

## Spatial distribution of physiological quality of *Arábica* coffee seeds to cultivate *Catuái*

*Distribución espacial de la calidad fisiológica de semillas de café  
Arábica cultivar Catuái*

José Carlos Lopes<sup>1\*</sup>, Maria de Fátima Idalina Qualhano Trigo<sup>1</sup>,  
Julião Soares de Souza Lima<sup>1</sup>, Samuel de Assis Silva<sup>2</sup>

### ABSTRACT

Brazil stands as the largest coffee producer in the world. However one of the factors capable of undermining the potential of this species is the poor quality of seeds. One tool that is being proposed for use in agriculture is the Geostatistics analysis to verify the existence and quantify the degree of spatial dependence of variables. The seeds were collected in a field with five years of age in an area of 0.8 ha, 50 sampling points. In the laboratory we used a completely randomized design (CRD) with four replicates of 25 seeds per point materialized with the aid of a total station. After removal of the scrolls, the seeds were treated with Captan (Orth Cide) to 0.1% for five minutes and subjected to the following determinations: moisture, germination first count of germination, root length and shoot length. Then the seeds were placed to develop in an incubator at temperature 20-30 °C for 60 days. In the results there was spatial dependence of the quality variables of physiological Catuái. The lowest range for the variable length of shoot (CPA) and greater range for the variable fresh weight (MFPA).

**Key words:** precision coffee, germination, geostatistical, vigor.

### RESUMEN

*El Brasil se destaca como el mayor productor de café del mundo. Sin embargo, uno de los factores capaces de afectar el potencial de esta especie es la mala calidad de las semillas. Una de las herramientas que se proponen para el uso en la agricultura es el análisis geoestadístico, para evaluar la existencia y cuantificar el grado de dependencia espacial de las variables estudiadas. Las semillas se recolectaron en una granja a la edad de cinco años, en un área de 0,8 ha en 50 puntos del muestreo. En el laboratorio se utilizó el diseño completamente al azar (DCA), con cuatro repeticiones de 25 semillas por punto que se materializó con la ayuda de una estación total. Después del retiro de los pergaminos, las semillas fueron tratadas con Captán (Orth Cide) 0,1% durante 5 minutos y está sujeta a las siguientes determinaciones: contenido de agua (humedad), germinación, primer corte de germinación, longitud de la raíz y la longitud de la parte aérea, peso fresco de la parte aérea; peso fresco de la raíz, materia seca de la parte aérea y materia seca de la raíz. Posteriormente, las semillas se colocaron para desarrollarse en el germinador a la temperatura de 20-30 °C durante 60 días. Los resultados mostraron la dependencia espacial de las variables de calidad fisiológica de cultivar Catuái. Siendo la gama más pequeña para la longitud variable de la parte aérea (LPA) y de mayor alcance para la variable longitud de peso fresco de la parte aérea (MFPA).*

**Palabras clave:** producción de café de precisión, germinación, geoestadística, fuerza.

### Introduction

One of the factors that may be prejudicial to the coffee plant's potential is the poor quality of seeds used for seedling production, which suggests the need to obtain seeds with high physiologic and sanitary quality. The feasible seeds from most species,

when submitted to ideal conditions during the germination trial, germinate immediately, issuing normal seedlings, capable of generating an adult plant in the field (Brasil, 2009).

Due to the major economic importance of the coffee culture in Brazil, the study and development of new techniques of dealing with the coffee culture

<sup>1</sup> Programa de Pós Graduação em Produção Vegetal, CCA-UFES, Alto Universitário, Caixa Postal 16, CEP: 29500-000, Alegre, ES, Brasil.

<sup>2</sup> Universidade Federal de Viçosa – DEA/UFV, Av. Ph. Rolfs, Campus Universitário, 36570-000, Viçosa, MG, Brasil.

\* Corresponding author: jcufoes@bol.com.br

are fundamental for reducing losses arising from inappropriate handling, which leads to productivity breakdown or even to values under the productive potentials of the currently grown varieties (Silva and Lima, 2012).

Taking into account the importance of good quality seeds in the productive process of the coffee plantation, one must bear in mind that there are variations in the physical-chemical-biologic features of the ground due to the weather, the adopted handling, cultivated species, among others that affect the management, which may lead to loss of productivity, loss of yield and quality of the beverage.

The initial development of conilon coffee plant seedlings on soils with different textures and substrates was studied by Braun *et al.* (2009), presenting statistical difference of the fresh and dry mass, and the aerial part, when comparing the substrates at the soil textures' level.

