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Nutritional diagnosis in a Conilon coffee plantation in the northern region of the Espírito Santo state

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Abstract

The soils of Coastal Tablelands are characterized by low natural fertility, which reinforces the importance of assessing soil fertility and leaf nutrition of crops. The objective of this study is to present a diagnosis of soil fertility and leaf nutrition of coffee plantations with Conilon from Coastal Tablelands in the northern area of the Espírito Santo state. A total of 49 soil samples were collected at a depth of 0-0.20 m and 49 leaf samples. In the soil, we can find Al^{3+}, Ca^{2+}, Mg^{2+}, K^{+}, (H+Al), SB, V, CTC, pH (water), P Mehlich-1, carbon (C), organic matter (MO), nitrogen (N), Cu^{2+}, Fe^{2+}, Mn^{2+}, Zn^{2+}, and in the leaves N, P, K, Ca, Mg, Cu, Fe, Mn and Zn contents. Soil fertility and leaf nutrition were diagnosed, followed by the identification of deficit elements after comparison with reference coffee crops. In the soil, most coffee plantations have low levels of MO, K, Ca, Mg, Fe, Al and (H+Al), with P in excess, and the other attributes at medium levels. As for the leaves, most coffee plantations have low levels of N, P, K, Mg, Cu, Fe, and Zn, with Mn at an adequate level and Ca at a high level. The soil and leaf elements evaluated are mostly at lower levels than the reference crops.

Keywords: Weathered Soils. *Coffee canephora*. Nutritional Diagnosis.

Introduction

The first step towards achieving improvements in soil attributes is knowing the characteristics related to its formation and to its physical and chemical attributes, especially, those classified as dystrocohesic, as is the case of many of the Coastal Tablelands soils. The Coastal Tablelands comprise a type of geomorphological formation that occurs significantly in the North of Espírito Santo and above this landscape one of the main producing regions of Conilon coffee in Brazil. The land is predominantly smoothly bumpy, and may have wavy surfaces in its interior and, strong wavy in the dissection areas. However, it rarely exceeds 30% slope (FONTANA *et al.,* 2016).

Regarding the soil quality in the state of Espírito Santo, in general, by the fertility index carried out by Pires *et al.* (2003), most of the fertility attributes evaluated are at low levels, requiring liming and fertilization for its usage in agriculture. Such information reinforces the importance of correct soil management, promoting better conditions for the development of the root system and nutrient absorption, especially for Conilon coffee.

Through the chemical and physical analysis of the soil, it is possible to know its characteristics and fertility status, which are important to determine sources, quantities, and the most appropriate time for the application of correctives and fertilizers (COVRE *et al.,* 2018).

In this sense, the correct interpretation of the chemical analysis of the soil and leaves provides information that favors recommendations and the management of inputs, aiming to achieve a better balance or nutritional balance. This analysis directly reflects on the increase in productivity and greater profitability of coffee plantations, in addition to the conservation of soil, water, and nutrients resources.

This work was produced to present a diagnosis of soil fertility and leaf nutrition of coffee plantations with Conilon in Coastal Tablelands in the northern region of the Espírito Santo state.

Material and methods

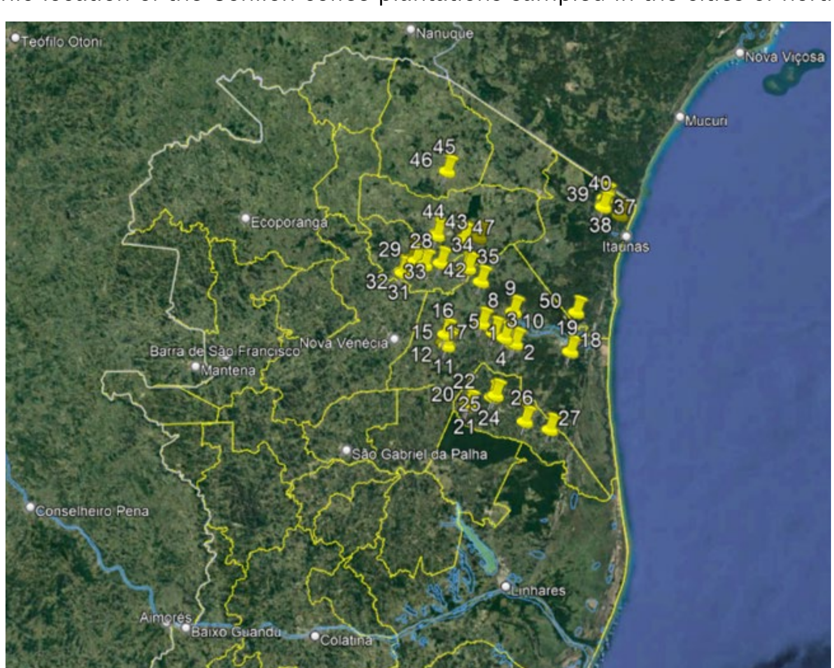
The study area included the cities located in the Coastal Tablelands of the northern region of Espírito Santo: São Mateus, Jaguaré, Boa Esperança, Pinheiros, Conceição da Barra, and Montanha. According to the climate classification proposed by Köppen, this region has an Aw climate, that is, humid tropical in summer and dry winter with annual precipitation and average temperature between 1,000 and 1,400 mm and 23°C, respectively (ÁLVARES *et al.,* 2014).

