47.4

Nut: Nutrients and Na; BY_{MP}: Bunch Yield at the maximum point of the boundary line; OL_{BL}: optimal levels by the BL method. DEF: Deficient; TSF: Tending to sufficient; SUF: Sufficient; H: High; and TEX: Tending to excessive.

from those found in the present study. In general, for N, P, Mg, S, B, Fe and Zn, the BL and SR methods led to higher limits for the diagnostic ranges ('Deficient', 'Tending to sufficient', 'Sufficient', 'High' and 'Tending to excessive') compared to those proposed by these authors. However, for K, both methods (BL and SR) had all the ranges of the reference values included in the interval of the 'Sufficient' range determined by Rodrigues Filho et al. (2021a). On the other hand, the values adjusted for most nutrients were very close to the ranges proposed by Silva (2015) by the SR method, for northern Minas Gerais, a region with greater climatic similarity, with pronounced divergence only for B and Mn. However, the continuous supply of B in the present study justifies the higher values, while the higher and wider limits for Mn in the study conducted by Silva (2015) are justified by the absence of correction factor (k) for high variability in the SR method, in addition to the greater environmental heterogeneity, because the author worked with data from 52 banana plantations.

The lower amplitude observed in the reference values of K is due to the high homogeneity of its data set, with CV of only 6% (Table 2), that is, the nutritional content was at very high levels, both in the soil (Table 1) and in the plant (MARQUES et al., 2022). In addition, the applied doses of organic fertilizer were determined according to the nutritional requirement of banana for this nutrient (K_2O). Thus, the improved fertility and the additional supply of organic sources favored the establishment of narrower and more precise diagnostic ranges for this nutrient. According to Arantes et al. (2016), the high contents of K in the soil contribute to its greater absorption and increase of leaf contents. However, according to these same authors, the high contents in the leaf characterize luxury consumption, mainly for K, as it has a higher rate of cycling in the crop, corroborated by Marques et al. (2022).

The determination of the boundary line (BL) considered the relations between the bunch yield (BY) in the plots and the respective nutritional contents in the leaf of 'Prata-Anã' banana (Figure 2). It can be seen that all nutrients showed polynomial quadratic regression equations, with moderate to high coefficients of determination, R^2 ranging from 0.72 to 0.98 and adjusted R^2 from 0.67 to 0.97.

The lowest adjusted coefficients of determination (R^2_{adj}) were observed for Mn (0.67), Zn (0.67), B (0.76), S (0.77) and Na (0.77) (Figure 2J, 2K, 2G, 2F and 2L, respectively). Almeida et al. (2016) explain that the lower R^2 values may be related to the magnitude of the data variation found in leaf tissue analyses for the nutrients. This statement corroborates the high coefficients of variation recorded in the present study, mainly for the nutrients Mn, B and Na (Table 2) and supported by other studies (RODRIGUES FILHO et al., 2021a, b, c).

However, this observation did not apply to the R^2_{adj} of the Zn boundary line, which despite having a relatively low CV, 18% (Table 2), resulted in R^2_{adj} of only 67% (Figure 2K). This occurred, possibly, due to the interactions with other nutrients, especially P, that is, its excess may have influenced the absorption of Zn by the plant, since the P contents in the soil are very high (Table 1). According to Lucena et al. (2021), the solubility of Zn in most soils is controlled by phosphate activity, because Zn is generally less abundant than P in soils and, therefore, virtually all Zn, but not P, is used in the formation of zinc phosphate.

In the MCh method, the lower and upper limits of nutrient sufficiency values were determined according to the classes with higher MCh value, higher frequency of high-yielding plots, as well as higher frequency of plots with yields greater than or equal to 45.79 t ha^{-1} (Table 4). In view of these observations, it was found that K was the only nutrient with sufficiency range selected in classes 2 and 3, ranging from 31.6 to 34.6 g kg^{-1}, that is, close to the highest contents recorded for this nutrient. These

