

SITE SPECIFIC SOIL FERTILITY MANAGEMENT OF AN OXISOL CULTIVATED WITH CORN FOR APPLICATION OF LIME AND GYPSUM

A. M. Coelho¹, G. J. de O. Lima², T. F. Cunha²

¹Embrapa Maize and Sorghum Research Institute, Sete Lagoas- MG, Brazil,
e-mail: amcoelho@cnpmc.embrapa.br, phone +55-31-3027-1145, fax +55-31- 3027-1188

²Campo Agricultural and Environmental Analyses, Paracatu-MG, Brazil,
e-mail: ap@campanalises.com.br, phone +55-38-3671-1164

Abstract

Due to the necessity to improve soil fertility diagnostic, the researchers have been searched for more efficient technologies on agronomic, economic and environmental aspects. One of these technologies is the use of the concept of site-specific for soil fertility management. This research was conducted in a farm field (100 ha) located in Corinto, Minas Gerais state, starting in the 2007-2008 growing season. The soil is classified as Clay Oxisol, cropped with corn (*Zea mays* L.) and irrigated with a center-pivot sprinkler irrigation system. Grid cell of 1 ha was used for collecting soil samples from 0 to 20 cm and 20 to 40 cm depths. Data of pH, Al³⁺, Ca²⁺, Mg²⁺, CEC, base saturation (BS), Al³⁺ saturation in the CEC at soil pH (effective CEC) and organic matter were submitted to geostatistical analysis and interpolated by point-kriging using the modeled semi-variograms. Based on the maps of BS and Al³⁺ saturation, it was possible to define zones of management for application of lime and gypsum. The threshold used to the definition of the rates of lime was 60 % of BS in the top of 20 cm. The criteria based on values of Ca (<0.5 cmol_c dm⁻³) and Al³⁺ saturation (>25 %) in the subsoil (20 to 40 cm) were used for gypsum application. With these informations, maps of application of lime and gypsum at variable rate were generated. The rates of lime range from 0 to 3 t ha⁻¹ and for gypsum of 0 and 1 t ha⁻¹. The costs of soil sampling with GPS, soil chemical analyses, field mapping with GIS and application of lime and gypsum, were evaluated. Allocating the cost of site-specific soil acidity management, over a useful lifetime of four years, the cost of the technological package, US\$ 18.40 per hectare, become economically feasible.

Keywords: soil acidity, spatial variability, variable rate, economic aspects, *Zea mays* L.

Introduction

Soil analysis should be the basis for all programs of soil fertility evaluation and the building of a nutrient management plan. It can be complemented by other techniques, but it is the only one

that efficiently, on a routine basis, makes it possible to anticipate the existing soil constraint for the growth and development of plants. In general, the current soil tests performed in the laboratories in Brazil, are both precise and accurate in determining the nutrient supplying power of the soil that is being analyzed. Most states also have certification programs that ensure that the laboratories are performing the correct test and are proficient in the exact procedure (Cantarella, 1999). However, the greatest difficulty for soil fertility evaluation is collecting the right soil samples to test and that represents the area sampled. Also, soil sampling has often been described as the weak link in soil testing. Thus, there is the necessity to improve soil fertility diagnostic, and the researchers have been searched for more efficient technologies on agronomic, economic and environmental aspects.

One of these technologies is the use of the concept of site-specific for soil fertility management. It is based on information about spatial variability of soil attributes and involve customize management of fertilizer and soil amendments (lime and gypsum), in sub-regions of a field, in order to reduce soil variability, optimizing productivity and profitability (Mulla and Hernández, 2006; Coelho, 2008a). The aim of precision farming research is to help farmers optimize the management of their fields so that gross returns are maximized for each management area. To do this, the farmer needs to know how the conditions for growing crops vary over the area of interest. The objective of this research was to identify the spatial variability of soil fertility, with emphasis in the soil acidity, to define management zones for application of lime and gypsum at variable rate, in an Oxisol cropped with corn. Also, the profitability was evaluated to obtain the balance cost of soil sampling with the value of information.

Materials and Methods

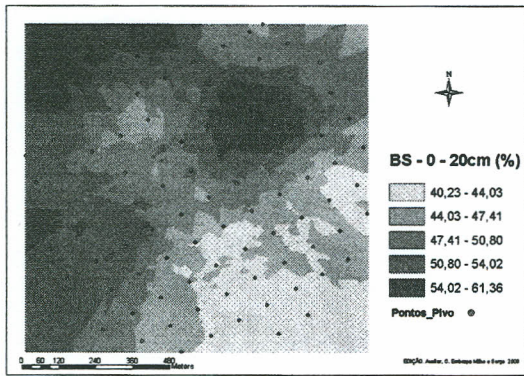
This research was conducted in a farm field (100 ha) located in Corinto (18° 13'S, 44° 36'W, 550 m above sea level), Minas Gerais state, starting in the 2007-2008 growing season. The soil is classified as Clay Oxisol (47 % of clay), cropped with corn and irrigated with a center-pivot sprinkler irrigation system. A georeferenced grid cell of 1 ha, was used for collecting soil samples from 0 to 20 cm and 20 to 40 cm depths. Five soil cores were randomly collected within a 5-m radius of the grid-line intersection (node) and composited as one soil sample. Soil test analyses were carried out according to methodology described by Embrapa (1997). Data of pH, Al³⁺, Ca²⁺, Mg²⁺, CEC, percent base saturation (BS), percent Al³⁺ saturation in the CEC at soil pH (effective CEC) and organic matter were submitted to geostatistical analysis, as described by Isaaks and Srivastava (1989), and interpolated by point-kriging using the modeled semi-variograms. Based on the maps of BS and Al³⁺ saturation, it was possible to define zones