In each city, properties with Conilon coffee (Coffea canephora) located at the top of the Tableland were selected. The main soil classes are Latossolos Amarelos e Argissolos Amarelos, which might be dystrophic or dystrocohesic, according to the classification by the Brazilian System of Soil Classification (SiBCS) (SANTOS *et al.,* 2018).

Sampling was carried out from March to July 2018, in crops in total production, between 2 and 16 years old and with different genotypes, totaling 30 properties and 49 coffee plantations sampled (Figure 1). Coffee trees in general were at the stage of grain filling and fruit maturation (Figure 2). The density of plants per hectare in the fields ranged from 2,500 to 4,000, and the average productivity estimated by the producers was 63 bags per hectare (25 to 100 bags per hectare). Most of the crops sampled were managed with irrigation, fertilization, liming and phytosanitary control, with or without the help of a responsible technician. In general, soil fertility analyzes were carried out once a year.

Soil samples for fertility analysis were taken from the canopy projection of the plants and collected through a probe at a depth of 0-0.20 m, composing at least 15 simple samples in an area of 1 ha. The samples were crushed and subjected to drying in an oven with forced air circulation, at a temperature of 50°C until constant weight. Then, they were sieved in a granulometric sieve with a mesh of 2 mm.

Figure 1. Geographic location of the Conilon coffee plantations sampled in the cities of northern Espírito Santo



In chemical analyses, Al^{3+}, Ca^{2+}, Mg^{2+}, K^{+}, potential acidity (H+Al), SB, V, CTC, pH (water), Mehlich-1 phosphorus (P), organic carbon (C), organic matter (MO), nitrogen (N) and micronutrients (Cu^{2+}, Fe^{2+}, Mn^{2+}, Zn^{2+}). In the physical analysis, the granulometry was determined with the coarse sand, fine sand, silt, and clay fractions. Organic matter was obtained by multiplying the carbon content by 1.724 (TEIXEIRA *et al.,* 2017).

Soil samples with an undisturbed structure in the projection of the canopy of the plants were also taken, through the insertion of a steel ring with sharp edges and an internal volume of 91.55 cm^3, at a depth of 0-0.10 m, for analysis of soil density, totaling five samples per plot. Total porosity was calculated from the ratio between soil density (Ds) and particle density (Dp) according to the formula: 1-(ds/dp)*100 (TEIXEIRA *et al.,* 2017).

As for the physical properties, the average soil density is 1.43 g cm^{-3}, with a minimum of 1.24 g cm^{-3} and a maximum of 1.7 g cm^{-3}; the average particle density is 2.55 g cm^{-3}, with a minimum of 2.06 g cm^{-3} and a maximum of 2.82 g cm^{-3}; and the total porosity of 43.7%. In the granulometric composition of the soil, coarse sand varied from 426 g kg^{-1} to 802 g kg^{-1}, fine sand from 88 g kg^{-1} to 254 g kg^{-1}, silt from 10 g kg^{-1} to 62 g kg^{-1}, and clay from 80 g kg^{-1} to 360 g kg^{-1}. The predominant texture was sandy loam.