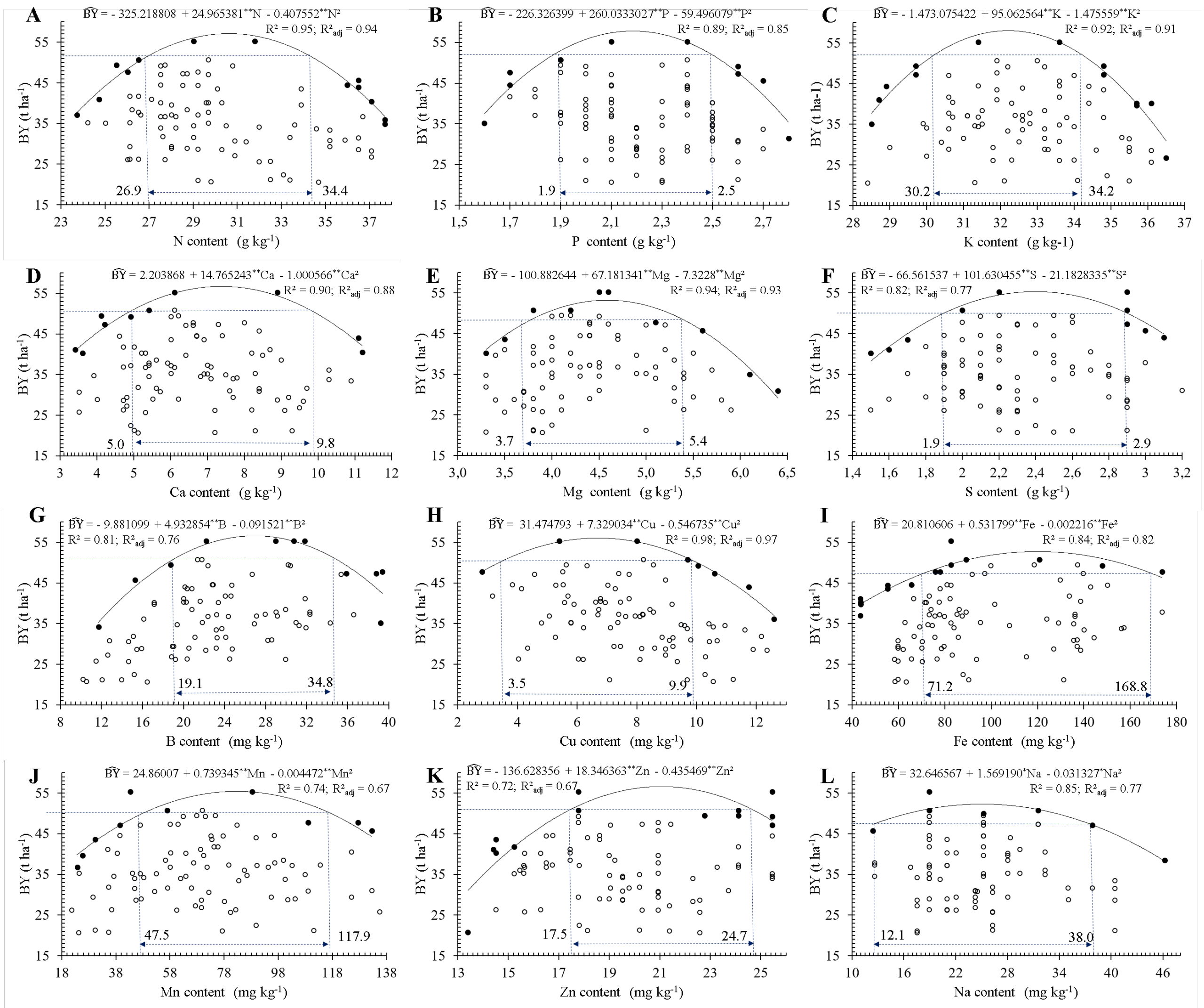

Figure 2. Boundary line (BL) adjusted according to the relationship between average bunch yield (BY) and leaf concentrations of N (A), P (B), K (C), Ca (D), Mg (E), S (F) B (G), Cu (H), Fe (I), Mn (J), Zn (K) and Na (L) of ‘Prata-Anã’ banana in improved fertility soil, Guanambi, BA, Brazil. **Significant ($p \leq 0.01$) by t-test. R^2_{adj} = adjusted coefficient of determination.

high contents result from the high soil fertility. Damatto Junior et al. (2011a) also observed high nutritional contents of K in the first cycle of ‘Prata-Anã’ banana and only observed significant positive effects of organic fertilization on the yield of the 5th cycle of the crop, even in low-fertility soil.

