SPATIAL VARIABILITY OF THE NUTRITIONAL CONDITION OF CANEPHORA COFFEE AIMING SPECIFIC MANAGEMENT

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ABSTRACT: Mapping the plant nutritional condition allows viewing different regions in a cropping area, providing the producers with different criteria to use foliar and soil fertilization. The aim of this study was to evaluate the spatial variability of the nutritional condition of canephora coffee (Coffea canephora Pierre ex Froehner) regarding the site specific management of foliar and soil fertilization. In a one hectare area 60 georeferenced points were sampled at irregular intervals. There were five plants in each sampled point; two pairs of leaves were removed from the lateral branches (3rd and 4th pairs from extremity to the basis) in the cardinal points of each plant, counting up 40 leaves per point. The foliar samples were chemically analyzed for the following nutrients: N, P, K, Ca, Mg, S, B, Cu and Zn. The same pattern of spatial dependence was presented with adjustment for K and B. Except for N and P, which presented random distribution, the other nutrients presented mild to severe spatial dependence justifying the geostatistical data analysis for making maps for differential and located, foliar and soil fertilizer application in coffee crop.

Index terms: Leaf nutrition, variograms, precision agriculture.

VARIABILIDADE ESPACIAL DO ESTADO NUTRICIONAL DO CAFEEIRO CANEPHORA VISANDO O MANEJO LOCALIZADO

RESUMO: *O mapeamento do estado nutricional de plantas possibilita visualizar diferentes regiões em uma área de cultivo, proporcionando aos cafeicultores critérios diferenciados na aplicação de adubos via foliar e o solo. Objetivou-se, neste trabalho, trabalho foi avaliar a variabilidade espacial do estado nutricional do cafeeiro canephora (Coffea canephora Pierre ex Froehner), visando o manejo localizado da adubação via foliar e no solo. Em uma área de um hectare foram amostrados 60 pontos georreferenciados em intervalos irregulares. Cada ponto amostral foi constituído de cinco plantas, foram retirados dois pares de folhas dos ramos laterais (3º e 4º pares contando da extremidade para a base) nos pontos cardeais de cada planta, totalizando 80 folhas por ponto. As amostras foliares foram analisadas, quimicamente, para os nutrientes N, P, K, Ca, Mg, S, B, Cu e Zn. O mesmo padrão de dependência espacial foi apresentado com ajuste do modelo esférico para os nutrientes K e B. Com exceção do N e P, que apresentaram distribuição aleatória, os demais nutrientes apresentaram moderada a forte dependência espacial, o que justifica a análise dos dados pela geoestatística para confecção de mapas de aplicação diferenciada e localizada de fertilizantes via foliar e solo na lavoura cafeeira.*

Palavras-chave: Nutrição foliar, variogramas e agricultura de precisão.

1 INTRODUCTION

In Brazil, almost all coffee crops, popularly known as Robusta, is the cultivar canephora (*Coffea canephora* Pierre ex Froehner), and Espírito Santo State is the biggest national producer. Currently, more than 75% of coffee produced in that state is from this cultivar, corresponding to 73% of the Brazilian production, with 7,850 processed coffee bags (COMPANHIA NACIONAL DE ABASTECIMENTO - CONAB, 2008). Such culture increased in quality, quantity and offer regularity, becoming outstanding worldwide reference in coffee production (BRAGANÇA et al., 2001).

Foliar diagnosis was developed to provide information on the plant nutritional condition serving as guide for nutrition management to improve productivity. There are several technologies for

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canephora coffee production in Espírito Santo State; however, little is known about spatial variability of the plant nutritional condition.

According to Silva et al. (2008), there is a vast field of research of precision coffee culture due to its economic value and its importance to our country, with modern technology of production in different crops. However, the number of research using precision agriculture techniques to characterize the spatial variability of coffee is not a Brazilian reality.

The management of canephora coffee, considering correction and soil fertilization, is the application, based on mean values, of a compound sample from sub-samples collected in a zig-zag area, unconsidered variability and distance between the points. Because of this variability, it is necessary to establish a rigorous sampling criterion to obtain representative information of a certain area (OLIVEIRA, 2007).

This study aims to map the spatial variability of the plant nutritional condition of canephora coffee allowing the specific management of foliar and soil fertilization.