Silva *et al.* (2010a) verified that the catuai and catucaí species presented spatial variability regarding productivity, and the amounts were higher for catuai variety, as well as the percentage of peel and the yield, of which the variation was only perceptible by using geostatistics, since the average didn't enable to state such difference. According to Mummey *et al.* (2002) geostatistics, in turn, has been used in the past few years as an important tool for modeling and interpretation of the spatial variability of the different features of ground and plant.

A study on ground fertility under the Arabica coffee cultivar was performed by Silva and Lima (2012) using geostatistics techniques and correlating the textural fractions of the ground with chemical features of the ground, finding significant and negative correlation of K with total and positive sand of Mg, with the silt in a Red-Yellow humic Latosol.

Various research efforts have studied the spatial and temporal variability of features related to plants and soils, individually or jointly with other features in the attempt to clarify the presence of differentiated zones in the production area, aiming at the precision of cultures handling. According to Souza *et al.* (2004) the spatial variability of the soils is result of pedogenetic processes, and may be demonstrated by the results of assessments and analyses, considering that chemical and physical properties have specific interconnections, so that such interactions directly influence the growth and development of cultures.

In this context, the purpose of this paper was to study the feasibility of geostatistical methods in features that characterize the physiologic quality of *Coffea arabica* L. seeds, cv Catuai Red 44 produced in mountain region.

## Material and Methods

The work was conducted at Jaguarai Farm, city of Reduto, Zona da Mata Mineira. The studied area is located at 20° 45' 45,4" latitude S and 41° 32' 9,75" longitude W, with average height of 796 meters, where the seeds of *Coffea arabica* L., Catuai variety, were picked manually. The region's climate is Cwa, according to the Köppen classification, with average temperature of the coldest month lower than 20 °C and, in the hottest month, higher than 27 °C.

In a hillside, a grid with 50 points was built, and each point was composed of three plants, from which the seeds were collected in the cherry stage (Figure 1). The points were materialized with wooden stacks and the topographic assessment was performed using a full station.

The analyses of the seeds were performed in the Laboratory of Seeds of the Department of Vegetable Production of the Center of Agricultural Sciences in the Federal University of Espírito Santo (Laboratório de Análise de Sementes do Departamento de Produção Vegetal do Centro de Ciências Agrárias da Universidade Federal do Espírito Santo), where, in the experimental stage, the seeds were kept in plastic bags (35 x 22 x 0.10 cm) and stored in a chamber with controlled temperature of 10 °C. Initially, the pulp was removed from the seeds, and later, after the parchment was removed

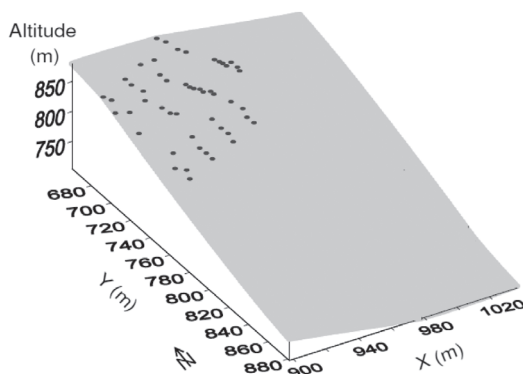


Figure 1. Digital elevation model of the slope with the distribution of the sampling points in the area involved in the study.

(Araújo *et al.*, 2004), they were treated with Captan (Orth Cide) at 0.1% for five minutes and submitted to the following determinations: water contents (U) – using two repetitions of 2 g of seed of each cultivar per collection point, employing the green house method  $105 \pm 3$  C, for 24 hours (Brasil, 2009); germination trial (G) – with four repetitions of 25 seeds per treatment, which were distributed between three germitest® type paper sheets, damp with distilled water, at the proportion of 3.0 times the weight of the dry paper. The paper rolls were places in vertical position inside plastic jars, in order to maintain the base of the rolls always damp, which were maintained inside the germinator, under alternate temperature of 20-30 °C.

The germination percentage was obtained by assessment after 15 days and 30 days from seeding (Brasil, 2009), and the seeds which presented protrusion of primary root with 2 mm length were considered germinated; jointly with the germination trial, the vigor of the seeds was assessed by the first germination count test (G1) – which was obtained considering the percentage of seedlings that, as of 15 days post seeding presented radicular emission; by the analysis of root length (CR) and aerial part length (CPA) - at 45 days after the seeding, the measurement was taken with the aid of a millimeter ruler and by the fresh (MFR) and dry mass of roots (MSR) and aerial part (MFPA), (MSPA). The fresh mass was taken in a four-digit electronic scale immediately