The ranges of the optimal values for S, B and Zn were between classes 3 and 4, resulting in the intervals of 2.0 to 2.5 mg kg^{-1}, 28.4 to 41.7 mg kg^{-1} and 17.4 to 21.4 mg kg^{-1}, respectively. For N and Fe, the ranges of the contents were between classes 3 and 5, with variations from 25.9 to 32.6 g kg^{-1} and from 71.4 to 154.6 mg kg^{-1}, respectively. Regarding P, Mg and Mn, classes 4 and 5 were the most representative, with the following nutritional ranges: 1.8 to 2.2 g kg^{-1}, 3.8 to 5.0 g kg^{-1} and 48.0 to 92.9 mg kg^{-1}, respectively. The nutrients with ranges of optimal values determined in a single class were Ca, Na and Cu: Ca (6.0 to 7.3 g kg^{-1}) and Na (29.3 to 37.7 mg kg^{-1}) in class 4, and Cu (4.3 to 5.8 mg kg^{-1}) in class 5, the latter being in one of the classes with the lowest nutritional contents recorded.

Some nutrients (P, K, S, B, Cu, Fe and Mn) showed classes with high MCh values distant from each other. Although uncommon, this behavior has already been reported by Almeida et al. (2016), who justified that it resulted from possible interactions between

Table 4. Mathematical chance (MCh) values established for different classes of distribution of leaf nutrient contents of 'Prata-Anã' banana in improved fertility soil. Guanambi, BA, Brazil.

Nut	CL [1]	LL_i	UL_i	OL	BY_i	P1[3]	P2[4]	MCh	Nut	LL_i	UL_i	OL	BY_i	P1[3]	P2[4]	MCh
		-----g kg^{-1}-----			t ha^{-1}	----%----		t ha^{-1}		-----mg kg^{-1}-----			t ha^{-1}	-----%-----		t ha^{-1}
Nitrogen	1	34.9	37.1		42.3	0	0	0	Boron	48.3	54.9		47.8	7.1	100.0	12.8
	2	32.6	34.9		41.6	0	0	0		41.7	48.3		42.1	0	0	0
	3	30.4	32.6	29.3	52.3	14.3	100	19.8		35.1	41.7	35.0	45.4	28.6	80.0	21.7
	4	28.1	30.4		43.7	42.9	37.5	17.5		28.4	35.0		42.6	21.4	33.3	11.4
	5	25.9	28.1		42.2	35.7	29.4	13.7		21.8	28.4		42.4	21.4	21.4	9.1
	6	23.7	25.9		42.6	7.1	33.3	6.6		15.2	21.8		43.5	21.4	21.4	9.3
Phosphorus	1	2.5	2.7		47.4	14.3	66.7	14.6	Copper	10.3	11.8		45.7	7.1	50.0	8.6
	2	2.4	2.5		42.9	21.4	23.1	9.5		8.8	10.3		46.4	14.3	50.0	12.4
	3	2.2	2.3	2.0	42.3	7.1	33.3	6.5		7.3	8.8	5.0	42.1	35.7	31.3	14.1
	4	2.0	2.2		42.5	28.6	26.7	11.7		5.8	7.3		40.9	7.1	10.0	3.5
	5	1.8	2.0		44.6	21.4	60.0	16.0		4.3	5.8		45.3	28.6	44.4	16.1
	6	1.7	1.8		42.8	7.1	16.7	4.7		2.8	4.3		44.4	7.1	25.0	5.9
Potassium	1	34.6	36.1		42.5	14.3	28.6	8.6	Iron	182.4	210.1		47.1	7.1	100	12.6
	2	33.1	34.6		44.4	21.4	30.0	11.2		154.6	182.4		47	14.3	66.7	14.5
	3	31.6	33.1	33.1	43.6	28.6	36.4	14.1		126.9	154.6	113.0	43.7	21.4	30.0	11.1
	4	30.1	31.6		41.2	14.3	18.2	6.6		99.2	126.9		47.3	21.4	75.0	19.0
	5	28.6	30.1		45.6	14.3	50.0	12.2		71.4	99.1		41.9	35.7	22.7	11.9
	6	27.2	28.6		43.7	7.1	50.0	8.3		43.7	71.4		41.8	0	0	0
Calcium	1	9.9	11.2		42.3	0	0	0	Manganese	137.9	160.4		55.3	7.1	100	14.8
	2	8.6	9.9		45.0	7.1	33.3	6.9		115.4	137.9		44.7	7.1	33.3	6.9
	3	7.3	8.6	6.6	44.2	14.3	33.3	9.7		93.0	115.4	70.5	40.8	7.1	12.5	3.9
	4	6.0	7.3		44.4	50.0	43.8	20.8		70.5	92.9		44.2	28.6	33.3	13.6
	5	4.7	6.0		40.5	14.3	15.4	6.0		48.0	70.5		43.5	42.9	42.9	18.6
	6	3.4	4.7		44.5	14.3	40.0	10.6		25.5	48.0		41.5	7.1	14.3	4.2
Magnesium	1	6.2	6.8		40.5	0	0	0	Zinc	23.4	25.5		45.8	7.1	33.3	7.1
	2	5.6	6.2		0	0	0	0		21.4	23.4		38.9	0	0	0
	3	5.0	5.6	4.4	43.0	21.4	37.5	12.2		19.4	21.4	19.4	45.2	28.6	50.0	17.1
	4	4.4	5.0		44.6	28.6	40.0	15.1		17.4	19.4		44.4	57.1	53.3	24.5
	5	3.8	4.4		43.3	42.9	33.3	16.3		15.4	17.4		40.8	0	0	0
	6	3.3	3.8		41.8	7.1	12.5	4.0		13.4	15.4		40.1	7.1	20.0	4.8
Sulfur	1	2.8	3.1		46.8	21.4	50.0	15.3	Sodium	54.6	63.1		44.5	7.1	33.3	6.9
	2	2.6	2.8		41.4	14.3	33.3	9.0		46.2	54.6		42.4	14.3	28.6	8.6
	3	2.3	2.5	2.3	44.2	28.6	50.0	16.7		37.7	46.1	33.5	47.1	7.1	100.0	12.6
	4	2.0	2.3		44.0	35.7	33.3	15.2		29.3	37.7		45.4	21.4	60.0	16.3
	5	1.7	2.0		39.6	0	0	0		20.8	29.2		42.2	21.4	18.8	8.5
	6	1.5	1.7		41.6	0	0	0		12.4	20.8		42.4	28.6	30.8	12.6

