Relations between the yield of bean (*Phaseolus vulgaris* L.) and chemical attributes of an Acrustox under no-tillage

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Abstract

In crop year 2006/07, in Selvíria, MS, Brazil, were analyzed the productivity of beans because of the chemical attributes of an Acrustox cultivated under conditions of high technological level of management by no-tillage irrigated with pivot central. The objective was to select, among the attributes studied soil, the one with the best representation to explain the variability of agricultural productivity. Geostatistical grid was installed to collect data from soil and plant, with 117 sampling points in an area of 2,025 m² and homogeneous slope of 0.055 m m⁻¹. From the standpoint of linear and spatial bean yield was respectively explained in terms of P and soil pH. So much for the values of phosphorus (P) in the intermediate layer and subsurface between 24-26 mg dm⁻³, as well as for Hydrogen (pH) in the surface layer between 5.0 to 5.4, resulted in sites with the most high yield (2,160-2,665 kg ha⁻¹).

Keywords: Soil management, no-tillage system, agricultural sustainability, *Phaseolus vulgaris* L.

1. Introduction

In Brazil, the culture of bean (*Phaseolus vulgaris* L.), constitutes one of the most major farms, not only for the area of cultivation as well as by value of production. It is a vegetable essential in basic power of the national population, since it is the main source of protein and iron (Buratto *et al.*, 2009). Regarding the arrangement of the root system in the soil, it resembles fasciculate, once the primary root is not a typical axial, and mostly lie within the first 0.20 m deep, with 62-87% of

the first 0.10 m (Montanari *et al.*, 2010). As a result, the plant operates fundamentally their surface layer, being therefore very sensitive to the lack of moisture, to compaction and soil fertility (Vieira *et al.*, 2006). The bean is one of the main crops planted in the Midwest, Northeast and Southeast of Brazil, being that in crop year 2009/2010, the acreage for the “third season” in these areas was approximately 560 thousand hectares, with an average productivity of 1,909 kg ha⁻¹ (Conab, 2012).

In some areas of the mid-western region of Brazil soil has gone through some physical and chemical degradation problems, being that: a) is deficient in phosphorus (P) due to the acidic pH and the presence of high proportions of oxides of Fe and Al in the clay fraction, which makes phosphate fixation, thereby decreasing the availability of P applied, in addition to the natural process of formation which features the labile and no-labile P; and b) as a result of its intensive usage has also suffered heavily with erosion, loss of fertility, organic matter content reduction and mainly with the compressed layers formation (Novais and Smyth, 1999; Ramos *et al.*, 2010). This compression generates substantial change their structure, triggering the reorganization of the particles and their aggregates, which may limit the absorption of nutrients, the infiltration and redistribution of water, gas exchange and growth of root system, resulting in decreased crop yields (Roque *et al.*, 2008), in addition to, the P deficiency is considered to be limiting for plant productivity in tropical regions (Fageria and Baligar, 1996).

Under the conditions of climate and soils of the Cerrado (Brazilian Savanna), the no-tillage system is a successful management practice (Corrêa and Sharma, 2004; Carneiro *et al.*, 2009; Carvalho *et al.*, 2011a), however requires more information about species for coverage, which should have a good biomass production and be persistent enough for adequate physical protection of the soil and nutrient availability, during periods in which there is excess or shortage of water, resulting in benefits for the later culture.

The geostatistical analysis of soil variability can indicate management alternatives, not only to reduce the effects of variability of soil attributes on agricultural production, but also to increase their response to the various cultural practices employed (Trangmar *et al.*, 1985; Carvalho *et al.*, 2011b; Carvalho *et al.*, 2012). Thus, the collection of spatial values of a given attribute may reveal wide variations because the soil is a product of the action of various factors training varies greatly in its three dimensions, especially the

surface (Roque *et al.*, 2008; Montanari *et al.*, 2012). These procedures for determining whether or not an attribute presents spatial structure and, once you know the model of spatial dependence, it is possible to map the area studied. Thus, the zones are established specific management that are critical to the application of inputs with varying rates, conditions necessary for precision agriculture (Coelho, 2003).