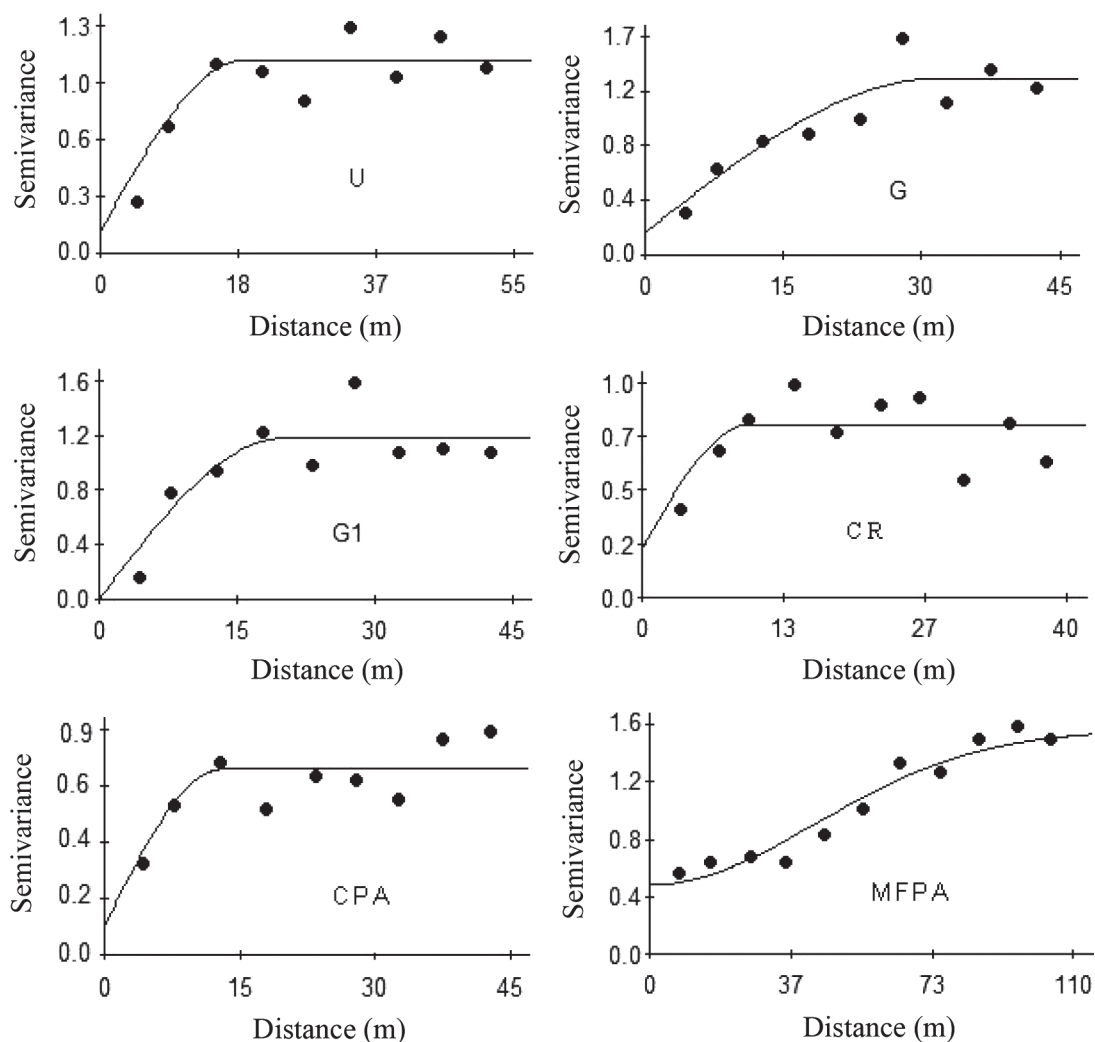


Figure 2. Variogramas staggered to moisture variables (U), germination (G), first count of germination (G1), root length (CR), length of the shoot (CPA) and mass fresh of shoot (MFPA) to cultivate *Catuai*.

after the measurement. The dry mass (MSR), after submitting to a green house at 105 °C for 72 hours, was weighed soon after. Fully randomized design (FRD) was used with four repetitions of 25 seeds.

The values found were assessed through position and dispersion measurement, in descriptive and explorative statistical analysis, using the Shapiro-Wilk's test ( $p < 0.05$ ) to test the normality of data.

To check the existence and quantify the degree of spatial dependency of the physiologic quality of seeds between sampling points, the theoretic functions were adjusted to the experimental variograms models, based on the stationarity assumption of the intrinsic hypothesis and as per the equation of the variogram:

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

In which:  $N(h)$  is the number of pairs of values  $Z(xi)$ ,  $Z(xi + h)$ , separated by a vector  $h$ , and  $xi$  is a spatial position of the variable  $Z$ . In the variogram adjustment, the following parameters were defined: nugget effect ( $C_0$ ), corresponding to the intersection value in the semi variances axis; plateau ( $C_0+C$ ), approximately equal to the data variance value; and range ( $a$ ), which represents the distance in which the variogram reaches the plateau value and the distance of spatial dependence between samples (Vieira, 2000).