CV(%)	BY	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	Na
	5.51	6.30	13.14	6.28	21.41	9.22	13.28	34.39	30.25	32.34	38.65	13.12	43.62

Nut: Nutrients and Na; [1]CL= Classes; LL_i= Lower limit of class *i*; UL_i= Upper limit of class *i*; OL= optimal level in the optimal range (median of the optimal range); BY_i= Bunch yield of plots in class *i*; [3]P1 = probability or frequency of high-yielding plots in class *i* relative to the total of high-yielding plots; [4]P2 = probability or frequency of high-yielding plots in class *i* relative to the total of plots in class *i*. MCh = mathematical chance of the factor in class *i*; CV: coefficient of variation for yield ≥ 45.79 t ha^{-1} and nutrients.

nutrients and the dilution effect. However, these authors point out that this statement cannot be conclusive because this method does not evaluate interactions between nutrients.

The optimal and critical nutrient ranges and levels by the methods studied (SR, BL, MCh and CLz), as well as the values established in the literature, both by Silva (2015) and by Rodrigues Filho et al. (2021a), for ‘Prata-Anã’ banana cultivated in Minas Gerais and Bahia, respectively, can be observed in Table 5. In general, the optimal ranges proposed in this study for N, P, Mg, S and B were higher than those reported in the literature. These responses are probably due to the high improved fertility of the soil and the use of organic fertilization, which increased the availability in the soil and the concentrations of the nutrients in the banana leaf tissues.