With the emergence of the precision agriculture, lately in Brazil the study of geostatistics in respect of soil attributes and the productivity of the bean has been increasingly intensifying (Freddi *et al.*, 2005; Santos *et al.*, 2005; Carvalho *et al.*, 2006; Kitamura *et al.*, 2007; Roque *et al.*, 2008; Martins *et al.*, 2009).

Given the above, having the bean culture established in Selvíria, Mato Grosso do Sul State, Brazil, under conditions of high technological level of management, the objective of this research was to search among the studied chemical attributes of soil under no-tillage, those that best present to explain, linear and spatially, grain productivity variability of beans.

2. Material and Methods

2.1. Description of research area

The experiment was conducted at Farm Teaching, research and extension of the Faculty of Engineering of Ilha Solteira (FEIS/UNESP), in the municipality of Selvíria (MS, Brazil), at Lat. 20°22'S and Long. 51°22'W, with an annual average rainfall is 1,300 mm, while their average temperature is 74.6°F. The climate is type Aw, according to Köppen-Geiger, characterized as tropical wet with a rainy season in the summer and dry in winter. The soil in which the grid was installed is an Acrustox dystroferic typical very clayey (Soil Survey Staff, 1998). Their granulometry, parsed from the surface up to 0.30 m, is 620 g kg⁻¹ clay, 100 g kg⁻¹ of silt, 60 g kg⁻¹ of coarse sand and 220 g kg⁻¹ of fine sand, which gives very clayey texture. This has been

grown for at least twenty years with the succession of crops of maize and beans sown in summer and winter respectively. In the years 1998 and 2003, in two seasons, the soil was prepared with the plow of moldboard. However, on the other, by tillage system irrigated under center pivot.

2.2. sampling and measurements

The test plant searched was the bean (*Phaseolus vulgaris* L.), sown in 5/6/2006 after desiccation weed with the herbicide glyphosate, at a dose of 1.8 kg ha⁻¹ of the active ingredient. The cultivar sown was the Pérola, whose cultivation was conducted in accordance with the instructions for the main agricultural crops of the State of São Paulo, Brazil (Fahl *et al.*, 1998). Thus, the spacing was 0.45 m, with a final density of 16 plants per line of sowing. The x and y directions were established in the Cartesian Coordinate System, established between two agricultural terraces, where was sown the culture studied. It was the common optical level, effecting the global staking after sowing in experimental grid, i.e., in June 2006. This grid was constituted of 9 transects of 40 x 40 m in length with an area of 2,025 m². The transects were spaced out of 5.00 m, with sample points in the form of 5.00 m x 5.00 m, containing 81 of them. However, were added, within the large grid points with spaces smaller than those mentioned, with 1.67 m between them, in order to elaborate the study of spatial dependence. As in this case were 36, the total sample points of the grid were 117.

The attributes of soil were studied: a) phosphorus (P), b) organic matter (OM), and c) potential Hydrogen (pH), collected in 6/18/2006 in three depths: 1st) 0-0.10 m, 2nd) 0.10-0.20 m and 3th) 0.20-0.30m. Was evaluated the productivity of grain of bean (PGB) held in 8/14/2006. Collected four lines of sowing (1.80 m), so there are always two on either side of the sample point. As the length in the direction of the lines also amounted to 1.80 m, the area harvested was 3.24 m². Therefore, the list of 10 attributes searched was the following: PGB, OM1, OM2, OM3, P1, P2, P3, pH1, pH2 and pH3.