The parameters of the variogram were adjusted and scaled by data variance. Depending on the

behavior of the semi variance with the distance, the models may be classified as: models with plateau and models without plateau, and the ones that fulfill only the intrinsic hypothesis. The models of spherical, exponential and Gaussian variograms were adjusted to the data, and the model selection criterion was based on the minimization of the sum of residues' square and the coefficient of multiple determination ( $R^2$ ) of the adjustment of theoretical models to the experimental variograms. Next, the  $R^2$  of the cross validation (observed values versus estimated values) was used as election criterion. In case of equality between results of cross validation, the chosen model was the one which presented the smallest nugget effect ( $C_0$ ).

For the analysis of the spatial dependence index (SDI), the relationship  $C/(C_0+C)$  was used, and the intervals proposed by Zimback (2001) which ranks the spatial dependence as weak ( $SDI < 25\%$ ); moderated ( $25\% \leq SDI < 75\%$ ); and strong ( $SDI \geq 75\%$ ). In case of proven spatial dependence, the method of ordinary kriging interpolation was used to estimate values in non-sampled 1 Cations with minimum variance to build the thematic maps.

## Results and Discussion

Table 1 presents the descriptive analysis of data that characterize the physiologic quality of catuai coffee seeds (*Coffea arabica* L.).

It was verified that the median and the average are close for all variables of the study, evidencing a symmetric distribution confirmed by the values

Table 1. Descriptive statistics of the variables under study to cultivate Catuai

Variables	Catuai								
	Average	Median	Minimum	Máximo	s	CV(%)	Cs	Ck	W
U	43.27	44.34	35.39	50.06	3.99	9.22	-0.45	-0.85	*
G	88.44	89.00	77.00	94.00	4.06	4.59	-0.71	0.25	ns
G1	84.21	83.00	75.00	92.00	4.07	4.84	-0.08	-0.29	ns
CR	5.39	5.20	3.40	7.50	0.94	17.38	0.20	-0.58	ns
CPA	3.51	3.50	3.00	4.10	0.30	8.52	0.53	-0.48	*
MFFPA	389.23	390.03	338.35	436.32	23.71	6.09	-0.24	-0.56	ns
MFR	82.31	83.39	58.46	106.51	10.33	12.55	0.07	-0.06	ns
MSPA	76.52	76.98	67.13	87.73	4.67	6.11	0.12	-0.31	ns
MSR	11.57	11.60	8.59	14.09	1.14	9.86	-0.05	0.34	ns

s = standar deviation; CV (%) = coefficient of variation; Cs = asymmetry; Ck = kurtosis; U = moisture (%); G = germination (%); G1 = first count of germination, CR = root length (cm); CPA = length of the shoot (cm); MFFPA = fresh mass of the shoot (mg plant<sup>-1</sup>); MFR = fresh mass of root (mg plant<sup>-1</sup>); MSPA = dry mass of the shoot (mg plant<sup>-1</sup>); MSR = dry mass of root (mg plant<sup>-1</sup>); ns normal distribution by Shapiro-Wilk's in level of 5% of probability; and \* non-normal distribution.

close to zero for the asymmetry coefficient, except for humidity (U) and aerial part length (CPA). U and CPA features presented platykurtic distribution, with kurtosis values lower than zero. Such results reflected on the data distribution behavior, since these variables were the only ones presenting a distribution that fall outside the normal distribution curve, analyzed by the Shapiro Wilk's test ( $p < 0.05$ ).

The variation coefficients (VC%), as per the Warrick and Nielsen (1980) classification (1980), who consider low values of  $VC < 12\%$ ; average on  $12\% < VC < 60\%$  and high on  $VC > 60\%$ , all variables in the study were presented within the VC low value range, except for root length (CR) and root fresh mass (MFR), classified as average.

The spatial analysis results, according to the geostatistical methodology for cultivar *catuai*, are found in Table 2 and Figures 3 and 4.

88.9% of the features' data of physiologic quality for *catuai* cultivar were adjusted to the spherical model and 11.1% to the Gaussian model. The spherical model was the most adjusted to the experimental variograms, confirming such mathematical model as the most adequate to the soil and plant parameters (Carvalho *et al.*, 2009).