This greater availability in the soil, especially of macronutrients, possibly increased the values of the ‘sufficiency’ ranges compared to those presented in the literature. Arantes et al. (2016), when evaluating the leaf contents of six ‘Prata’ banana cultivars, observed that all were above the range considered ideal by the literature and inferred that this result may be related to the availability of nutrients in the soil and the continuous translocation of nutrients among the family plants. Therefore, the establishment of optimal ranges for genotypes in regions with specific edaphoclimatic and management conditions is necessary to increase the accuracy of nutritional diagnoses, thus increasing the efficiency of fertilization and gains in yield and production quality. These considerations agree with Rodrigues Filho et al. (2021b, c), who consider the use of diagnostic methods to determine nutrient reference values under specific edaphoclimatic conditions as more accurate.

Among the methods evaluated, it was observed that, for most nutrients, except for N, Fe and Mn, the smallest amplitudes of the

Table 5. Optimal ranges and levels for macronutrients (g kg^{-1}), micronutrients and Na (mg kg^{-1}) adjusted by different methods for ‘Prata-Anã’ banana and comparison with the literature.

Methods	N	P	K	Ca	Mg	S
	----------g kg^{-1}----------					
SR	25.9 – 32.5	1.9 – 2.4	30.2 – 34.4	5.0 – 7.8	3.8 – 5.1	1.9 – 2.7
BL	26.9 – 34.4	1.9 – 2.5	30.2 – 34.2	5.0 – 9.8	3.7 – 5.4	1.9 – 2.9
OL_{BL}	30.6	2.2	32.2	7.4	4.6	2.4
MCh	25.9 – 32.6	1.8 – 2.2	31.6 – 34.6	6.0 – 7.3	3.8 – 5.0	2.0 – 2.5
OL_{MCh}	29.3	2.0	33.1	6.6	4.4	2.3
CLz	27.9	2.0	31.5	5.1	4.1	2.1
SR* (SILVA, 2015)	25.0 – 29.0	1.5 – 1.9	27.0 – 35.0	4.5 – 7.5	2.4 – 4.0	1.7 – 2.0
BL** (RODRIGUES FILHO et al., 2021a)	19.9 – 22.1	1.4 – 1.6	24.0 – 31.3	5.3 – 5.8	2.1 – 2.7	1.3 – 1.5
	B	**Cu**	**Fe**	**Mn**	**Zn**	**Na**
	----------mg kg^{-1}----------					
SR	20.4 – 33.8	5.5 – 8.5	72.1 – 133.7	54.8 – 99.4	15.5 – 21.1	21.6 – 37.9
BL	19.1 – 34.8	3.5 – 9.9	71.2 – 168.8	47.5 – 117.9	17.5 – 24.7	12.1 – 38.0
OL_{BL}	26.9	6.7	120.0	82.7	21.1	25.0
MCh	28.4 – 41.7	4.3 – 5.8	71.4 – 154.6	48.0 – 92.9	17.4 – 21.4	29.3 – 37.7
OL_{MCh}	35.0	5.0	113.0	70.5	19.4	33.5
CLz	21.1	4.9	73.5	51.5	17.2	19.0
SR* (SILVA, 2015)	12.0 – 25.0	2.6 – 8.8	72.0 – 157.0	173.0 – 630.0	14.0 – 25.0	20.0 – 60.0
BL** (RODRIGUES FILHO et al., 2021a)	13.7 – 16.4	4.4 – 5.2	39.0 – 55.0	64.0 – 91.0	12.4 – 14.5	-

SR: sufficiency range; BL: boundary line method; OL_{BL}: Optimal level by the BL method; MCh: mathematical chance method; OL_{MCh}: optimal level by MCh method; CLz: critical level by the reduced normal distribution method; *Optimal range by SR method for ‘Prata-Anã’ banana in northern Minas Gerais (SILVA, 2015). **Optimal range by the BL method for ‘Prata-Anã’ banana cultivated in Ponto Novo, BA (RODRIGUES FILHO et al., 2021a).

ranges were obtained by MCh. These results suggest that, among the univariate methods tested, MCh may be more sensitive for diagnosing optimal nutrient concentrations in the leaves than BL and SR, hence being more adequate to evaluate the nutritional status of 'Prata-Anã' banana. These results corroborate those observed by Almeida et al. (2016), who compared the sufficiency values of the BL method with those of MCh in pitaya crop and observed, for all nutrients, a lower amplitude of MCh.