Leaf sampling was carried out in the plots corresponding to the soil sampling, removing four leaves with petiole per plant from the third or fourth pair of leaves from the productive branches, located at the mid-height of the plant and around it, totaling 80 leaves per plot. The freshly harvested leaves were dried in an oven with forced air circulation at a temperature of 65°C until constant weight. Then, they were ground in a Willye mill and packed in plastic bags for further analysis. In the foliar analysis, macronutrients (N, P, K, Ca, Mg) and micronutrients (Cu, Fe, Mn, Zn) were determined (CARMO *et al.,* 2000).

Data analysis consisted of descriptive statistics (mean, mean standard deviation, and coefficient of variation). The diagnosis of soil fertility was carried out using studies carried out in Conilon coffee plantations in Espírito Santo (PREZOTTI *et al.,* 2007). The percentage of crops with nutrient content at low, medium, adequate, and high levels was calculated. In order to compare the coffee trees sampled in this study and coffee trees with productivity equal to or greater than 100 bags per hectare, the work by Cavalcanti et al. (2017) carried out in the extreme south of Bahia, due to the great geographical proximity between the two states, in addition to being more recent research. For the nutritional diagnosis of plants, the work developed in the North of Espírito Santo by Partelli *et al.* (2018).

Figure 2. Conilon coffee plantations in full production, sampled in the cities of northern Espírito Santo

Results and discussion

The absolute majority of the crops sampled have low organic matter (MO) content, with a general average of 13.0 g kg^{-1} (Table 1). The average N contained in the soil is 0.9 g kg^{-1}, but this data is not used as a factor to evaluate the soil quality or fertility, due to its dynamics in tropical soils.

In Coastal Tablelands, soils with low natural fertility, the medium and sandy texture associated with high temperature and humidity intensify the oxidation of MO, indicating a low C/N ratio. Along with this fact, in conventional crops, the intensive use and constant soil disturbance contribute to the reduction of MO content. However, its presence in the soil is mainly in the organic form. When evaluating the C/N ratio, with an average of 8.6, it was observed that the OM was already stabilized in the soil.

The P content represents the only chemical element with the highest proportion in the high index, with an average of 55 mg dm^{-3} (Table 1). Despite this, there is a wide variation in the levels concerning the average, that is, there are rural properties with a low level and others with a high level. For P, in addition to the variation related to the form of fertilizer application, the extractor used (Mehlich-1), as it is an acidic solution (pH around 2.0), dissolves poorly soluble forms of P, thus overestimating the available P contents in the soil.

The K content is in greater proportion in the low index, with an average of 67.2 mg dm^{-3}, as well as Ca and Mg, with an average of 2.5 and 0.7 $cmol_c$ dm^{-3}, respectively (Table 1). The sum of exchangeable bases (SB), base saturation (V), and cation exchange capacity (CTC) depends on the values of the cations present in the soil solution, showing its productive potential and the adsorption capacity of the nutrients available in the solution. These variables are in greater proportion to the appropriate indices (Table 1), allowing us to infer that the sampled soils show

Table 1. Contents of soil chemical attributes in the 0-0.20 m layer and the classification proposed by Prezotti *et al.* (2007).

Nutrient	Average	SD	CV (%)	Proportion of plantation (%)				Ideal range
				Low	Medium	Adequate	High	
C (g kg^{-1})	7,7	1,8	23,3	-	-	-	-	-
MO* (g kg^{-1})	13,0	3,0	23,3	98	0	2	0	15,0-30,0
N (g kg^{-1})	0,9	0,2	25,5	-	-	-	-	-
P (mg dm^{-3})	55	45	81	4	10	12	74	15,1-20
K (mg dm^{-3})	67	40	60	50	42	6	2	120-200
Ca ($cmol_c$ dm^{-3})	2,5	0,9	36,2	78	16	-	6	3,0-4,0
Mg ($cmol_c$ dm^{-3})	0,7	0,2	29,2	55	41	-	4	0,8-1,0
Cu (mg dm^{-3})	1	1	115	40	50	-	10	0,5-1
Fe (mg dm^{-3})	19	8	41,7	100	0	-	0	100-200
Mn (mg dm^{-3})	12	11	89,7	22	53	-	25	5-15
Zn (mg dm^{-3})	7	6	88,8	12	51	-	37	2-6
pH (H_2O)	5,9	0,5	8,3	8	-	74	18	5,5-6,5
Al^{3+} ($cmol_c$ dm^{-3})	0,02	0,1	261	98	2	-	0	-
H+Al ($cmol_c$ dm^{-3})	2,2	1,0	45,7	71	29	-	0	-
SB ($cmol_c$ dm^{-3})	3,4	1,1	31,8	6	88	-	6	2,0-5,0
CTC ($cmol_c$ dm^{-3})	5,5	1,3	24,3	42	0	58	0	4,5-10
V (%)	61,7	13,8	22,4	20	22	56	2	60-70

SD: standard deviation; CV: coefficient of variation.
*Obtained by multiplying the C content by 1.724

a positive response to the use of correctives and fertilizers.

