NUTRITIONAL DIAGNOSIS OF THE ORGANIC CONILON COFFEE TREES (*Coffea Canephora* Pierre ex Froehn): SUFFIENCY RANGE APPROACH FOR LEAVES AND SOIL

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(recebido: 5 outubro de 2005; aceito: 23 dezembro de 2005)

ABSTRACT: The objective of this study was to establish the Sufficiency Range Approach of both the Foliar (SRAF) and the soil nutrient contents (SRAS) of Conilon coffee trees (*Coffea canephora* Pierre ex Froehn), cultivated organically in Espírito Santo - Brazil. The nutritional diagnosis using Diagnosis Recommendation Integrated System (DRIS) 1and SRAF, was also compared. The nutrient contents of the leaves and soil were evaluated in 56 organic crops. To establish SRAF and SRAS, the foliar and the soil nutrient contents was used respectively, from 22 crops with high yield (equal or above 2,400 kg ha^{-1} coffee fruit processing). The comparison between DRIS and SRAF was performed through the ordination of the limiting nutrients and qui-square test. Results revealed that SRAF was of: N (g kg^{-1}) 26.2-29.0, P (g kg^{-1}) 1.51-1.75, K (g kg^{-1}) 14.7-18.7, Ca (g kg^{-1}) 12.4-14.6, Mg (g kg^{-1}) 2.92-4.19-6, S (g kg^{-1}) 1.85-2.33, B (mg kg^{-1}) 45.5-63.5, Cu (mg kg^{-1}) 11.1-21.1, Fe (mg kg^{-1}) 69.2-155.0, Mn (mg kg-1) 49.6-98.2 and Zn (mg kg-1) 7.83-9.97. The SRAS was of: P (mg dm^{-3}) 4.67-15.27, K (mg dm^{-3}) 62.7-258.00, Ca ($cmol_c$ dm^{-3}) 1.65-3.49, Mg ($cmol_c$ dm^{-3}) 0.61-0.99, S (mg dm^{-3}) 6.94-27.2, B (mg dm^{-3}) 0.43-0.61, Cu (mg dm^{-3}) 0.15-0.43, Fe (mg dm^{-3}) 31.05-100.20, Mn (mg dm^{-3}) 8.78-56.60 and Zn (mg dm^{-3}) 2.35-6.51. In several cases SRAF identified limitations in the organic Conilon coffee productivity that were not identified by DRIS. DRIS indicated limitation when the nutrient was inside of the SRAF. Manganese followed by P, Cu=Fe and N were the nutrients considered as deficient to the yield, when DRIS was used, on the other hand, when the SRAF was used Mn, Ca, Fe and N were considered deficient nutrients.

Key words: *Coffea canephora*, organic coffee, mineral contents.

FAIXA DE SUFICIÊNCIA FOLIAR, PRIMEIRA APROXIMAÇÃO PARA SOLO E DIAGNOSE NUTRICIONAL DO CAFEEIRO CONILON ORGÂNICO

RESUMO: *Faltam valores de referência de folha e solo, e diagnóstico nutricional de lavouras de café Conilon orgânico, cultivadas no Espírito Santo, assim, objetivou-se com este trabalho propor faixa de suficiência foliar (FSF) e uma primeira aproximação de teores químicos no solo, para cafeeiro Conilon (Coffea canephora Pierre ex Froehn) cultivado de forma orgânica no Espírito Santo – Brasil e, bem como realizar e comparar diagnóstico nutricional utilizando o DRIS e FSF. Determinaram-se as concentrações de nutrientes nas folhas e no solo de 56 lavouras orgânicas. Estabeleceu-se a FSF e a primeira aproximação utilizando concentrações foliares e do solo de 22 lavouras com alta produtividade (igual ou superior a 2.400kg ha^{-1} de café beneficiado). Para comparar o DRIS e FSF, os nutrientes limitantes foram quantificados e ordenados por meio do teste qui-quadrado. A FSF foi: em g kg^{-1} N 26,2-29,0, P 1,51-1,75, K 14, 7-18,7, Ca 12,4-14,6, Mg 2,92-4,19-6 e S 1,85-2,33 e em mg kg^{-1} B 45,5-63,5, Cu 11,1-21,1, Fe 69,2-155,0, Mn 49,6-98,2 e Zn 7,83-9,97. A primeira aproximação foi: em mg dm^{-3} P 4,67-15,27, K 62,7-258,0, S 6,94-27,2, B 0,43-0,61, Cu 0,15-0,43, Fe 31,05-100,2, Mn 8,78-56,60 e Zn 2,35-6,51 e, em $cmol_c$ dm^{-3} Ca 1,65-3,49 e Mg 0,61-0,99. Os resultados indicaram que a faixa crítica apontou limitação da produção em várias situações em que o DRIS não identificou. O DRIS indicou limitação quando o nutriente estava dentro da faixa crítica. O Mn seguido pelo P, Cu=Fe e N foram os nutrientes que se destacaram como limitantes da produção ao utilizar o DRIS. Ao considerar a faixa crítica o Mn, Ca, Fe e N foram considerados limitantes.*