On the other hand, the BL had, for all nutrients, except K, the greatest amplitudes of the 'sufficiency' values. One of the reasons that may explain the greater amplitudes of BL in this study is that the contents in the regression equation were estimated as a function of the estimated yield of 90%, both to the left and to the right of the maximum yield (inflection point of the curve), unlike Rodrigues Filho et al. (2021a), who determined the nutritional contents in the estimated yield range between 90% and 100%, which is the inflection point of the curve. Moreover, the higher values of BL are justified because this method considers the selection of pairs of yield and nutrient content values at the upper edge of the data set (Figure 2), which occurs whenever there is a cause-effect relationship between two variables, excluding the interference of the environmental factors of this relationship, represented by the points below that line.

Compared to the literature data, the amplitudes of the optimal ranges determined by the BL, SR and MCh methods were higher than those reported by Rodrigues Filho et al. (2021a), for all nutrients, except for K. Compared to the data presented by Silva (2015), the methods showed higher amplitudes for N, P, S and B, and lower amplitudes for K, Mn, Zn and Na.

Regarding the similarity of the lower and upper limits of the optimal ranges between the evaluated methods (Table 5), it was observed that they showed similar values for macronutrients, especially in relation to the SR method. However, between the MCh and BL methods, the greatest similarities were restricted to the lower limit of the optimal ranges of the following nutrients: P, K, Mg, S, Fe, Mn and Zn. Almeida et al. (2016), in pitaya crop, observed similarity between the limits of the 'sufficiency' ranges for N, K and Zn, except P, between these two methods (MCh and BL).

The 'sufficiency' ranges presented by both Silva (2015) and Rodrigues Filho et al. (2021a) had the lowest values of the lower limits of macronutrients, except for Ca, compared to all methods evaluated here. For micronutrients, this same behavior was only observed for B, due to the greater homogeneity of the experimental area and the continuous supply of B in the present study.

The optimal levels determined by the MCh (OL_{MCh}) and boundary line (OL_{BL}) methods were within the optimal ranges of the BL, MCh and SR methods for most nutrients, except Ca, B, Cu and Na (Table 5). In general, OL_{BL} was higher than OL_{MCh} for most nutrients, except for K, B and Na. On the other hand, the critical levels obtained by the reduced normal distribution (CLz) were close to the lower limits of the optimal ranges established by the BL, SR and MCh methods, and higher than the CLz established by Carvalho Júnior et al. (2019) for N, P, Mg, S, B and Fe.

In general, the micronutrients showed variations in the limits of the ranges determined for the nutritional contents among the evaluated methods (Table 5). According to Rodrigues Filho et al. (2021b), the inconsistency between the sufficiency ranges of micronutrients found in different studies or methods is due to the high fluctuations in leaf contents (high CV), as the absorption of nutrients is highly influenced by several factors such as soil pH, organic matter content, clay content and reduction potential, as also observed for other species (TEIXEIRA et al., 2021).

Conclusions

The nutrient reference values determined by the univariate methods SR, BL, MCh and CLz can be used efficiently for the diagnosis of the nutritional status of “Prata-Anã” banana in improved fertility soils. Among the evaluated methods, MCh had more accurate sufficiency values for interpreting the results of leaf analyses of “Prata-Anã” banana under improved soil fertility conditions. Nutrient reference values should be established for each genotype under site-specific conditions.

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References

ALMEIDA, E.I.B.; DEUS, J.A.L. de; CORRÊA, M.C. de M.; CRISOSTOMO, L.A.; NEVES, J.C.L. Linha de fronteira e chance matemática na determinação do estado nutricional de pitaia. **Revista Ciência Agronômica**, Fortaleza, v.47, n.4, p.744-54, 2016.

ALVES, J.F.T.; DONATO, S.L.R.; DONATO, P.E.R.; SILVA, J.A. da; GUIMARÃES, B.V.C. Establishment of sufficiency ranges to determine the nutritional status of ‘gigante’ forage cactus pear—macronutrients. **Journal of Agricultural Science**, Ottawa, v.11, n.18, p.213–21, 2019.

ARANTES, A. de M.; DONATO, S.L.R.; SIQUEIRA, D.L. de; AMORIM, E.P.; RODRIGUES FILHO, V.A. Chlorophyll index for real-time prediction of nutritional status of ‘Prata’ banana. **Revista Brasileira de Engenharia Agricola e Ambiental**, Campina Grande, v.20, n.2, p.99–106, 2016.