Exchangeable acidity (Al^{3+}) and potential acidity (H+Al) have low levels, with averages of 0.02 and 2.2 $cmol_c$ dm^{-3}, respectively (Table 1). The lower the Al^{3+} content in the soil, the better the plant development, since Al causes the coffee roots to thicken, reduces their growth, and prevents the formation of root hairs, impairing the absorption of water and nutrients (PREZOTTI; GUARCONI, 2013). Active acidity (pH) is within the expected range for Conilon coffee, with an average of 5.9 (Table 1). The pH value of the soil influences the forms of Al: with the elevation of the index, the Al passes to the insoluble form, which is non-toxic to the plants (SOBRAL *et al.,* 2015). This fact reinforces the importance of liming, aiming to reduce Al toxicity and increase the availability of Ca and Mg in the soil.

Of the micronutrients analyzed, Cu, Mn, and Zn have a medium index and Fe low index in all crops sampled (Table 1). Fe deficiency may be related to the application of high doses of limestone or high levels of P in crops (PREZOTTI; GUARCONI, 2013), as occurred in this research. Similar results were observed by Costa *et al.* (2000), in which Fe was one of the most limiting nutrients in a large number of Conilon coffee crops.

The finding of deficiency in the soil of most nutrients is related to the low concentration of these compounds in the soils of Coastal Tablelands, due to their extraction via consecutive crops. In many crops, nutrients were not added or were added in insufficient amounts, in addition to heterogeneous or incorrect distribution. Soil pH ranged from 4.7 to 7.1, which may have contributed negatively to the availability of nutrients in the soil and their absorption by plants.

Data on leaf nutrients, in general, revealed coefficients of variation considered high, indicating that there was a great dispersion of values in relation to the average (Table 2). One of the possible explanations for the heterogeneity of the samples is the great technological variation of the crops sampled, in which countless genetic materials, types, and forms of application of fertilizers are used.

As for the levels, N, P, K, Mg, Cu, Fe, and Zn are in a deficiency state in the plants. Only the Mn content has a higher percentage at the appropriate level, while Ca is at a high level, with Mn averages of 70.5 mg kg^{-1} and Ca 13.8 g kg^{-1}, respectively (Table 2).

In addition to the considerations already presented regarding the variability of leaf nutrients associated with genetics and inputs, samples

Table 2. Descriptive statistics of leaf nutrients and classification proposed by Prezotti *et al.* (2007).

Nutrient	Average	SD	CV (%)	Proportion of plantation (%)			Ideal range
				Low	Adequate	High	
N (g kg^{-1})	23,0	3,0	13,3	100	0	0	29,0 – 32,0
P (g kg^{-1})	0,9	0,2	16,7	96	4	0	1,2 – 1,6
K (g kg^{-1})	13,7	3,0	22,1	100	0	0	18,0 – 22,0
Ca (g kg^{-1})	13,8	2,6	18,6	8	24	68	10,0 – 13,0
Mg (g kg^{-1})	3,0	0,8	25,8	71	29	0	3,1 – 4,5
Cu (mg kg^{-1})	8,5	6,2	73,4	53	38	9	8– 16
Fe (mg kg^{-1})	70,0	60,8	87,4	82	12	6	70 – 180
Mn (mg kg^{-1})	70,5	52,7	75,0	37	58	5	50 – 200
Zn (mg kg^{-1})	4,4	4,3	97,8	94	6	0	10 – 20

SD: standard deviation; CV: coefficient of variation.

were taken during the period of grain filling and ripening of Conilon coffee fruits, in which these nutrients are in a state of deficiency in the plants. In the study by Prezotti and Bragança (2013), the number of nutrients accumulated in the coffee plant varied with the location, time of year, age, organs, and tissues of the plant, which allowed the conclusion that the levels of N, P and K in all plant parts declined over the months after flowering, as occurred in this study.