On spatial analysis, according to Vieira (2000) the nugget effect ( $C_0$ ) values described the spatial discontinuity between the samples, that is, the undetected variability during the sampling process. The spatial dependence ranges vary from 10 m for root length (RL) to 105 m for fresh mass of aerial part (MFPA). According to Corá *et al.*

(2004), estimates made through ordinary kriging interpolation using values of higher ranges tend to be more reliable due to spatial discontinuity and similarity between the neighbors, and, thus, are more reliable for estimating unmeasured values using the interpolation method.

Scaling of variograms' parameters by the variance of data presented in Table 2 show features with the same spatial distribution pattern, that is, the same model (spherical) and close ranges, with CR and CPA (ranges close to 10 m); U and G1 (ranges close to 20 m) and G, MFR, MSPA and MSR (ranges close to 30 m).

All of the attributes studied in the present paper present, according to a classification presented by Zimback (2001), Strong spatial dependence, except for root length (CR) and fresh mass of aerial part (MFPA), which presents moderate spatial dependence for *catuai*, due to presenting higher  $C_0$ . However, low correlation between two attributes any, do not invalidate the hypothesis of significant spatial correlation  $C_{curred}$  between them (Kitamura *et al.*, 2007).

After the definition of variograms' models and parameters, data were interpolated through ordinary kriging in order to build thematic maps of: seeds' humidity (U), germination (G), first germination count (G1), root length (CR) and aerial part length (CPA), fresh mass of aerial part (MFPA), root fresh mass (MFR), dry mass of aerial part (MSPA) and root dry mass (MSR) of *Coffea arabica* L. (Figures 5, 6 and 7). Variables that distinguish safely lots of

Table 2. Parameters and models of the staggered variogramas adjusted for the variables under study from cultivars *Catuai*.

Variables	Models and parameters							
	Model	$C_0$	$C_0+C$	a (m)	$R^2$ (%)	IDE (%)	$R^2$ (VC) (%)	p-value
U	Spherical	0.13	1.13	19	82	89	28.0	0.00
G	Spherical	0.18	1.39	32	83	87	21.3	0.00
G1	Spherical	0.10	1.15	20	75	99	24.9	0.00
CR	Spherical	0.22	0.78	10	47	72	21.3	0.01
CPA	Spherical	0.11	0.71	13	61	85	26.7	0.00
MFPA	Gaussian	0.47	1.52	105	95	70	31.2	0.00
MFR	Spherical	0.17	0.91	30	84	81	32.6	0.00
MSPA	Spherical	0.10	1.23	29	81	93	21.7	0.00
MSR	Spherical	0.20	1.50	27	70	87	27.0	0.00

U = moisture; G = germination (%); G1 = first count of germination; CR = root length (cm); CPA = length of the shoot (cm); MFPA = mass fresh of shoot ( $\text{mg planta}^{-1}$ ); MFR = fresh mass of root ( $\text{mg planta}^{-1}$ ); MSPA = dry mass of the shoot ( $\text{mg planta}^{-1}$ ); MSR = dry mass of root ( $\text{mg planta}^{-1}$ );  $C_0$  - nugget effect;  $C_0+C$  - landing; IDE - spatial dependency index ( $C/C_0 + C$ ); a - range;  $e R^2$  - coefficient of determination of the variogram model;  $R^2$  (VC) - coefficient of determination of cross-validation; p- the significance value estimate.