CARVALHO JÚNIOR, I.S.; MOREIRA, E.D.S.; PEGORARO, R.F.; FRAZÃO, L.A.; SAMPAIO, R.A.; FERNANDES, L.A. Critical levels and nutritional evaluation of irrigated “Prata-Anã” banana. **Revista Brasileira de Ciências Agrarias**, Recife, v.14, n.4, p.1–7, 2019.

CUNHA, J.F.; CASARIN, V.; PROCHNOW, L.I. Balanço de nutrientes na agricultura brasileira. **Informações Agronômicas**, Piracicaba, v.130, n.19, p.1–11, 2010.

DAMATTO JUNIOR, E.R.; VILLAS BÔAS, R.L.; LEONEL, S.; FERNANDES, D.M. Alterações em propriedades de solo adubado com doses de composto orgânico sob cultivo de bananeira. **Revista Brasileira de Fruticultura**, Jaboticabal, v.28, n.3, p.546–49, 2006.

DAMATTO JUNIOR, E.R.; VILLAS BÔAS, R.L.; LEONEL, S.; NOMURA, E.S.; FUZITANI, E.J. Crescimento e produção de bananeira Prata-Anã adubada com composto orgânico durante cinco safras. **Revista Brasileira de Fruticultura**, Jaboticabal, v.33, n.1, p.713–721,Número Especial, 2011ª.

DAMATTO JUNIOR, E.R.; VILLAS BÔAS, R.L.; NOMURA, E.S.; FUZITANI, E.J.; GARCIA, V.A. Alterações nos teores nutricionais foliares de bananeira “Prata-Anã” adubada com composto orgânico em cinco ciclos de produção. **Revista Brasileira de Fruticultura**, Jaboticabal, v.33, n.1, p.692-8, 2011b. Número Especial

DECHEN, A.R.; NACHTIGAL, G.R.; CARMELHO, Q.A. de C.; SANTOS, L.A.; SPERANDIO, M.V.L. Micronutrientes. *In*: FERNANDES, M.S.; SOUZA, S.R. de; SANTOS, L.A. (ed.). **Nutrição mineral de plantas**. 2.ed. Viçosa, MG: Sociedade Brasileira de Ciência do Solo, 2018. p.670.

DEUS, J.A.L. de; NEVES, J.C.L.; NETO, A.J. de L.; NATALE, W.; VÍCTOR HUGO ALVAREZ, V.; ALBUQUERQUE, F.M.R de. Partitioning of macronutrients and nutritional efficiency in fertigated prata banana. **Revista Brasileira de Fruticultura**, Jaboticabal, v.42, n.4, p.1–13, 2020.

DONATO, S.L.R.; RODRIGUES, M.G.V.; SOUZA, I. de. Considerações sobre índices técnicos e econômicos de produção para a cultura da bananeira. **Informe Agropecuário**, Belo Horizonte, v.36, n.288, p.116-26, 2015.

FAOSTAT. **Food and Agriculture Organization of the United Nations. Statistics division**. Rome, 2020. Disponível em: https://www.fao.org/faostat/en/#data/QCL. Acesso em: 7 fev. 2022.

LUCENA, J.J.; MASAGUER, A.; RODRIGUES, L.A. O sistema solo. *In*: MARTINEZ, H.E.P.; LUCENA, J.J.; BONILLA, I. (ed.). **Relação solo-planta**: bases para a nutrição e produção vegetal. Viçosa: UFV, 2021. p.18–56.

MAIA, C.E.; MORAIS, E.R.C. de; OLIVEIRA, M. de. Nível crítico pelo critério da distribuição normal reduzida: uma nova proposta para interpretação de análise foliar. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v.5, n.2, p.235-8, 2001.

MARQUES, P.R.R.; DONATO, S.L.R.; SÃO JOSÉ, A.R.; ROSA, R.C.C.; ARANTES, A.de M. Nutritional status and production of 'Prata-Anã' (AAB) and 'BRS Platina' (AAAB) banana plants with organic fertilization. **Nativa**, Sinop, v.10, n.1, p.60-8, 2022.

MARSCHNER, P. **Marschner's mineral nutrition of higher plants**. 3.ed. London: Academic Press, 2012. p.651.