2 MATERIAL AND METHODS

This trail was carried out during the 2004/2005 season at Fazenda Experimental Bananal do Norte of the Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural (INCAPER), in the town of Cachoeiro do Itapemirim, south of Espírito Santo State. The geographic coordinates of the experimental area are Latitude 20º 45' 17,31" S and Longitude 41º 17'8,86" W (Greenwich), at mean altitude of 113 meters.

The coffee species studied was *Coffea canephora* Pierre ex Froehner, var. Robusta Tropical - 'Emcaper 8151', grown with 2.90 x 0.9 m spacing and five years of age.

Leaves were collected in a sample grid built in a 1.0-hectare area, counting up 60 georeferenced points at irregular intervals. The nutritional coffee condition was assessed in December 2005, corresponding to the phases of grain filling and fruit maturation. Each point had five plants for leaf sampling at the mean plant height; two pairs of leaves were removed from the lateral branches (3rd and 4th pairs counting from the extremity to the basis) in the cardinal points, counting up 40 leaves per point,

according to Prezotti and Bragança (1995) sampling procedure. After the leaf processing, the following nutrients were determined: N, P, K, Ca, Mg, S, B, Cu and Zn.

According to Willson (1985), the interpretation and comparison of the nutritional condition results were based on mean contents considering the intervals of nutrient critical levels in canephora coffee leaves. This author established the intervals in: deficient to subnormal, subnormal to normal and normal to excessive which were later reclassified in low, mean and high, respectively.

Data were analyzed in three different phases: (i) distribution of frequency and test of normality by Kolmogorov-Smirnov test (KS) at 5% of probability; (ii) statistical summary (mean, median, minimum, maximum, standard deviation and variation coefficient, skewness and kurtosis; and (iii) geostatistics to quantify the degree of spatial dependence, through the Matheron's classical variogram supported by the software GS+ (ROBERTSON, 2004). The variogram was estimated by the expression:

$$\hat{\gamma}(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(x_i) - Z(x_i + h)]^2$$

where: g is the experimental variance, result of the sampled values $Z(x_i)$, $Z(x_i + h)$; h is the distance between sampling points and N(h) is the total number of likely pairs of points in the sampling area (BACHMAIER; BACKES, 2008). In the theoretical model adjustment: spherical, exponential and gaussian defined the nugget effect parameters (C_0), sill $(C_0 + C)$, reach range (a) and the spatial dependence index (SDI) as Zimback (2001). The models were chosen based on the correlation coefficient between the observed values and the ones estimated by cross-validation. In order to estimate the values in non-measured places, interpolation was done by means of ordinary krigage for attribute mapping.

3 RESULTS AND DISCUSSION

Table 1 shows the results of descriptive statistics and frequency distribution of nutritional coffee condition. Except for Mg, Cu and Zn, the other nutrients presented normal distribution by

Kolmogorov-Smirnov test (KS) at 5% of probability. Souza et al. (1997) found normal distribution for Mg and Cu in citrus leaves. This way, regarding the regional peculiarities and the lack of studies related to spatial variability of the nutritional condition of canephora coffee, it is difficult to compare results of other authors with the ones of this study.

According to classification Gomes (1987), the variation coefficient (CV) was low for N and K (CV < 10%); average for P, Ca, Mg, S, Cu and B (10% < CV < 20%); high for Zn (20% < CV < 30%) and very high for Fe (CV > 30%). Souza et al. (1997) also found low CV for N in citrus leaves.

According to the intervals proposed by Willson (1985) for critical nutritional levels in leaves of canephora coffee, the average values found in leaves of canephora coffee can be considered: low for Mg ($<0,30$ dag kg^{-1}), S ($<0,22$ dag kg^{-1}), Zn ($<10,0$ mg kg^{-1}) and Fe (<40 mg kg^{-1}); average for N ($2,70 - 3,30$ dag kg^{-1}), Ca ($0,80 - 1,50$ dag kg^{-1}), Cu ($20,0 - 40,0$ mg kg^{-1}) and B ($35,0 – 90,0$ mg kg^{-1}); and high for P ($>0,15\%$) and K ($>2,20$ dag kg^{-1}). The very high CV for Fe (37.46%) can confirm the results of Embleton et al. (1973) that the variation for one element in leaves is higher when the former is deficient, although this premise was not confirmed

for Mg and S. The low levels of Fe and Zn micronutrients corroborate Costa et al. (2000) who examined a canephora crop in Espírito Santo State and concluded that in many crops Fe is considered limiting for production.

