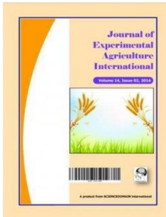

Journal of Experimental Agriculture International

22(2): 1-7, 2018; Article no.JEAI.40559
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Use of the Integrated Diagnosis and Recommendation System and Sufficiency Band for Nutritional Status of Conilon Coffee

Abel Souza da Fonseca[1*], Julião Soares de Souza Lima[1] and Samuel de Assis Silva[1]

[1]Federal University of Espírito Santo, R: Felicio Alcure, s/n 29500-000, Alegre, ES, Brazil.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript

Article Information

DOI: 10.9734/JEAI/2018/40559
Editor(s):
(1) Marco Aurelio Cristancho, Professor, National Center for Coffee Research, CENICAFÉ, Colombia.
Reviewers:
(1) Bouhafa Karima, Regional Agricultural Research Center of Meknès, Morocco.
(2) Ade Onanuga, Canada.
Complete Peer review History: http://www.sciencedomain.org/review-history/24027

Original Research Article

Received 24th January 2018
Accepted 29th March 2018
Published 6th April 2018

ABSTRACT

Knowing the nutritional conditions of the crop is an important factor to understand its development, indicating the leaf nutrient contents and making possible correlations with the productivity in order to equate the presented variations. The objective of this paper was to diagnose the most limiting nutritional factors to obtaining high yields by Diagnosis And Recommendation Integrated System (DRIS) method and sufficiency ranges for conilon coffee culture. In the coffee crop of the variety Robusta Tropical - Emcaper 8151, located in the county of Cachoeiro de Itapemirim - ES, an irregular mesh was built, with 140 georeferenced points. To obtain the data of the leaf analysis at each point, two pairs of leaves of the lateral branches were collected at the average height of each plant at the 4 cardinal points. In the interpretation of the foliar analysis results by the DRIS method, indexes were calculated for each nutrient of each sample and for the evaluation by the sufficiency range, tabulated values were used. The Diagnosis by DRIS and the Range of sufficiency determined P, Fe, Zn and S as the most limiting nutrients by deficiency. The DRIS method showed greater sensitivity when assessing nutrient deficiencies. Showing lower N limitation and showing difference between Fe and K deficiencies.

**Corresponding author: E-mail: abelsouzafonseca@gmail.com;*

Keywords: Coffea canephora; foliar analysis; nutritional balance; DRIS; nutrients.

1. INTRODUCTION

Knowing the nutritional conditions of the crop is an important factor to understand its development, indicating the leaf nutrient contents and making it possible to correlate with the productivity in order to equate the presented variations. Researches have been carried out with conilon coffee in an attempt to interpret and optimize the application of fertilizers [1]. Currently, with the implementation of precision agriculture in coffee (Precision Coffee), the coffee grower aims to optimize resources and environmental issues through the application of fertilizers with differentiated dosages [2].

In order for a crop to be able to express its maximum productive potential in a sustainable manner, appropriate management adoptions should consider not only soil fertility but also nutritional status [3] which makes it fundamental the study and the development of techniques that seek to reduce losses due to inadequate management and consequent productivity losses [4].

Beaufils [5] recommends the Diagnosis and Recommendation Integrated System (DRIS) as it encompasses the concept of balance between minerals and allows the direct and precise nutritional diagnosis, since the plant is considered the soil nutrient extractor itself.

Fonseca et al. [6] demonstrated the efficiency of DRIS in conilon coffee plantations in the spatial analysis, where the nutritional diagnosis of the plants led to the determination of the nutritional limitation of each nutrient. The DRIS compares the two-to-two ratio of nutrient contents in the crop studied with reference crops, in this way it is possible to obtain the Nutritional Balance Index (NBI), which is the modular sum of the DRIS indexes obtained from each element, nutritional balance of the crop. The closer to zero the index, the more nutritionally balanced the crop will be.