MARTINEZ, H.E.P.; MENEZES, J.F.S.; SOUZA, R.B. de; ALVAREZ VENEGAS, V.H.; GUIMARÃES, P.T.G. Faixas críticas de concentrações de nutrientes e avaliação do estado nutricional de cafeeiros em quatro regiões de Minas Gerais. **Pesquisa Agropecuária Brasileira**, Brasília, DF, v.38, n.6, p.703-13, 2003.

ORR, R.; NELSON, P.N. Impacts of soil abiotic attributes on Fusarium wilt, focusing on bananas. **Applied Soil Ecology**, Amsterdam, v.132, p.20–33, 2018.

RODRIGUES FILHO, V.A.; NEVES, J.C.L.; DONATO, S.L.R.; GUIMARÃES, B.V.C. Potential nutrient-response curves and sufficiency ranges for 'Prata-Anã' banana cultivated under two environmental conditions. **Scientia Agricola**, Piracicaba, v.78, n. 1, p.1–12, 2021a. Suplemento

RODRIGUES FILHO, V.A.; NEVES, J.C.L.; DONATO, S.L.R.; GUIMARÃES, B.V.C. Universality of kenworthy and dris norms for prata and cavendish bananas grown in two environments. **Revista Brasileira de Ciencia do Solo**, Viçosa, MG, v.45, n.e0200120, p.1–14, 2021b.

RODRIGUES FILHO, V.A.; NEVES, J.C.L.; DONATO, S.L.R.; GUIMARÃES, B.V.C. Potential nutrient-response curves and sufficiency ranges of 'Grande Naine' banana cultivated in two environment. **Revista Brasileira de Fruticultura**, Jaboticabal, v.43, n.1, p.1–18, 2021c.

RODRIGUES, M.G.V.; PACHECO, D.D.; NATALE, W.; SILVA, J.T.A. da. Amostragem foliar da bananeira 'Prata-Anã'. **Revista Brasileira de Fruticultura**, Jaboticabal, v.32, n.1, p.321-25, 2010.

RODRIGUES, M.G.V.; RUGGIERO, C.; NATALE, W.; PACHECO, D.D. Nutrição e produção da bananeira 'Prata- Anã' adubada com Zinco e Boro diretamente no rizoma, via muda desbastada. **Revista Brasileira de Fruticultura**, Jaboticabal, v.29, n.3, p.645-51, 2007.

SANTOS, H.G.; JACOMINE, P.K.T.; ANJOS, L.H.C.; OLIVEIRA, V.A.; LUMBRERAS, J.F.; COELHO, M.R.; ALMEIDA, J.A.; FILHO, J.C.A.; OLIVEIRA, J.B.; CUNHA, T.J.F. **Sistema brasileiro de classificação de solos**. 5.ed. Brasília, DF: EMBRAPA, 2018. p.356.

SILVA, J.T.A. da. Solo, adubação e nutrição para bananeira. **Informe Agropecuário**, Belo Horizonte, v.36, n.288, p.74–83, 2015.

SILVA, J.T.A. da .Solo, adubação e nutrição. *In*: DONATO, S.L.R.; BORÉM, A.; RODRIGUES, M.G.V. (ed.). **Banana**: do plantio a colheita. Belo Horizonte: EPAMIG, 2021. p.77–97.

TEIXEIRA, M.B.; DONATO, S.L.R.; SILVA, J.A. da; DONATO, P.E.R. Reference values for nutritional diagnosis of 'Gigante' cactus pear by DRIS and BIK methods. **Ciência e Agrotecnologia**, Lavras, v.45, n.e010721, p.1–11, 2021.

WADT, P.G.S.; ALVAREZ V., V.H.; NOVAIS, R.F.; FONSECA, S.; BARROS, N.F. O método da chance matemática na interpretação de dados de levantamento nutricional de eucalipto. **Revista Brasileira de Ciência do Solo**, Viçosa, MG, v.22, n.4, p.773-8, 1998.

WALWORTH, J.L.; LETZSCH, W.S.; SUMNER, M.E.Use of Boundary lines in establishing diagnostic norms. **Soil Science Society of America Journal**, Madison, v.50, n.1, p.123-28, 1986.