Figures 1 shows variograms scaled by variance and parameters and models adjusted for each attribute what permitted to compare visually the spatial variability standard.

The spherical model was the best adjusted to experimental variograms. Several researches show this model as the best adapted to describe the behavior of variograms of soil and plant attributes (SANCHEZ et al., 2005; TRANGMAR et al., 1985).

The lower reach range was 16.50 m for Zn, and the higher one was 47.60 m for B. The values of the reach of spatial dependence provide significant information for experimental plan and evaluation since, according to Vieira (2000), the reach value shows to which distance the point will be correlated. The same standard of spatial dependence is presented with the spherical model, with very similar reaches for K (45.0 m) and B (47.60 m) showing spatial association among them. This information is important for if it indicates that the variability of these variables has spatial correlations (SHIRATSUCHI, 2001).

Table 1 – Descriptive statistics and distribution of frequency of the nutritional level in canephora coffee leaves (*Coffea canephora* Pierre ex Froehner).

Attributes				Values		Coefficients			Test
	Mean	Median	s	Min.	Max.	CV	C_s	C_k	KS
N[1]	2.79	2.80	0.12	2.60	3.00	4.30	0.12	-0.90	p>0.10[ns]
P[1]	0.15	0.15	0.02	0.12	0.19	13.30	0.42	-0.36	p>0.20[ns]
K[1]	2.33	2.40	0.22	1.50	2.65	9.44	-1.23	2.32	p>0.20[ns]
Ca[1]	1.40	1.40	0.25	1.00	1.95	17.86	0.21	-0.96	p>0.20[ns]
Mg[1]	0.29	0.30	0.03	0.25	0.35	10.34	0.18	-0.53	p<0.01*
S[1]	0.20	0.20	0.03	0.13	0.28	15.00	0.24	-0.87	p>0.20[ns]
Cu[2]	21.07	20.00	3.38	15.00	30.00	16.04	0.54	0.00	p<0.01*
Zn[2]	9.50	9.00	2.13	7.00	16.00	22.42	1.14	1.11	p<0.05[*]
Fe[2]	54.81	50.00	20.53	20.00	100.00	37.46	0.30	-0.65	p>0.20[ns]
B[2]	59.04	60.00	6.83	47.00	78.00	11.57	0.31	0.07	p>0.20[ns]