The soil available phosphorus content (P) was determined by extraction method with ion exchange resin, given as mg dm⁻³ (Raij *et al.*, 1987), the pH was determined potentiometrically in 0.01M CaCl₂ solution, while the organic carbon was by wet combustion method, by colorimetric, resulting in soil organic matter content (OM) by the following expression (Raij *et al.*, 1987):

$$OM = C \cdot 17.24 \quad (1)$$

where: OM is the quantity of organic matter (g dm⁻³) and C is the carbon content (g dm⁻³). All analyses were performed in the laboratory of soil physics and Chemistry Engineering College of Calcutta – UNESP.

2.3. Data analysis

For the attributes studied, there was the classical descriptive analysis, with the aid of SAS statistical software (Schlotzhaver and Littell, 1997), which were calculated the mean, median, minimum and maximum values, standard deviation, coefficient of variation, kurtosis, asymmetry and frequency distribution. Was then performed to identify outliers, making the substitution by the average of the values contained in the grid surrounding geostatistics. To perform the test of the hypothesis of normality, or lognormality, was used the Shapiro & Wilk 5%. Was assembled the correlation matrix, aiming to make the linear regressions for the combinations, two by two, among the attributes studied. Therefore, was selected those of higher linear correlation and thus could exhibit cross semivariogram and the resulting cokriging. For each attribute, was to study the spatial dependence using the semivariogram simple calculation based on the assumptions of stationarity of the intrinsic hypothesis, using the Gamma Design Software package (GS+, 2004)

$$SDE = [C / (C + C_0)] \cdot 100 \quad (2)$$

where: SDE is the appraiser spatial dependence; C, the structural variance; and C + Co, the landing. The interpretation proposed for the SDE was as follows: $25\% \leq \text{SDE}$ indicated spatial weakly dependent variable; $25\% < \text{SDE} \leq 75\%$ indicated spatial variable moderately dependent; and $\text{SDE} > 75\%$ indicated spatial strongly dependent variable. However, cross-validation is a tool used to evaluate alternative models of single and cross semivariograms, which will affect subsequently respectively kriging and cokriging. In its analysis, each point contained within the spatial domain is removed individually, with their estimated value as if it did not exist. Thus, one can construct a graph of observed versus estimated values for all points. The correlation coefficient (r) between such values reflects the efficiency of setting, by the technique given the sum of squares of deviations, representing the linear regression equation in question.

With a perfect fit would present the regression coefficient equal to 1 and the line of best fit coincide with the perfect model, i.e., with the linear coefficient equal to zero and the angular equal to 1 (GS+, 2004). Thus, working on getting the optimal number of neighbors, were obtained by interpolation maps of kriging and co-kriging for analysis of spatial dependence and interdependence between attributes.

3. Results and Discussion

In table 1, are displayed the descriptive analysis of some chemical attributes studied in no-tillage system, where the productivity of grain (PGB) presented high variability, representing a 21% variation coefficient. However, this data were similar to those of Freddi *et al.* (2005), Martins (2007) and Kitamura *et al.* (2007) when investigated an Acrustox dystroferic under no-tillage in regular knitting 135 points, which were also high variability of 24% for the grain productivity of beans, but disagrees with of Megda *et al.* (2008), where she earned average variability (19%) to the bean grain productivity.

The organic matter (OM) in the depths of 0-0.10, 0.10-0.20 and 0.20-0.30 m showed high variability average, 14, 19 and 21% respectively (Table 1). These data corroborate with those of Bezerra (2008), where he studied under no-tillage, a Typic Acrustox with 125 sample points, obtained high variability with 26 and 23% values in the depths 0-0.10 and 0.10-0.20 m, respectively.

At all depths to the content of phosphorus (P), showed very high variability (Table 1), with variations between 32 to 62%, so these data agree with those of Souza *et al.* (1998), which was 31 to 61% at depths 0-0.05 and 0.05-0.20 m, respectively, who studied an Ultisol dystrophic in minimum cultivation system with a 40 grid points; and those of Bezerra (2008) where he worked in a Typic Acrustox under no-tillage in a grid of 125 points, which he obtained in the depths of 0-0.10 and 0.10-0.20 m a 58-52% variability.