The range in which the nutrient contents in the leaf are adequate is taken as the range of sufficiency. When the content of a given nutrient is between the maximum and minimum values of the sufficiency range, the culture is considered to be well nourished; If it is above or below the range, it is considered that the culture may present nutritional problems. The main disadvantage of interpretation is that it does not take into account the relationship between nutrients and the variation of their concentrations with the development of the crop.

Souza et al. [7] analyzed the nutritional status of cotton by DRIS methods and sufficiency ranges, and concluded that the two methods of interpretation complement each other and have the potential to perform efficient mineral nutrition for this crop, but the DRIS method presented greater sensitivity to diagnose deficiencies of micronutrients.

As seen above, the objective of this research was to diagnose the most limiting nutritional factors to obtaining high yields by the DRIS methods and sufficiency ranges for conilon coffee culture.

2. MATERIALS AND METHODS

The study was conducted in a coffee crop of the variety Robusta Tropical - Emcaper 8151, located in the county of Cachoeiro do Itapemirim, ES, located at 20º45'17,31" south latitude and 41º17 '8,86" west longitude, with an average elevation of 113 m. The soil was classified as dystrophic Red-yellow Latosol with clay texture, with mean grain size fractions = 415.6 g kg -1, silt = 190.5 g kg -1 and total sand = 393.9 g kg- 1 in the 0-0.20 m layer [8].

The studied crop was 11 years after its planting, at a spacing of 2.9 x 0.9 m and totaling an area of one hectare. Planting fertilization was performed with 0.130 kg per 20-00-20 formulated plants (NPK) and an application of 0.080 kg per super simple plants (SS) with doses varying according to soil analysis. In the area was constructed an irregular mesh, with 140 georeferenced points, spaced in approximately 10 m, in the coffee line, and each sampling point composed of five coffee plants, totaling an area of 13.05 m² per point.

Leaf analysis was used to obtain data that allow the characterization of the nutritional status of the plant at each point. In order to obtain these data, two pairs of leaves of the lateral branches (3rd and 4th pairs counting from the tip to the base) were collected at the mean height of each plant [9]. The leaves, collected in January 2011, were packed in a paper envelope, oven dried at 65 ° C until constant mass, ground and then sent to the analysis laboratory of the Agricultural Sciences Center - UFES. The samples were analyzed to obtain the dry matter concentrations of the macronutrients: N, P, K, Ca, Mg and S; and of the micronutrients: Fe, B, Zn, Mn and Cu. The methodology was in agreement with EMBRAPA [10].

In order to evaluate the distribution of variables, a descriptive statistical analysis was performed: position measurements (mean and median); Dispersion measurements (maximum and minimum values, standard deviation, variance and coefficient of variation); Dispersion (coefficient of asymmetry and kurtosis); And the normality check of the data at 5% significance by the Kolmogorov-Smirnov (KS) test.

For nutrient interpretation by the sufficiency range, the nutrient concentration considered adequate for conilon coffee (Table 1), described by Bragança, Prezotti and Lani [11], was used.

In order to determine the nutritional balance indexes (NBI), the functions of the ratios between two nutrients were calculated: f (A / B) = (A / B - a / b) k/ s, where f (A / B) A / B is the value of the ratio between the two nutrients in the leaves under diagnosis, a / b is the norm value (reference tillage), "k" Is an arbitrary constant, which we consider equal to 1, and "s" is the standard deviation of the relation in the reference population. The reference population DRIS (standard) was used according to Partelli et al. [12], which established DRIS standards for the county of Vila Valério – ES.

The indexes DRIS were calculated as follows: Index A = {[f (A / B) + ... + f (A / Z)] - [f (B / A) + ... + f (Z / A)]} / (n+m), Where f (A / B) is the reduced normal function of the direct relationship between the contents of two nutrients A and B, f (B / A) is the reduced normal function of the inverse relationship between the contents of two nutrients B and A, n is the number of functions where the nutrient A in analysis appears in the numerator (direct relations) m is the number of functions where the nutrient A in analysis appears in the denominator (inverse relations).

The Index of Nutritional Balance was obtained by means of the sum of the absolute values of each index: NBI = | Index A | + | Index B | + ... + | Index Z |.