Palavras-chave: Coffea canephora, café orgânico, concentrações adequadas.

1 INTRODUCTION

The nutritional diagnosis of a plant and/or crop depends on reference values, usually established in calibration experiments carried out in controlled atmospheres. Thus, to be reliable, these reference values should be applied in the diagnosis for nutritional status of species cultivated under the same conditions of the experimental assay. Furthermore, these values are subject to constant revisions, as a consequence of the introduction of new vegetal materials, new cultivation techniques and different atmospheres, demanding new calibration experiments (WADT et al., 1998a), which would consume time and expense of resources for perennial cultures. A practical and efficient alternative would be the use of nutritional information associated to the respective yield of a commercial crop in a specific area, and from these data obtain reference

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values based on high yield crops (WADT et al., 1998a; REIS JÚNIOR & MONNERAT 2003b).

Studies using the analysis of leaf nutrient content as a complement of the soil analysis has been shown very efficient to evaluate plant nutritional status (CARMO et al., 2002), because the soil analysis allows to verify the nutrient content of the soil. On the other hand, foliar analysis represents the nutritional status of the plant, which works as extractor of nutrients from soil (BEAUFILS, 1973). However, in general, there is no direct correlation between the foliate and the soil nutrient contents, since, other factors as aeration, acidity and humidity of the soil also affect the plant nutrient uptake.

The correct interpretation of foliate and soil analysis results can provide information to the rational use of inputs, improving the nutritional balance of the plants and, consequently, increasing of the crop yields. Therefore, the establishment of reference norms and methods for an efficient and practical nutritional diagnosis, based on analytical results of the soil and leaves of such crop is very important to evaluate the plant nutritional status.

Different critical nutrient levels for the coffee plant which varies according to the specific area are registered in literature (MARTINEZ et al., 2003). Some workers also point out that the reference values for Diagnosis Recommendation Integrated System (DRIS) should be regional (REIS JÚNIOR & MONNERAT, 2003a) and specific for the cultivation technology (PARTELLI, 2004).

Among the methods used for chemical analysis interpretation, the critical level is most used, because the interpretation of the results is relatively easy and it has independence among the indexes. However, the critical range is static and it doesn't determine the order of deficiency or excess of the nutrient to be diagnosed (BALDOCK & SCHULTE, 1996; LUCENA, 1997). On the other hand, the Diagnosis and Recommendation Integrated System (DRIS) is dynamic and incorporates the concept of nutritional balance among the minerals in plant tissues (BALDOCK & SCHULTE, 1996). Mourão Filho (2005) has pointed out that DRIS completes the diagnosis done by the critical range, because it orders deficiency or excess where the critical range doesn't.

The DRIS technique is based on the calculation of indexes for each nutrient, which is evaluated in function of the relationship of the reasons of the ratios of each element with the others, comparing them two by two, with other relationships considered patterns, whose mineral composition are obtained from a population highly productive plants (WADT et al., 1998b; REIS JÚNIOR & MONNERAT 2003b).

DRIS index makes possible to define the nutrients deviation degree of the sample, and its location in relation to the nutritional status, if appropriate, in deficiency or in excess. It also allows to identify nutritional unbalance even when there is not, at least a single nutrient out of the critical range, but it has some limitations and disadvantages, as the complexity and the fact of a certain nutrient influencing negatively on the interpretation of another one (BALDOCK & SCHULTE, 1996).

The Conilon coffee (*Coffea canephora* Pierre ex Froehn) has great importance in the socio-economical scenery in Espírito Santo State (CETCAF, 2004), and organic coffee plots had grown considerable, however, there is no information on reference values of leaf and soil, as well as a nutritional diagnosis. In this context, the objective of this work was to propose the Sufficiency Range Approach of both, the Foliar (SRAF) and the soil nutrient contents (SRAS) of Conilon coffee trees, organic cultivated in Espírito Santo - Brazil. We also compared the nutritional diagnosis using Diagnosis Recommendation Integrated System (DRIS) and SRAF.