In relation to the potential hydrogen (pH), low variability was obtained in three layers of soil, with coefficients of variation between 4-8%, so these data are similar to those achieved by Freddi (2003) and Bezerra (2008), when they found a variance between 4-7%, studying in an Acrustox dystroferic and dystrophic under no-tillage, respectively (Table 1).

When a statistical variable has normal frequency distribution to measure of central tendency most suitable to represent it to be average. In contrast, the median, or the geometric mean, if lognormal type (Montanari, 2010). Thus, the tendency to represent the attributes PGB, OM3, pH1, pH2 and pH3 shall be the average, because they had the frequency distribution of the normal type, with positive, asymmetry coefficients between 0.020 and 0.347. Already the negative kurtosis coefficients were between -0.680 and -0.316. However, all were significant at 5% probability by normality test of Shapiro and Wilk, since such a likelihood ranged from 0.055 and 0.850 (Table 1). Though, the normal frequency distribution obtained for such attributes, as the magnitudes of the coefficients of skewness and kurtosis were in general

agreement with observed data by Souza *et al.*, 1998, Megda *et al.* (2008) and Montanari *et al.* (2008). The attributes OM1 and P2 show frequency distribution of the type tending to lognormal, P1 and P3 had frequency distribution lognormal type, whereas the OM2 type undetermined. Based on geostatistics studies, that evaluate the correlations between the average productivity of beans and soil attributes,

the average yield obtained (2,201 kg ha⁻¹) (Table 1) was 15.2% lower than those of Kitamura *et al.* (2007) and Martins *et al.* (2009), which were 2,594 kg ha⁻¹. However, they were 21.7% and 31.1% bigger than the Roque *et al.* (2008) and Carvalho *et al.* (2006), respectively, which were 1,809 and 1,679 kg ha⁻¹.

Table 1. Descriptive analysis of the productivity of beans and some chemical properties of a Typic Acrustox under no-tillage in Selvíria, MS, Brazil.

Attributes ^(a)	Measures Descriptive Statistics								Probability test ^(B)	
	Mean	Median	Value		Standar	Coefficient				
			minimum	maximum	d Deviation n	variation (%)	kurtosis	Asymmetry		
Pr<w	FD									
Attribute plant										
PGB (kg ha ⁻¹)	2200.9	2206.9	1225.2	3390.0	464.7	21.1	-0.625	0.020	0.217 ^{ns}	NO
Chemical soil attribrutes										
OM1 (g dm ⁻³)	18.3	18.1	13.5	25.4	2.671	14.6	-0.633	0.090	0.017 [*]	TL
OM2 (g dm ⁻³)	17.7	16.9	9.1	24.2	3.352	18.9	-	-	-	IN
OM3 (g dm ⁻³)	14.8	14.6	6.9	22.9	3.100	20.8	-0.316	0.094	0.202 ^{ns}	NO
P1 (mg dm ⁻³)	20.0	20.0	7.0	40.0	6.557	32.7	-0.160	0.017	0.092 ^{ns}	LN
P2 (mg dm ⁻³)	17.0	16.0	4.0	51.0	8.928	52.7	0.115	-0.052	0.403 ^{ns}	TL
P3 (mg dm ⁻³)	11.6	10.0	2.0	38.0	7.220	62.4	0.229	-0.043	0.083 ^{ns}	LN
pH1 (CaCl ₂)	4.9	4.9	4.2	5.7	0.347	7.0	-0.680	0.347	0.174 ^{ns}	NO
pH2 (CaCl ₂)	5.0	5.0	4.3	5.7	0.331	6.6	-0.488	0.051	0.595 ^{ns}	NO
pH3 (CaCl ₂)	5.0	5.0	4.3	5.8	0.338	6.7	-0.383	0.036	0.840 ^{ns}	NO

^(a)PGB = productivity of grain of bean; OM, P, pH, going 1 and 3, are respectively the content of organic matter, phosphorus and hydrogen potential, collected in layers of soil from 0.00-0.10, 0.10-0.20 and 0.20-0.30 m; ^(b)FD = frequency distribution, and NO, LN, TL and IN respectively type normal, lognormal, tending to lognormal and indeterminate. *Significant at the 5%; ^{ns} not significant.