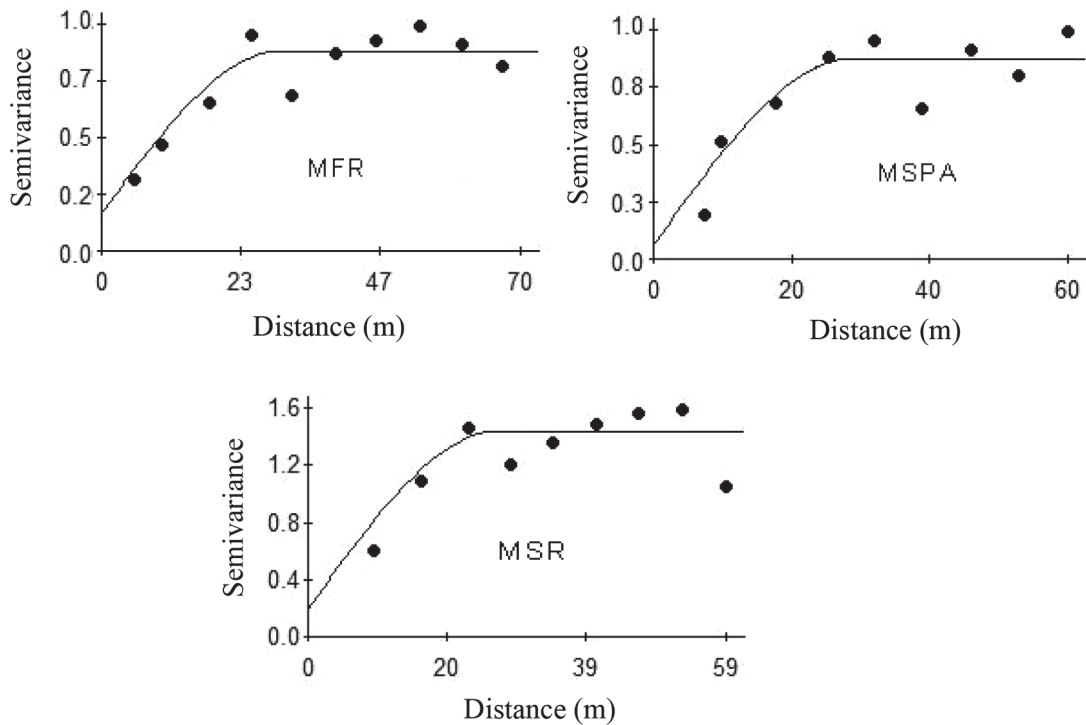


Figure 3. Variogramas staggered to moisture variables fresh mass of root (MFR) dry mass of the shoot (MSPA) and dry mass of root (MSR) to cultivate Catuaí.

high and low vigor, because of the differences that are found are attributed to the behavior of seed in storage and at the stage of establishment in the field (Marcos Filho, 2005).

It is observed in Figure 4, in germination (G) map, that a great part of the area presented values above 87%, considered above the standards of basic seeds from Minas Gerais, for which minimum germination must be of 70% (IMA, 2013), and the abovementioned methods may be considered highly efficient. The upper central region, as well as for first germination count (G1), presented the lowest values. Although only the first germination count is not recommended for determining the vigor of a lot of seeds, tomato seed has the distinction of lots more vigorous (Maciel *et al.*, 2012), and as Ciate to germination and speed germination growing were observed in *Bixa orellana* (Lopes *et al.*, 2008).

For humidity (U) and root length (CR) variables of *Coffea arabica* L. seeds, higher values are observed in the central to upper parts and, for coffee seeds, the feasibility, assessed by germination and vigor, is fundamental during the storing pr Cess,

and the seeds with higher water contents preserve their feasibility for a longer period during storage than seeds with lower water contents. Araújo *et al.* (2008) working with coffee seeds storage verified that those which were not submitted to supplementary artificial drying pr Cess (quick dehydration), but were dehydrated only in the shadow, and stored with humidity after hygroscopic balance, from 14.5 to 18.5%, at a temperature of 7 °C, maintained their germinative power above 80% for a period of nine months. It is important to highlight that, although the germination test is an indicative pr Cedure as official method to assess the capacity of seeds to produce regular seedlings under optimum conditions (Brasil, 2009), it not always reveals differences between seeds batches during storage or in field. A treatment performed in coffee Arabica seeds with sodium hyp Chlorite, at concentrations of 7.5 and 10%, determined high rates of first germination count, as vigor index; however, there has been decrease in overall germination (Meireles *et al.*, 2007). Nevertheless, a treatment of conilon coffee seeds in any humidity, with sodium hyp Chlorite solutions at 7% concentration of active