2 MATERIAL AND METHODS

The experiment was carried out in the North of Espírito Santo State – Brazil, in organic Conilon coffee crops. In this region, the tropical climate is predominant (humid an hot summer, dry winter), with annual precipitation average of 1200 mm and annual temperature average of 23ºC. The predominant soil is a distrofic Red-Yellow Latosol (typic Hapludox) (EMBRAPA, 1999; SOIL SURVEY STAFF, 1990). Fifty-six organic coffee crops (certified or in certification process) representative of the region were selected, with at least 30 months of conversion from traditional to organic cultivation (BRASIL, 1999). Yield, age, spacing between plants and inputs were evaluated on crops. Thereafter, foliar and soil analysis was performed. Approximately 150 leaves from 50 plants in each coffee crop were colleted randomly. The leaves were colleted on branches from the superior part of the trees, from third and fourth pair of plagiotropic braches, starting from the apex. Each composite soil sample was made from 15 simple samples colleted randomly in a depth of 0-20 cm. The foliar and soil nutrient contents were quantified according to procedure described by Silva (1999).

For determination of the Sufficiency Range Approach for Leaves (SRAF) and soil (SRAS), the nutrient contents of the leaves and the soil of the 22 coffee crops of high yields (productivity equal or above 2,400 kg ha^{-1} of coffee fruit processing), were used respectively. According to Reis Júnior & Monnerat (2003b), this quantity of crops is enough to obtain the DRIS norms. The nutrients contents mean, plus or minus the standard deviation was considered for sufficiency range.

The nutrient indexes were obtained by specific norms in agreement with the sampling time, using the relationships and the concentrations of the nutrients and comparing them to the referred norms, as it is done in M-DRIS (HALLMARK et al., 1987). However, the diagnosis was accomplished in the same way as it is done in DRIS (DRIS with inclusion of the dry matter) (PARTELLI, 2004; MOURÃO FILHO, 2005). To calculate the reduced normal relationship between two nutrients, it was used the method described by Jones (1981), with sensibility constant of 10.

To perform the nutritional diagnosis of the coffee crops and to compare the methods (DRIS and sufficiency range approach), it was quantified the number of crops where the nutrient contents were below or above of critical ranges, were the nutrient had index more negative and more positive DRIS and, were the DRIS index was superior, in absolute value, to the nutritional balance average index (WADT et al 1998b), based on sufficiency range approach and DRIS norms presented in the present work, making an ordering of the frequencies. Furthermore, the qui-square test, as used by Wadt et al. (1998b), to verify if the observed frequencies were the same to the expected ones, at 5% of probability, was used.

To establish the sufficiency range approach for soil, the number of coffee crops (among the 22 crops selected as high yield), were the soil nutrient content was above or below to the values considered adequate by Bragança et al. (2001): P (15-20 $mg.dm^{-3}$), K (100-120 $mg.dm^{-3}$), Ca (3-4 $cmolc.dm^{-3}$), Mg (0.8-1 $cmolc.dm^{-3}$), S (15-20 $mg.dm^{-3}$), Zn (2-3 $mg.dm^{-3}$), B (0.8-1 $mg.dm^{-3}$), Cu (0.5-1 $mg.dm^{-3}$), Mn (100-200 $mg.dm^{-3}$) and Fe (2-3 $mg.dm^{-3}$), were quantified for the Conilon coffee trees cultivated conventionally in Espírito Santo State – Brazil.

3 RESULTS AND DISCUSSION

The foliar critical ranges of the 22 Conilon coffee organic crops of high yield (equal or above 2,400 Kg ha^{-1} of coffee fruit processing) are presented in Table 1. These values were used to establish the sufficiency range approach for leaves (SRAF) for Conilon coffee trees, organic cultivated in Espírito Santo State – Brazil. According to Partelli (2004) any reference value used in plant nutritional diagnosis should be specific for the cultivation technology.