Regarding other nutrients, Bragança *et al.* (2007) state that the accumulation of micronutrients such as Fe and Zn occurs in the roots, Mn in the leaves, Cu in the trunk, and orthotropic branches. Marré *et al.* (2015), in a study on the accumulation of micronutrients in Conilon coffee fruits, observed that the accumulation rates of Fe, Cu, and Mn were found from the 76th day after anthesis. In addition, Zn exhibited a phase of slow accumulation at the beginning of fruit formation, followed by a phase of rapid accumulation in the middle period of the formation/maturation cycle, so the rate of these elements in the leaves is lower during the granulation phase.

The low levels of most leaf nutrients are also influenced by the high demand during fruit development, which tends to be higher during fruit expansion and grain filling (PARTELLI et *al.,* 2014), a period in which nutrients present in the leaves and other plants parts are translocated to the fruits in a source/sink relationship (PARTELLI *et al.,* 2016). Covre *et al.* (2018) observed that, throughout the development of Conilon coffee fruits, the levels of N, P, K, Ca, and Mg in the leaves decreased markedly due to the high translocation of these nutrients to the fruit. The high levels of Ca in the leaves found in this study may be associated with their low mobility. According to Altoé *et al.* (2016), after being initially acquired by the roots, most of the Ca is transported in the xylem to the leaves, and, after being allocated in the leaves, the Ca becomes immobile in the plant.

Santos *et al.* (2021) evaluated different genotypes and obtained higher concentrations of the main nutrients for the leaves in the first collection period (August), which were reduced for the last periods evaluated (May), possibly due to mobilization for fruits. These same authors reinforce that for nutritional diagnosis it is important to make comparisons of genetic diversity and the periods or phases of the production cycle. In this sense, Silva *et al.* (2021) evaluated the concentration of nutrients in the leaves and stated that to improve the efficiency of nutritional diagnosis, in addition to the sampling periods of pre-flowering and grain filling, the variability of genotype for leaf nutrients and their concentrations must also be taken into account.

As for the soil fertility of Conilon coffee, it can be seen that the levels of P, Ca and Zn in the soil of the crops sampled in this study are above the amount found in the reference crops. OM and the elements K, Mg, Cu, Fe, and Mn have lower averages, with emphasis on Fe, with an imbalance of nutrients (Figure 3). As for leaf nutrition, all nutrients are found with averages below the amount found in reference crops (Figure 4). The difference between the average values of the sampled crops and the reference crops is expected, since the higher the productivity of Conilon coffee plants, the greater their demand for nutrients (SANTOS *et al.,* 2015). If Conilon coffee producers from Tabuleiros Costeiros do Norte do Espírito Santo want to reach this level of productivity, they must, among other factors, pay attention to the nutritional status of their crop, carrying out sampling at the indicated times and adding the deficit elements.

Conclusions

Coffee plantation soils have low levels of MO, K, Ca, Mg, Fe, Al, and (H+Al), with Fe and MO being the most limiting attributes. P is above the limit, and the other attributes analyzed are at medium levels.

Figure 3. Organic matter and nutrients in the soil of the crops sampled in this study compared to crops with productivity equal to or greater than 100 bags ha^{-1} (CAVALCANTI *et al.*, 2017)