[1]dag kg^{-1}; [2]mg kg^{-1}; s - standard deviation; Min. minimum; Max. maximum; CV - variation coefficient; C_s - skewness coefficient; C_k - Kurtosis coefficient; ns – not significant test normality Kolmogorov-Smirnov (KS) the 5% of probability (Normally distributed); * not- normally distributed.
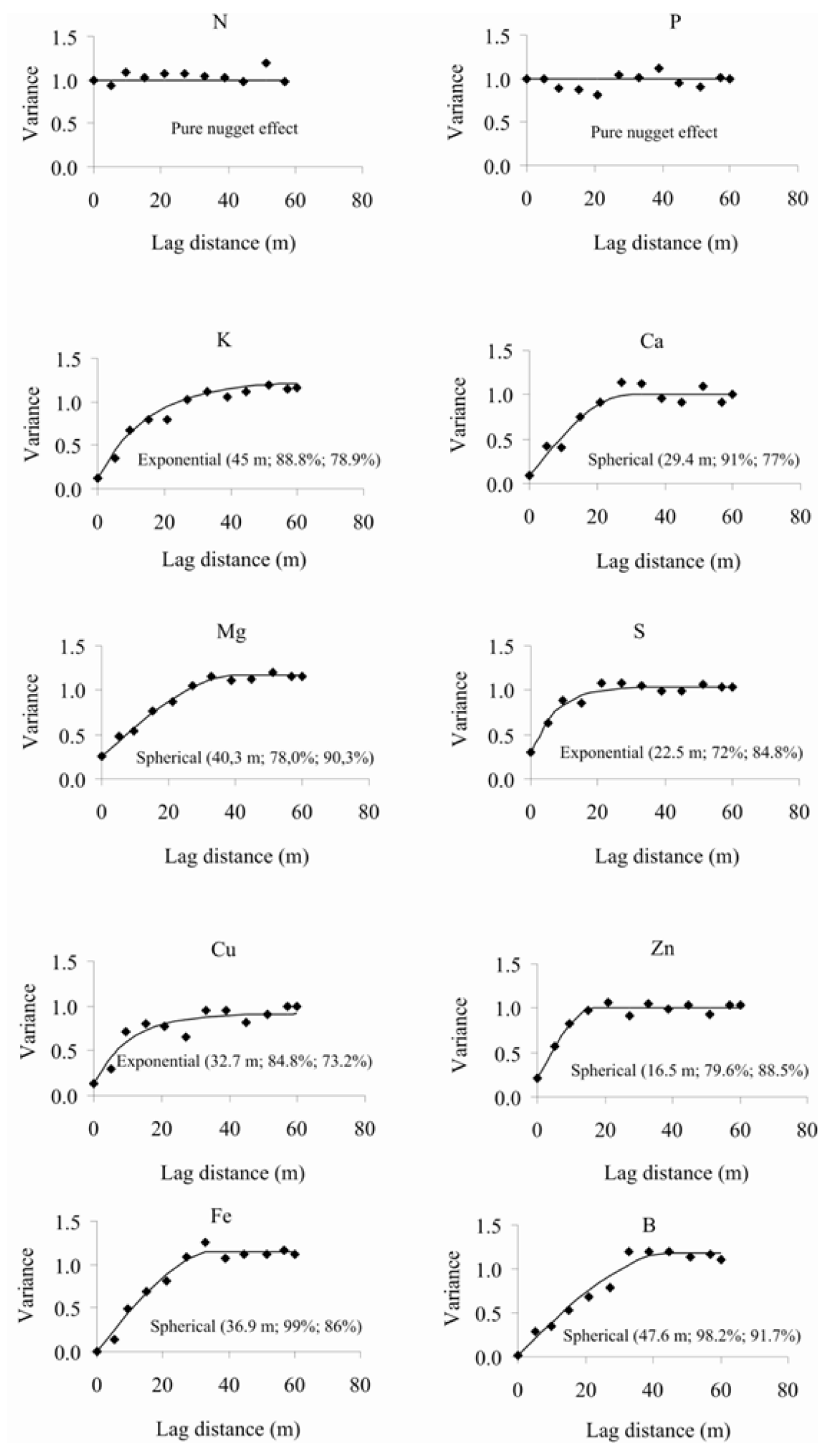
Figure 1 – Models and parameters (a, SDI and R², respectively) of scale variograms for the levels of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), copper (Cu), (Zn), iron (Fe) and boron (B) in canephora coffee leaves (*Coffea canephora* Pierre ex Froehner).

N and P attributes did not present spatial dependence, showing a random distribution (pure nugget effect). It shows that, in the sampling scale used, the observations of these attributes did not present spatial correlation, distributing independently in space; what prevents their expression due to the distance of separation adopted. This requires higher proximity between the points of collection in case of a new sampling (ORTIZ, 2003). According to Guimarães (2000), in these cases, if there is spatial dependence, it will show a distance shorter than the smaller spacing between the samples.

As for the spatial dependence index (SDI), the values of K, Ca, Mg, Cu and Zn present strong spatial dependence (SDI > 75%). S values show mild spatial dependence (25% < SDI < 75%); and no attribute presents weak spatial dependence (SDI < 25%), according to classification proposed by Zimback (2001). In this case, the most variance of these attributes is spatial, confirmed by the low C_0 values, which indicates the value of variance for distance zero (VIEIRA, 2000) and represents the component of spatial variability that cannot be related to a specific cause (random variability). The adjustment of models and the presence of spatial dependence show that data distribution is not random and that the values are dependent on the distance among the samples. This way, it is proposed to consider the higher reach found when choosing the distances in future sampling so that it is representative.

Figure 2 shows that the most part of the area presents low and average concentration of Mg, S, Zn and Cu, according to the classification of Willson (1985). As for S, this result can be due to soil poor in organic material or the use of fertilizers with concentrated formulas without this nutrient. Therefore, in this specific case, fertilizers which contain this nutrient must have the preference, in order to correct its lack. Depending on the mean values found and comparing with the critical level intervals proposed by Willson (1985), it is verified that these nutrients present low levels. However, spatially the attributes vary among the low and average classes due to the amplitude found in leaf nutrients. Therefore, if the foliar fertilization were recommended, without considering spatial variability, it would be excessively applied in some regions and deficiently in others.