The comparison between the Diagnosis and Recommendation Integrated System (DRIS) and the Sufficiency Range Approach for Leaves (SRAF), by qui-square test, showed that when compared the contrasts of the SRAF with the other two DRIS criteria, differences between the observed and expected frequencies occurred only for calcium (Table 2), indicating that these differences are due to the use of the different methods. However, considering only the SRAF to perform the nutritional diagnosis, the majority of nutrients were considered limiting to yield (Table 2), contrasting with DRIS that considered limiting to yield the nutrient with more negative DRIS index. This pattern occurred for most nutrients when negative and higher DRIS indexes (in absolute value), when compared to the mean Nutritional Balance Index (mNBI) were considered. An example of this was observed with Ca (Table 2), when the SRAF was utilized this nutrient was considered limiting in 25 of the 56 coffee crops. However, when DRIS was used Ca was the most limiting nutrient only in one crop or in 5 crops when considering the biggest index (in absolute values), compared to mNBI. This fact can be exemplified in Table 3, where N, P and Ca in crop 43, were below the SRAF, nevertheless, when the DRIS was considered mNBI using as parameter (WADT et al., 1998b), those nutrients were not identified as limiting to crop yield. This may be due to the narrow critical range established that had a very low standard deviation. On the other hand, in this situation nutrient is inside of the critical range (SRAF), but the DRIS indicates that it can show a positive or null response to fertilizer (see Table 3, crop 40, for Mg). In other words, according to DRIS Mg can be coffee yield limiting, but it is inside the SRAF.

Table 1 – Sufficiency range approach for leaves (SRAF), average and variation coefficient (CV) of nutrients in the leaves of 22 crops of high yield of coffee Conilon under organic cultivation in Espírito Santo – Brazil.

Nutrients	SRAF	Mean	CV (%)
N (g kg^{-1})	26,2-29,0	27,6	5,19
P (g kg^{-1})	1,51-1,75	1,63	7,42
K (g kg^{-1})	14,7-18,7	16,7	12,0
Ca (g kg^{-1})	12,4-14,6	13,5	8,36
Mg (g kg^{-1})	2,92-4,16	3,54	17,6
S (g kg^{-1})	1,85-2,33	2,09	11,6
B (mg kg^{-1})	45,5-63,5	54,5	16,5
Cu (mg kg^{-1})	11,1-21,1	16,1	31,2
Fe (mg kg^{-1})	69,2-155	112	38,1
Mn (mg kg^{-1})	49,6-98,2	73,9	32,9
Zn (mg kg^{-1})	7,83-9,97	8,90	12,1

Table 2 – Number of coffee crops in summer and winter with deficient or excessive nutrient content in leaves.

	Number of coffee crops										
	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
< FC	20ns	17ns	5ns	25*	6ns	14ns	5ns	14ns	21ns	26ns	16ns
> FC	5	11	22	3	6	6	7	12	4	4	10
RPA	7ns	6ns	3ns	1*	3ns	0ns	2ns	10ns	4ns	17ns	3ns
RNA	0	7	13	0	4	1	8	7	5	3	8
RNP	14ns	19ns	7ns	5*	8ns	7ns	5ns	16ns	16ns	25ns	8ns
RNN	1	11	26	3	10	7	18	19	8	8	11

RPA when the index of the nutrient is highly negative and RNP is when the nutrient index is not the most negative index, but becomes larger than mNBI in absolute value (Wadt et al., 1998b).
ns = non significant. * significant at 5%, among the contrasts <FC with RPA and >FC with RNP.
The contrasts between RPA and RNP were not significant.

It was observed that Mn (in 26 crops), Ca (in 25 crops), Fe (in 21 crops) and N (in 20 crops) were deficient nutrients in most of the coffee crops (Table 2), when SRAF was considered. However, when most negative DRIS index was considered, Mn (in 17 crops) and Cu (in 10 crops) were the limiting nutrients. Similar results were found by Mourão-Filho (2005), when working with orange.

Table 3 – Nutrient content of two coffee crops with diagnosis through sufficiency range approach for leaves (SRAF) in comparison with DRIS index.