In addition to the conventional evaluation by the DRIS index, the percentage of total limitation occurrence was considered, where all variables with negative indices of each sample were evaluated; The percentage of occurrence of total limitation; And the percentage of occurrence in the first, second and third order, corresponding to the first, second, and third most negative index respectively in each sample. This first, second and third order percentage was obtained after the DRIS indexes were organized in descending order, to facilitate the quick visualization and interpretation of the analyzes, as suggested by Amaral et al. [13]

Table 1. Nutrient sufficiency ranges for interpretation of leaf analysis in conilon coffee

Nutrient	Interpretation class		
	Low	Appropriate	High
		---------------------------g kg^{-1}---------------------------	
N	< 29,0	29,0 – 32,0	> 32,0
P	< 1,2	1,2 – 1,6	> 1,6
K	< 20,0	20,0 – 25,0	> 25,0
Ca	< 10,0	10,0 – 15,0	> 15,0
Mg	< 3,5	3,5 – 4,0	> 4,0
S	< 2,0	2,0 – 2,5	>2,5
		---------------------------mg kg^1---------------------------	
Fe	< 120	120 – 150	> 150
Zn	< 10	10 – 15	> 15
Mn	< 60	60 -80	> 80
B	< 50	50 – 60	>60
Cu	< 10	10 – 20	>20

Source: Adapted from Bragança, Prezotti and Lani [11]

3. RESULTS AND DISCUSSION

The descriptive analysis of nutrient theorists is shown in Table 2. With the exception of Fe and Zn, all nutrients presented very close measures values of central (median and median).

The coefficients of variation (CV), according to the classification proposed by Warrick and Nielsen (1980), with the exception of N (low = CV <12%), are in the range of 12 to 60%, being classified as average. This lower variability of N in leaves compared to the mean was also found by Silva and Lima [4] and by Partelli, Vieira and Martins [14].

The average of N, P, Ca and Cu are within the suitable range for coffee plantations, described by Bragança, Prezotti and Lani [11]. The low requirement of P by coffee was supplied by the phosphate fertilization of the soil. The conilon coffee has high efficiency in the extraction of P from the soil, although the macronutrient is less required for growth and production in quantitative terms, in contrast, it has great importance in the flowering, fruiting and maturation of the fruits.

In contrast to the low requirement of P, the N is the nutrient most demanded by the plant. According to Bragança et al. [15] N is among the nutrients recommended in higher quantities for fertilization of coffee plantations in production phase, and as a more abundant nutrient in the coffee tree, is directly linked to photosynthesis, due to its importance in the synthesis of chlorophyll, and participates in the development of the plant.

Fe and K are the most deficient nutrients in the crop. The iron deficiency can be very critical and even so the plant can continue on fruiting satisfactorily in the short term. The coffee potassium requirements are equivalent to those of nitrogen [16] and potassium appears with a higher concentration in the fruits, in particular in the coffee pulp, but without participating in organic molecules [17]. Thus the low K content may have occurred due to migration of the nutrients to the fruit.

Although Zn and S are also in a less critical situation, they are also deficient in the crop, necessitating the correction of these nutrients. Lime and phosphate fertilization can cause Zn deficiencies by decreasing the absorption of the element caused by P (uncompetitive inhibition) and insolubilization of Zn by calcareous. The deficiency in Fe, Zn and S were also observed by Oliveira et al. [9] studying the variability of nutritional status of conilon coffee.

The Mn and B were the nutrients in excess in the crop, and the average Mn concentration of the crop is 2.5 times greater than the maximum limit of the sufficiency range, which is 80 mg kg -1. Partelli, Vieira and Costa [18] observed that the Mn occurred as a limiting factor when performing a diagnosis in the organic and conventional crops of the State of Espírito Santo. This excess of Mn found in this study may be related to the continuous use of acidifying nitrogenous fertilizers in the crop.