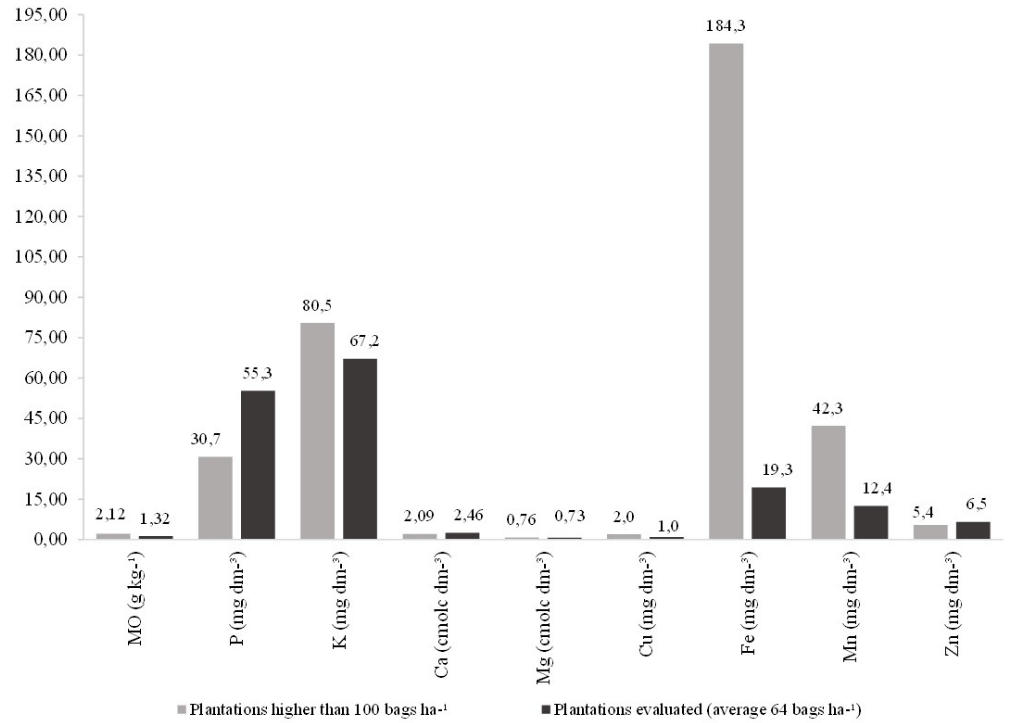
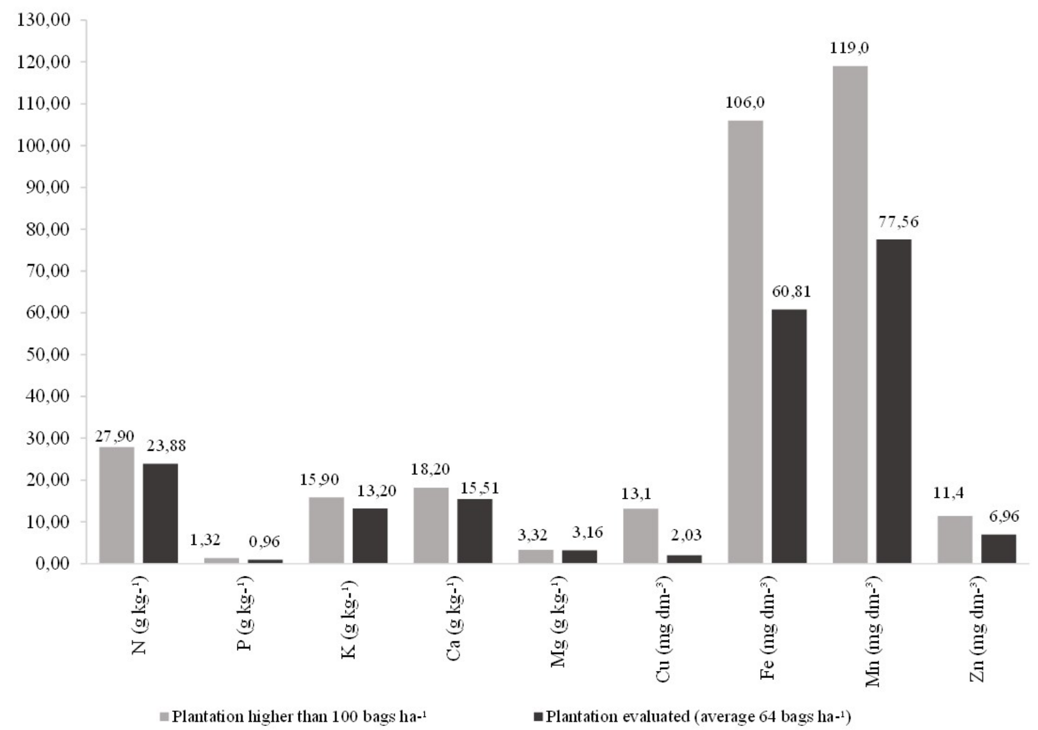


Figure 4. Nutrients in the leaves of the crops sampled in this study compared to crops with productivity equal to or greater than 100 bags ha^{-1} (PARTELLI *et al.*, 2016)



Coffee leaves have low levels of N, P, K, Mg, Cu, Fe, and Zn, with N and K being the most limiting nutrients. Only the Mn content of most coffee plantations is at an adequate level, while Ca has a high index.

The indices of MO, K, Ca, Mg, Fe, Al, and (H+Al) in the soil and N, P, K, Mg, Cu, Fe, and Zn in the leaves are at lower levels than those found in reference crops in productivity.

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