Crop	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	mNBI
40	25,0	1,50	16,8	13,4	3,0	2,0	56,9	15,9	111	113	8,56	-
	B	B	M	M	M	M	M	M	M	A	M	
	-8,80	-4,73	1,61	3,10	-7,24	-1,10	3,19	0,74	3,34	12,36	-1,08	4,14
43	25,7	1,50	13,8	12,3	3,2	2,2	72,2	16,6	87	46,3	8,0	-
	B	B	B	B	M	M	A	M	M	B	M	
	- 3,81	-2,37	-7,4	-0,55	-2,7	6,44	17,72	3,74	-2,34	-8,45	-2,13	5,21

g kg^{-1} for macronutrients and mg kg^{-1} for micronutrients
mNBI = mean Nutritional Balance Index
If lower (B), medium (M) or high (A) in DRIS index

The differences pointed out by the two methods of nutritional diagnosis (DRIS and SRAF) are due to its characteristics. SRAF is static, and it is only based on the nutrient content in plant leaves. On the other hand, DRIS index is dynamic and it makes diagnosis using multiple two-way comparisons between the levels of various plant nutrients and integrates these comparisons into a series of nutrient indexes (WALWORTH et al., 1986). Some authors have used efficiently the DRIS index to make the nutritional diagnosis analysis in several crops (LUCENA, 1997; WADT et al., 1998b; WADT et al., 1999; MOURÃO FILHO al., 2002; MOURÃO FILHO & AZEVEDO, 2003; REIS JÚNIOR & MONNERAT 2003b; SANTOS et al., 2004; MOURÃO FILHO, 2005).

The efficiency of DRIS index can be confirmed due the occurrence of its high correlation with the nutrient content in leaves, as well as, the existence of negative correlation between the yield and mNBI. However, there is no validation of DRIS index for organic Conilon coffee trees. To obtain the DRIS index, it is necessary to calculate the reduced normal relationship of the content of two nutrients, which is based on both the average of the DRIS norm and the crop to be diagnosed, as well as, on the variation of the data of the norms, using the variation coefficient in the equation of Beaufils (1973) and the standard deviation in the equation described by Jones (1981). Therefore, DRIS considers the effects of data variation, in other words, as larger the standard deviation of the nutrient is in DRIS norm, smaller will be the value in reduced normal relationship and, consequently, smaller will be the DRIS index of the nutrient involved in the diagnosis.

The sufficiency approach for soil (SRAS) is showed on Table 4. Soil nutrient content of P, Ca, B, Cu, and Fe in the majority of the coffee crops (18, 18, 22, 19 and 19 crops, respectively) was below of the levels considered sufficiency by Bragança et al. (2001), however all these crops had high yields (equal or above 2,400 Kg ha^{-1} of coffee fruit processing), as well as presented sufficiency foliar nutrient contents. On the other hand, Zn and Mn soil nutrient contents in 18 and 16 crops respectively, were higher than those levels suggested by Bragança et al. (2001). However, the sufficiency range soil nutrient suggested by these authors was established using coffee crops conventionally cultivated form, using heavy fertilization.

The present work demonstrated that cultivation of coffee tree in the North of Espírito Santo State – Brazil, utilizing organic inputs has provided sufficient available nutrients in soil, which led to a high yield with foliar nutrient content inside the critical range. These results indicates that the sufficiency range approach for leaves (Table 1) and soil (Table 4) established in the present work can be used successfully to make a nutritional diagnosis of the organic Conilon coffee trees in Espírito Santo State – Brazil.

Table 4 – Sufficiency range approach for soil (SRAS), average and variation coefficient (CV) of the nutrients in the leaves of 22 crops of high yield of coffee Conilon under organic cultivation in Espírito Santo - Brazil.

Nutritious	SRAS	Average	CV (%)
P (mg dm^{-3})	4,67-15,27	9,97	53,16
K (mg dm^{-3})	62,7-258	160	60,83
Ca ($cmol_c$ dm^{-3})	1,65-3,49	2,57	37,50
Mg ($cmol_c$ dm^{-3})	0,61-0,99	0,80	23,82
S (mg dm^{-3})	6,94-27,2	17,09	59,38
B (mg dm^{-3})	0,43-0,61	0,52	16,56
Cu (mg dm^{-3})	0,15-0,43	0,29	47,32
Fe (mg dm^{-3})	31,05-100,2	65,60	52,67
Mn (mg dm^{-3})	8,78-56,6	32,69	73,13
Zn (mg dm^{-3})	2,35-6,51	4,43	46,97

P, K, Fe, Zn, Mn, and Zn for the extractor Mehlich 1; Ca, Mg and Al extractor KCl; H+Al extractor SMP; B extractor hot water; S extractor phosphate monocálcio in acetic acid.

4 ACKNOWLEDGEMENTS

To the Universidade Estadual do Norte Fluminense Darcy Ribeiro - UENF for the scholarship and laboratory structure; to FAPERJ and MIBASA, for the financial support of the work; to INCAPER for the accomplishment of the soil analyses; and, to the farmers for making available the coffee crops.

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