Interpreting the variants of the leaf analysis form the coffee plant for the sufficiency range (Table 3), the nutrients that presented the highest percentages of samples below the minimum limit of the adequate range were K (100%), Fe (100%), Zn (96, 43%), S (92.14%), N (61.43%), Mg (59.29%). The nutrients that presented the highest percentages of samples above the maximum limit of the adequate range were B

Table 2. Descriptive statistics of the leaf macro and micronutrients of the coffee plantations

Nutrients	Average	Md	s	Minimum	Maximum	CV(%)	KS
N (g kg^{-1})	28,80	28,70	0,17	25,20	32,90	5,02	p<0,05*
P (g kg^{-1})	1,50	1,50	0,03	0,70	2,00	20,59	p<0,01*
K (g kg^{-1})	10,20	10,00	0,24	5,00	16,40	23,89	$p>0,20^{ns}$
Ca(g kg^{-1})	13,00	13,20	0,28	7,10	19,90	21,28	$p>0,20^{ns}$
Mg (g kg^{-1})	3,30	3,40	0,08	1,50	5,10	22,16	$p<0,10^{ns}$
S (g kg^{-1})	1,50	1,60	0,03	0,80	2,20	19,65	p<0,05*
B (mg kg^{-1})	105,19	105,10	24,31	65,80	174,00	23,11	$p>0,20^{ns}$
Cu (mg kg^{-1})	15,80	15,81	4,26	6,13	25,18	26,95	$p>0,20^{ns}$
Fe (mg kg^{-1})	48,60	54,00	18,65	2,50	93,00	38,40	p<0,01*
Mn (mg kg^{-1})	203,60	205,50	54,83	89,00	323,00	26,93	$p>0,20^{ns}$
Zn (mg kg^{-1})	6,83	7,54	2,19	1,82	10,87	31,99	p<0,01*

*Md - Median; s - standard deviation; CV - coefficient of variation; ns - normal distribution by Kolmogorov-Smirnov test (KS) at 5% probability; And * non-normal distribution*

Table 3 - Frequency distribution of macro and micronutrients obtained by leaf analysis of 140 conilon leaf samples

Variable	Interpretation criteria[1]		
	Below	Proper	Above
	-----%-----		
N	61,43	36,43	2,14
P	16,43	50,00	33,57
K	100,00	0,00	0,00
Ca	16,43	61,43	22,14
Mg	59,29	24,29	16,43
S	92,14	7,86	0,00
B	0,00	0,00	100,00
Cu	9,29	71,43	19,29
Fe	100,00	0,00	0,00
Mn	0,00	0,00	100,00
Zn	96,43	3,57	0,00

[1] Based on the appropriate levels described by Bragança, Prezotti and Lani [11].

(100%) and Mn (100%). The order of deficiency limitation according to the range of sufficiency was K = Fe> Zn> S> N> Mg> P = Ca> Cu. By ordering for excess we have Mn = B> P> Ca> Cu> Mg > N.

Table 4 shows the frequency distribution of the DRIS indexes, of each nutrient, according to their order of limitation. Analysis of the crop by DRIS allowed to determine the levels of deficiency in the following order: Fe> K> Zn> S> Mg> N> Ca> Cu> P> B> Mn; In which the first 3 nutrients are the only ones that appear as a first-order limitation, as shown in Table 4. As a second-order limiting, besides Fe, K and Zn, we have S, and of the third order P And Mg to the former.

The evaluation by the method of the sufficiency range shows that K and Fe are equally limitating in the coffee crop, both presented 100% of the samples below the adequate range (Table 3), whereas by the DRIS method these presented 77.81% of less deficiencies. K and Fe are the two most deficient nutrients when evaluated by both of the methods. Although they represented 22.19% of the negative indexes when evaluated by the DRIS method, Fe was more limiting in first order (62.14%) than K (33.57%) (Table 4). The DRIS is shown to be more sensitive in the evaluation of nutrient limitation in the crop, demonstrating that Fe is 28.57% more limiting than K in the first order.