Two very distinct regions with high concentration of Fe in the inferior area and superior for Ca have been observed on maps of Fe and Ca. Cu and Zn present lower values in the superior area.
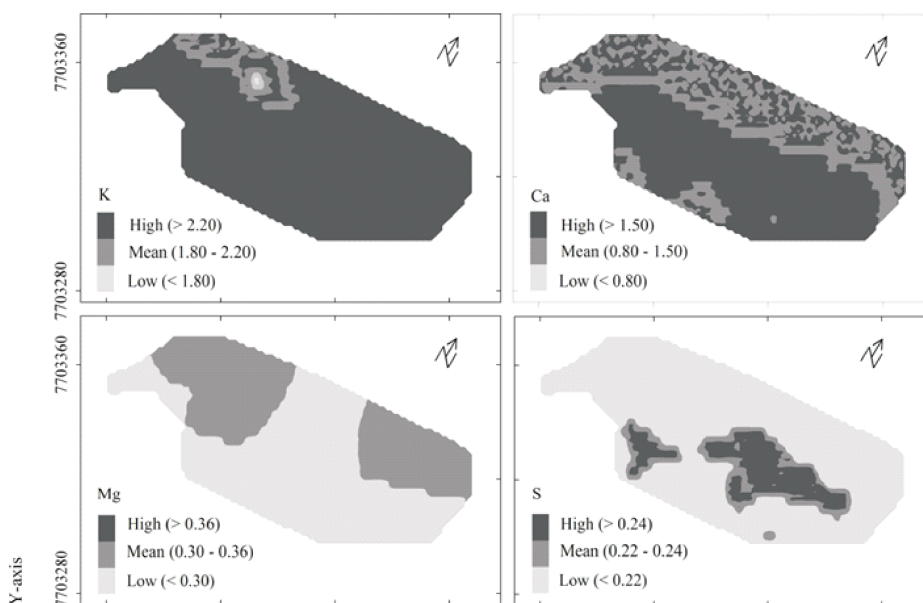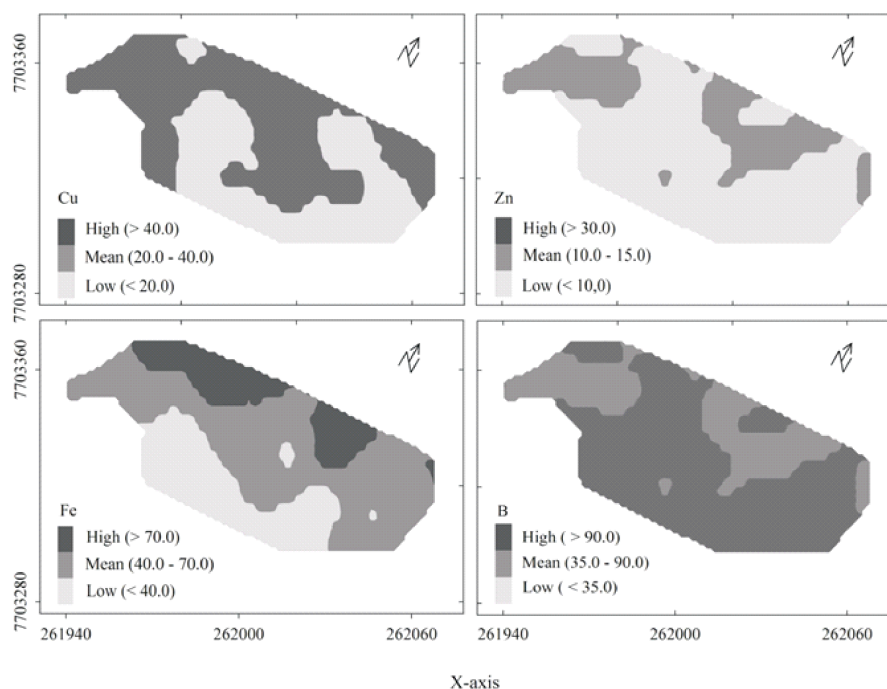

Figure 2 – Thematic maps of leaf concentration of potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), copper (Cu), zinc (Zn), iron (Fe) and boron (B).

Figure 2 – Continued ...

Figura 2 – Continua ...

X-axis

4 CONCLUSIONS

Except for N and P, which presented random distribution, the other nutrients presented mild to severe spatial dependence justifying the geostatistical data analysis for making maps for differential and located, foliar and soil fertilizer application in coffee crop. The same pattern of spatial dependence was presented with adjustment for K and B.

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