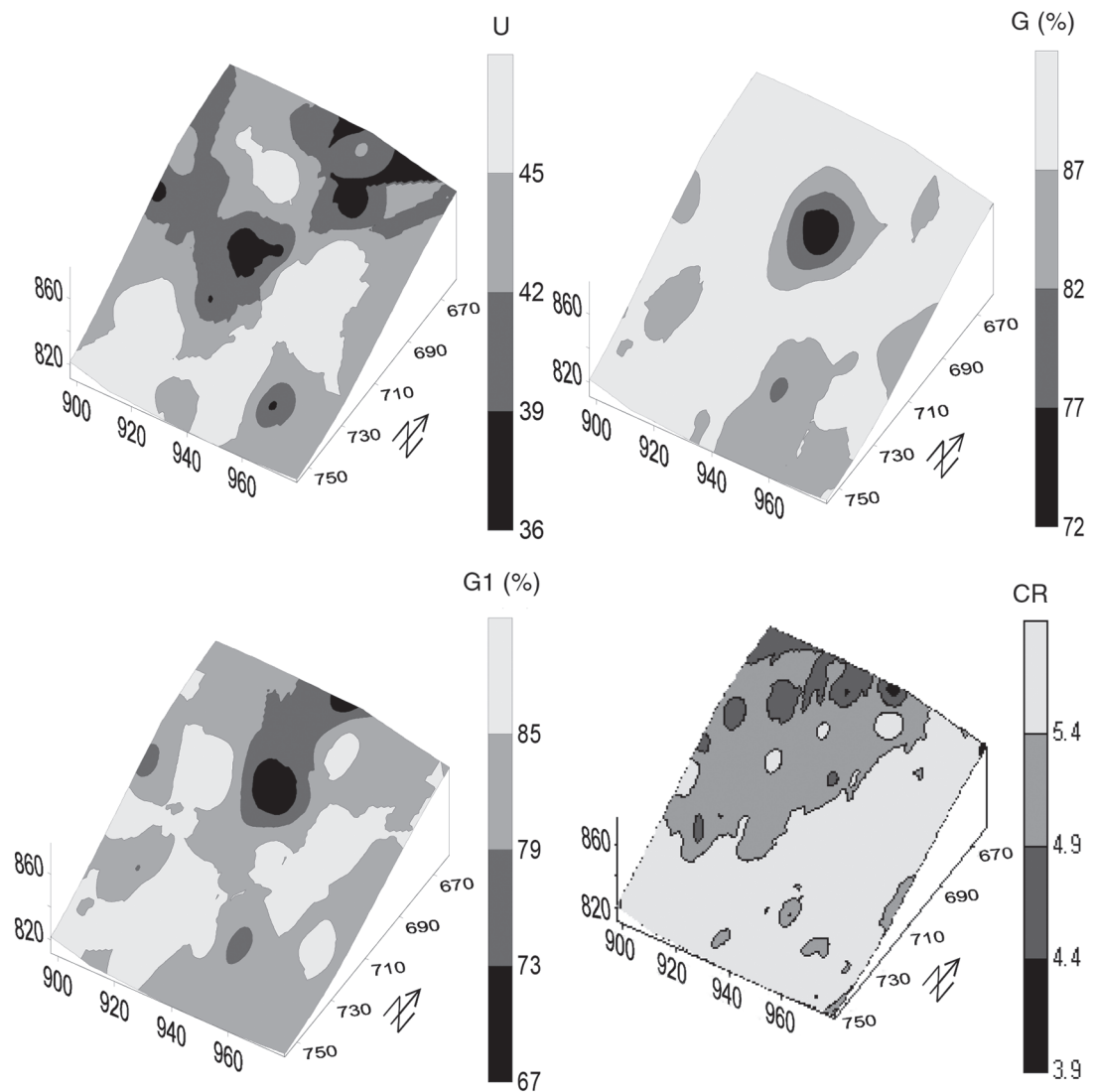


Figure 4. Thematic maps for the variable moisture (U), germination (G), first count of germination (G1) and root length (CR) to cultivate *Catuái*.

chloride significantly reduces germination (Rubim *et al.*, 2010). Thus, this dependence relationship between root and aerial part length features is justified because they are variables that similarly assess the vigor of seeds, whereas germination is a parameter independent from vigor, depending on the feasibility of seeds.

The aerial part length (CPA), Figure 5, presents the same spatial distribution pattern of the variable root length (CR), with the highest values presented in the lower right lateral part of the area. Studies involving root length are important in the assessment of seedlings' vigor, and it is an important variable

in the study of culture development in various types of soil. The inhibition of root growth is an indication of stress, as observed with high aluminum concentrations (Macedo *et al.*, 2008), caused by toxicity, its accumulation at the apex of the root (Horst *et al.*, 2010). The fresh mass of aerial part (MFPA) presents the highest spatial continuity ( $a = 105$  m) and its spatial distribution with the highest values is found, mostly, in the regions with the highest aerial part length (CPA), which shows the reliability of the geostatistical method. In Figures 5 and 6, it is verified certain similarity in the spatial distribution of root fresh mass (MFR)