According to Cantarella [19] the interaction between nutrients is the effect, positive or negative, that happens when adding a nutrient causes the increase or decrease of the response of the second element; Considering that the DRIS method evaluates this relationship between nutrients, with 2.73% of the DRIS negative indexes and 83.57% above the lower limit of the

Table 4. Percentage of occurrence of the most limiting nutrients by deficiency, diagnosed by the DRIS indexes obtained by the leaf analysis

Variable	% of occurrence[1]				Difference in relation to concentration range (%) [2]
	Total	1st order	2nd order	3rd order	
N	1,61	0,00	0,00	0,00	59,82
P	1,93	0,00	0,00	0,71	14,50
K	22,19	33,57	45,00	17,86	77,81
Ca	2,73	0,00	0,00	0,00	13,70
Mg	10,29	0,00	0,00	4,29	49,00
S	15,43	0,00	0,71	7,86	76,71
B	0,00	0,00	0,00	0,00	0,00
Cu	1,13	0,00	0,00	0,00	8,16
Fe	22,19	62,14	32,14	2,86	77,81
Mn	0,00	0,00	0,00	0,00	0,00
Zn	22,51	4,29	22,14	67,14	73,92

[1]In the total occurrence, all negative indexes are considered. In the percentages of occurrence of 1st, 2nd and 3rd order, the first, second and third most negative indexes of each sample are considered, respectively.
[2]Difference between the percentage of occurrence of samples in the class below the adequate, by the method of the concentration bands proposed by Bragança, Prezotti and Lani [11] and the percentage of total occurrence by the DRIS method.

sufficiency range, the levels of Ca can directly justify the low values of K and Mg, and indirectly those of N. Directly by the existing antagonism between K, Ca and Mg; Indirectly due to the synergism between K and N.

By the sufficiency range method, sulfur had 92.14% of the samples below the lower limit of the appropriate range and represented 15.43% of the DRIS negative indexes. This deficiency can be explained by a higher requirement of the nutrient in the metabolism, or by reducing the redistribution of the nutrient to the growth points, which affects the development of the plant [20]. The N had 61.43% of its samples below the lower limit of the range considered adequate; By the DRIS method, N corresponds to only 1.61% of the negative indexes. This may have occurred because the values of the N concentrations of the samples were just below the limit concentration of the range considered adequate.

The difference between the percentage of the occurrence of samples in the class below the adequate, by the method of the Sufficiency Ranges and the percentage of total occurrence, by the DRIS method, shows that when we use the relation between the nutrients, we have difference in the participation of each nutrient in the nutritional limitation value of the crop. The highest differences were observed for Fe (77.81%), K (77.81%), S (76.71%), Zn (73.92%) and N (59.82%).

The average NBI of the 140 points was equal to 25.5. The minimum value was 11.1 and the maximum was 80.3. This demonstrates the nutritional imbalance in the crop which is due to the deficiency and excess of the nutrients previously mentioned.

4. CONCLUSION

Diagnosis by DRIS and the Range of sufficiency determined P, Fe, Zn and S as the most limiting nutrients due to deficiency in the coffee crop.

The evaluation of the interaction between nutrients by the DRIS method altered the result interpreted through the range of sufficiency.

The DRIS method showed greater sensitivity when assessing nutrient deficiencies. Showing lower N limitation and showing the difference between Fe and K deficiencies.

DRIS is the most recommended method when it is of interest in the relationships between nutrients since the relation affects the evaluation of nutritional status.