The Table 2 shows the correlation matrix between the simple linear attribute bean (PGB) and soil chemical properties (organic matter, pH and P) for no-tillage. The correlation between the attributes of the plant with the soil (Table 2) showed a negative correlation for pairs 1) PGB x OM1 ($r = -0.031$), 2) PGB x P1 ($r = -0.116$), 3) PGB x pH2 ($r = -0.050$) and 4) PGB x pH3 ($r = -0.022$). Already the pairs 1) OM1 x OM2 ($r = 0.657^{**}$), 2) OM1 x OM3 ($r = 0.264^{**}$), 3) OM1 x P2 ($r = 0.327^{**}$), 4) OM1 x pH1 ($r = 0.507^{**}$), 5) OM1 x pH2 ($r = 0.467^{**}$), 6) OM1 x pH3 ($r = 0.369^{**}$), 7) OM2 x OM3 ($r = 0.533^{**}$), 8) OM2 x P2 ($r = 0.392^{**}$), 9)

OM2 x P3 ($r = 0.274^{**}$), 10) OM2 x pH1 ($r = 0.496^{**}$), 11) OM2 x pH2 ($r = 0.579^{**}$), 12) OM2 x pH3 ($r = 0.517^{**}$), 13) OM3 x P2 ($r = 0.286^{**}$), 14) OM3 x P3 ($r = 0.412^{**}$), 15) OM3 x pH2 ($r = 0.268^{**}$), 16) OM3 x pH3 ($r = 0.242^{**}$), 17) P1 x P2 ($r = 0.324^{**}$), 18) P1 x P3 ($r = 0.259^{**}$), 19) P1 x pH1 ($r = 0.295^{**}$), 20) P1 x pH2 ($r = 0.272^{**}$), 21) P1 x pH3 ($r = 0.244^{**}$), 22) P2 x P3 ($r = 0.410^{**}$), 23) P2 x pH1 ($r = 0.258^{**}$), 24) P2 x pH2 ($r = 0.194^{*}$), 25) P3 x pH1 ($r = 0.205^{*}$), 26) pH1 x pH2 ($r = 0.857^{**}$), 27) pH1 x pH3 ($r = 0.740^{**}$) and 28) pH2 x pH2 ($r = 0.872^{**}$), have direct significance.

Table 2. Matrix of simple linear correlation between yield of beans (PGB) and some chemical attributes of a Typic Acrustox under no-tillage in Selvíria, MS, Brazil.

Attributes ^(a)	Correlation coefficient ^(b)								
	PGB	OM1	OM2	OM3	P1	P2	P3	pH1	pH2
OM1	-0.031 ^{ns}	-	-	-	-	-	-	-	-
OM2	0.037	0.657^{**}	-	-	-	-	-	-	-
OM3	0.006	0.264^{**}	0.533^{**}	-	-	-	-	-	-
P1	-0.116	0.164	0.158	0.151	-	-	-	-	-
P2	0.103	0.327^{**}	0.392^{**}	0.286^{**}	0.324^{**}	-	-	-	-
P3	0.062	0.114	0.274^{**}	0.412^{**}	0.259^{**}	0.410^{**}	-	-	-
pH1	0.069	0.507^{**}	0.496^{**}	0.164	0.295^{**}	0.258^{**}	0.205[*]	-	-
pH2	-0.050	0.467^{**}	0.579^{**}	0.268^{**}	0.272^{**}	0.194[*]	0.156	0.857^{**}	-
pH3	-0.022	0.369^{**}	0.517^{**}	0.242^{**}	0.244^{**}	0.133	0.166	0.740^{**}	0.872^{**}

^(a) PGB = productivity of grain of bean; OM, P, pH, going 1 and 3, are respectively the content of organic matter, phosphorus and hydrogen potential, collected in layers of soil from 0.00-0.10, 0.10-0.20 and 0.20-0.30 m; ^(b) *Significant at the 5%, **Significant at the 1%. ^{ns} not significant.