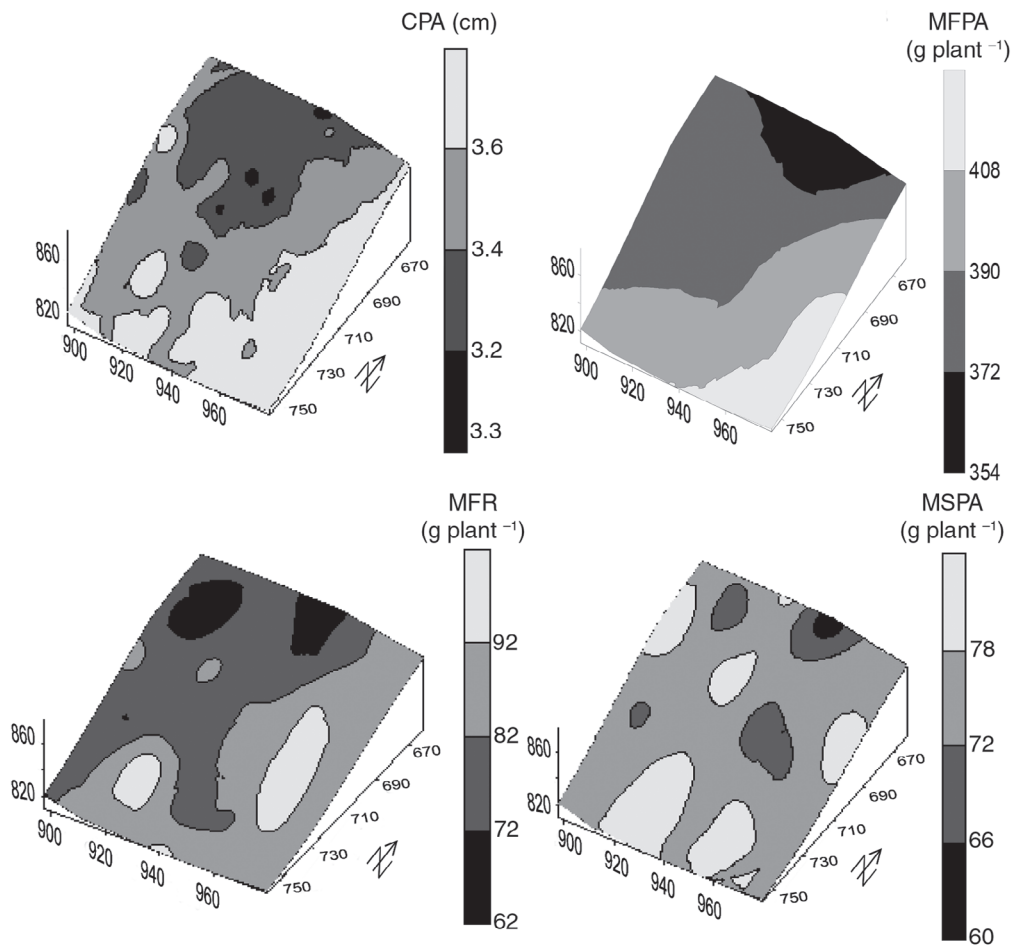


Figure 5. Thematic maps for the variable length of the shoot (CPA), mass fresh of shoot (MFPA), fresh mass of root (MFR) and dry mass of the shoot (MSPA) to cultivate Catauf.

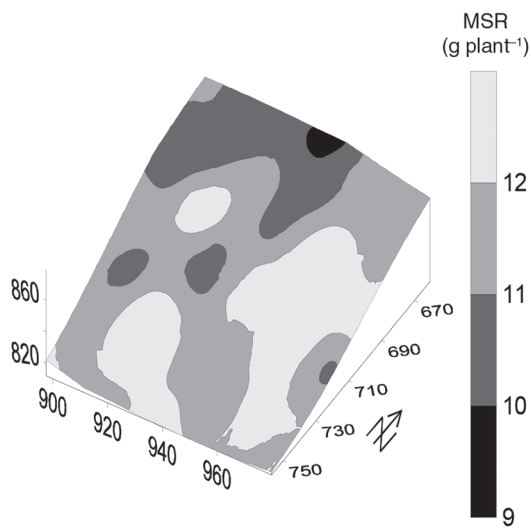


Figure 6. Thematic maps for the variable dry mass of root (MSR) to cultivate Catauf.

and root dry mass (MSR), a factor associated to the development of the aerial part and the radicular system, which ensures a reliable sampling for the collection of seeds with physiologic quality needed for the wanted plantation.

According to the results obtained, in agreement with Souza *et al.* (2003) and Sanchez *et al.* (2005), it is verified that, through the kriging maps, it is possible to obtain information that enable a better understanding of the spatial distribution pattern and a definition of the handling and collection zones of coffee seeds with higher physiologic quality, factors that may interfere in the plantation's production. Knowledge on the spatial variability of soil and plant properties that control crop yields is indispensable in modern agriculture, since minor changes can lead to great yield differences (Silva *et al.*, 2010b).



## Conclusions

The methodology based on spatial statistics, or geostatistics, is feasible in the characterization of the physiologic quality of catuai coffee seeds.

There are spatial dependence for humidity, germination, first germination count, root length, aerial part length, fresh mass of aerial part, dry mass of aerial part and root dry mass.

There is a spatial dependence for all studied variables, except for root fresh mass.

The scope of spatial dependency varies from 10 to 105 meters.

Spatial analysis may be used as a tool to define a region for Arabica coffee seeds sampling for the production of quality seedlings.

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