ACKNOWLEDGEMENTS

To Conselho Nacional de Desenvolvimento Científico e Tecnplógico (CNPQ) and Fundação de Amparo à pesquisa e Inovação do Espirito Santo (Fapes) for financial support.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Lima JSS, silva SA, Oliveira RB, Fonseca AS. Use of kriging techniques to estimate Conilon coffee productivity. Revista Ceres. 2016;63(1):54-61.
2. Silva FC, Silva FM, Scalco MS, Sales, RS. Correlation detachment coffee force fruit under different conditions nutrition. Coffee Science. 2016:11(2):169-179.
3. Silva AS, Lima JSS, Queiroz DM. Spatial variability in nutritional status of Arabic coffee based on DRIS index. Ceres. 2011;58(2):256-261.
4. Silva AS, Lima JSS. Assessment of the variability of the nutritional status and yield of coffee by principal component analysis and geostatistics. Ceres. 2012;59(2):271-277.
5. Beaufils ER. Diagnosis and recommendation integrated system (DRIS): A general scheme for experimentation and calibration based on principles developed from research in plant nutrition. Soil Science Bulletin. 1973;1(1):1-132.
6. Fonseca AS, Lima JSSL, Silva SA, Xavier AC, Drumond Neto, AP. Spatial variability of the productivity and the nutritional condition of *coffee canephora.* Coffee Science. 2015;10(4):420-428.
7. Souza RF, Leandro WM, Silva NB, Cunha PCR, Ximenes PA. Nutritional diagnosis for cotton under savannah by using the dris and sufficiency ranges methods. Pesquisa Agropecuária Tropical. 2011;41(2):220-228.
8. EMBRAPA. Manual de Métodos de Análise de Solo. Rio de Janeiro: EMBRAPA, 2011;230.

9. Oliveira RB, Lima JSS, Silva SA, Antuniassi ER, Silva, AF. Spatial variability of the nutritional condition of canephora coffee aiming specific management. Coffee Science. 2010;5(3):190-196.
10. EMBRAPA - Métodos de análise de tecidos vegetais utilizados na Embrapa. Rio de Janeiro: Embrapa Solos. 2000; 41.
11. Bragança SM, Prezotti LC, Lani JA. Nutrição do cafeeiro Conilon. In: Ferrão, RG. etal. (Ed.) Café Conilon Vitória: Incaper. 2007;299-327.
12. Partelli FL, Altoé JA, Amaral JFT, Schmildt ER, Lopes JCL, Caten A. Normas de referência do DRIS para o cafeeiro conilon (*Coffea canephora* Pierre ex Froehner). In: CONGRESSO BRASILEIRO DEPESQUISAS CAFEEIRAS, 28, 2002, Caxambu. Anais. Rio de Janeiro: SARC/PROCAFÉ, 2002;326-328.
13. Amaral JAT, Amaral JFT, Schmildt ER, Lopes JC, Coelho RI. Alguns atributos do dris para a interpretera análise foliar do cafeeiro. In: Andrade FV, Passo RR, Mendonça ES, Lima JSSL, Ferreira A. Tópicos especiais em produção Vegetal II. Alegre: Caufes. 2011;101-115.
14. Partelli FL, Vieira HD, Martins MA. Nutritional diagnosis of the organic Conilon coffee trees (*Coffea canephora* Pierre ex Froehn): Suffiency range approach for leaves and soil. Coffee Science. 2006;1:43-49.
15. Bragança SM, Silva EB, Martins AG, Santos LP, Lani JA, Volpi, PS. Response of conilon coffee (*Coffea canephora* Pierre ex Froehn.) plants to NPK application in condensed planting system. Coffee Sciece. 2009;4:67-75.
16. Silva EB, Nogueira FD, Guimaraes PTG, Furtini Neto AE. Sources and doses of potassium in yield of the coffee tree on red dusky latosol and yellow red latosol. Ciência e agrotecnologia. 2001;25(2):288-298.
17. Neves YP, Martinez HEP, Amaral JFT, Souza RB, Domingos DR. Yield and accumulation of dry matter, NP, K on *Coffea arábica* l. Cultivars. Coffee Science. 2006;1:156-167.
18. Partelli FL, Vieira HD, Costa AN. Diagnose nutricional em cafeeiro conilon orgânico e convencional no espírito Santo, utilizando o DRIS. Ciência Rural. 2005;35(6):1456-1460.
19. Cantarella H. Nitrogenio In: Novais RF. et al. (Eds.). Fertilized do solo (375-470). 1 ed Viçosa, MG: Sociedade Brasileira de Ciência do Solo; 2007.
20. Tomaz MA, Martinez HEP, Cruz CD, Freitas RS, Pereira AA, Sakiyama NS. Efficiency of absorption and use of nitrogen, phosphorus and sulphur on grafted coffee plants cultivated in pots. Ciência e agrotecnologia. 2009;33(4): 993-1001.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/24027