In Table 3 are presented the parameters of simple semivariograms adjusted for productivity of beans and some chemical attributes of an Acrustox dystroferic, Selvíria (MS, Brazil) under no-tillage. Already in Figures 1 and 2 were presented their respective semivariograms. With regard to the performance of semivariograms (Table 2), the relationship of decreasing them, analyzed by the greatness of the coefficient of determination (r^2), was as follows: 1) OM1 (0.997), 2) P1 (0.980), 3) pH3 (0.976), 4) P3 (0.968), 5) pH2 (0.936), 6) OM3 (0.920), 7) OM2 and P2 (0.912), 8) pH1 (0.851) and 9) PGB (0.766). So, for the first three, which had high coefficients of determination, the following was observed. For the first (OM1), its value of r^2 (0.997), which indicated that the best-fit attribute semivariographic, disagreeing that observed by Bezerra (2008), studying a cultivated with maize Acrustox, seeded on irrigated pastures, spatial variability found for OM1. For the second (P1, Table 2), the r^2 value (0.980), which indicated that the second best-fit attribute semivariographic, disagreed with the results found by Manzione (2002), Weirich Neto *et al.* (2005) who worked respectively with Oxisol udic and ustic that pure nugget effect have been detected for phosphorus.

Still on Table 3, the ratio reaches down was as follows: 1) pH3 (23.2 m); 2) OM2 (22.3 m); 3) pH1 and pH2 (21.1 m); 4) OM1 (19.2 m); 5) OM3 (15.5 m); 6) P2 (14.4 m); 7) P3 (11.1 m); 8) PGB (10.7 m); and 9) P1 (8.8 m). Therefore, under the conditions of this study, as well as to assist future research, in which the same attributes are involved, reaches values use in geostatistical packages, which will feed the computational programs employed in precision agriculture, in general, should not be lower than 8.6 m. Conversely, exclusively for plant attributes, should not be lower than 10.7 m.

In Figure 1 are shown the maps of kriging bean productivity and chemical attributes of an Acrustox dystroferic in Selvíria (MS, Brazil), under the no-tillage. Thus, in Figure 1, is the map of kriging

bean grain productivity (PGB) which presented the highest values (2,160-2,665 kg ha⁻¹) located mostly in the central region of the map. On the other hand, in the other regions, this productivity ranged from 1,487-1,992 kg ha⁻¹, corroborating with the values found by Martins *et al.* (2009) in which were of 2,595-3,379 kg ha⁻¹.

In Figure 1 are shown the maps of kriging of phosphorous (P2 and P3) and hydrogen potential (pH1). Thus, spatial similarity observed between the attributes specified in depth. Therefore, the maps of kriging of phosphorous (P) and potential hydrogen (pH), presented their highest values (24.8-26.0 mg dm⁻³ and 5.36) in the central regions of maps, respectively.

In Table 3 are presented the parameters of the cross-semivariograms, set between the productivity attribute of beans and an Acrustox dystroferic in Selvíria (MS). In Figure 2 are contained the cross-semivariograms, cross-validations and co-kriging maps between the plant attribute versus chemical soil attribute, getting attestation: PGB=f (P2), PGB=f(P3) and PGB=f(pH1) presented spatial dependence. With regard to the performance of cross-semivariograms (Table 3), the relationship of decreasing them, analyzed by the greatness of the coefficient of determination (r^2), was as follows: 1) [PGB=f(P2)] (0.880), 2) [PGB=f(pH1)] (0.821) and 3) [PGB=f(P3)] (0.656).

Table 3. Parameters of simple and cross-semivariograms adjusted for productivity of beans and some chemical attributes of a Typic Acrustox under no-tillage in Selvíria, MS, Brazil.

Attributes ^(a)	Model ^(b)	Parameters					Spatial dependency evaluator	
		Nugget effect (C ₀)	Landing (C ₀ +C)	Range (A ₀) (m)	r ²	SQD ^(c)		
							SDE ^(d)	Class
		γ(h) simple attribute plant						
PGB (kg ha ⁻¹)	exp (54)	4.650x10 ⁴	1.794x10 ⁵	10.7	0.766	1.220x10 ⁹	74.1	moderate
γ(h) simple chemical soil attributes								
OM1 (g dm ⁻³)	gau (102)	3.140	7.847	19.2	0.997	6.910x10 ⁻²	60.0	moderate
OM2 (g dm ⁻³)	gau (100)	5.480	1.425x10	22.3	0.912	5.450	56.0	moderate
OM3 (g dm ⁻³)	sph (102)	3.900	9.988	15.5	0.920	1.870	61.0	moderate
P1 (mg dm ⁻³)	gau (76)	1.320x10	3.625x10	8.8	0.980	6.800	64.1	moderate
P2 (mg dm ⁻³)	sph (91)	2.210x10	5.628x10	14.4	0.912	5.960x10	59.7	moderate
P3 (mg dm ⁻³)	exp (52)	9.100	5.250x10	11.1	0.968	2.040x10	82.7	strong
pH1 (CaCl ₂)	sph (91)	1.240x10 ⁻²	1.178x10 ⁻¹	21.1	0.851	1.490x10 ⁻³	89.5	strong
pH2 (CaCl ₂)	gau (91)	3.460x10 ⁻²	1.232x10 ⁻¹	21.1	0.936	5.7060x10 ⁻⁴	71.8	moderate
pH3 (CaCl ₂)	sph (89)	2.680x10 ⁻²	1.156x10 ⁻¹	23.2	0.976	1.861x10 ⁻⁴	76.8	strong
γ(h) cross between plant and soil attribute								
PGB=f(P2) (kg ha ⁻¹)	sph (46)	3.600x10	7.280x10 ²	14.0	0.880	5.377x10 ⁴	95.1	strong
PGB=f(P3) (kg ha ⁻¹)	gau (33)	2.300x10	6.261x10 ²	16.6	0.656	1.879x10 ⁵	96.3	strong
PGB=f(pH1) (kg ha ⁻¹)	gau (36)	2.200x10 ⁻¹	2.165x10	13.0	0.821	9.490x10	99.0	strong

^(a) PGB = productivity of grain of bean, OM = organic matter, P = phosphorus, pH = potential Hydrogen; ^(b) exp = exponential, gau = gaussian and sph = spherical; model succeeded by number in brackets, meaning the number of pairs in the first lag; ^(c) SQD = sum of squares deviations; ^(d) SDE = spatial dependency evaluator.

Figure 1. Components geostatistical productivity bean (PGB), phosphorus (P) and the hydrogen potential (pH) of a Typic Acrustox under no-tillage in Selvíria, MS, Brazil.

Figure 2. Components geostatistical productivity bean (PGB) as a function of P2, P3 and pH1 a Typic Acrustox under no-tillage in Selvíria, MS, Brazil.

Conclusions

In relation to the spatiality in the no-tillage system, grain productivity of bean could be estimated by means of the co-kriging with the value of P and the pH of the soil. Thus, pH values in the range of 5.0-5.4 indicated sites with the highest productivity from bean grains, established between 2,160-2,665 kg ha⁻¹, as well as between 24-26 mg dm⁻³ P.

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