of management for application of lime and gypsum. The threshold used to the definition of the rates of lime was 60 % of BS in the top of 20 cm. The criteria based on values of Ca ($<0.5 \text{ cmol}_c \text{ dm}^{-3}$) and Al^{3+} saturation ($>25 \%$) in the subsoil (20 to 40 cm) were used for gypsum application. The calculation of the rates of lime to bring soil BS to 60 %, was based on the following equation: $\text{RL}_{100} = [(60 - \text{BS}) * \text{CEC} / 100]$. Where, RL_{100} is the rate of lime with the effective calcium carbonate rating of 100 %. The rates of gypsum were based on clay content, according to Alvarez V, et al (1999). With these informations, maps of application of lime and gypsum at variable rate were generated. Based on these maps, lime and gypsum were applied at variable rates, on the soil surface, using a commercial spreader applicator. The costs of soil sampling with GPS, soil chemical analyses, field mapping with GIS and application of lime and gypsum at variable rate, are evaluated.

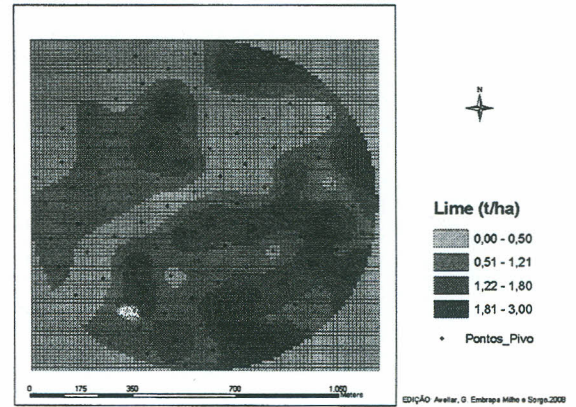
Results and Discussion

Since this study is ongoing, a complete analysis of site-specific soil fertility management is not yet possible. However, the observed spatial variability in the corn crop yield and nutrient levels has important implications for both variable and constant rate fertilizer and soil amendment (lime and gypsum) applications. The site in this study show large spatial variability in the soil attributes used as indicators of the soil acidity (Figure 1ac). In the topsoil (20 cm), spatial patterns in kriged BS (Figure 1a) show values ranging from about 40-60 % in a 100-ha field. The BS is approaching the deficiency in part southwest of the field ($< 50 \%$), yet is plentiful ($\text{BS} > 50 \%$) in parts northwest and southeast of the field. This variability (Figure 1a) afford the opportunity to differential application of limestone and the modern technology of precision farming. The spatial scale makes it feasible technologically. According to National Research Council (1997), soil variation is of interest when conditions vary over patches manageable by agricultural machinery.

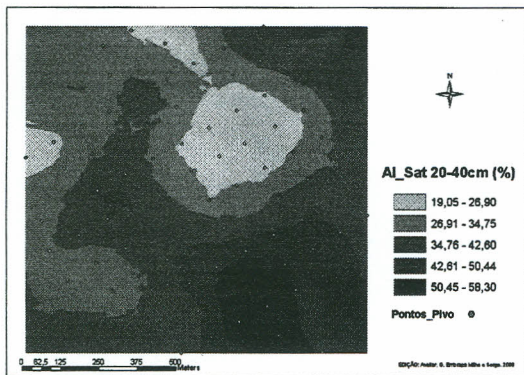
Based on map of BS (Figure 1a), four management zones were established for limestone application (Figure 1b): zone 1 - 0.0 t ha^{-1} , representing 27 ha; zone 2 - 0.3 to $<1.0 \text{ t ha}^{-1}$, representing 21 ha; zone 3 - 1.0 to $<2.0 \text{ t ha}^{-1}$, representing 38 ha and; zone 4 - 2.0 to 3.0 t ha^{-1} , representing 13 ha. Field-averaged soil test for BS was $49 \pm 10 \%$. For corn crop, the values of BS of 50 to 60 % are recommended (Coelho, 2008b). If the field is to be uniformly liming at a single rate to bring BS to 60 %, according to recommendation for corn, there is a necessity of 1.0 t ha^{-1} of limestone. Although the total consumption of the limestone (99 t), is similar for both, uniform and variable rate application, the large variability in the soil acidity, justify the use of variable rate technology.



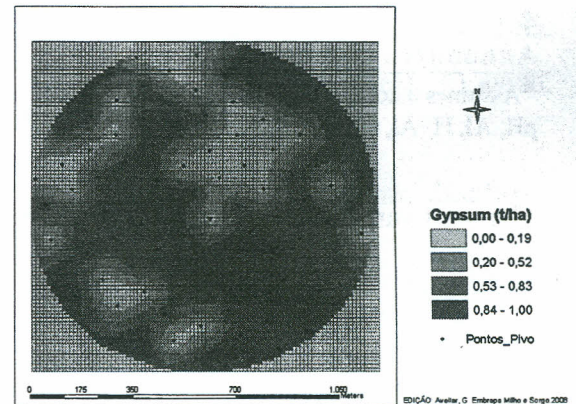
a) Map of base saturation 0-20 cm depth



b) Map of lime application



c) Map of Al³⁺ saturation 20-40 cm depth



d) Map of gypsum application

Figure 1: Interpolated maps of base saturation (a); lime application (b); aluminum saturation (c) and, gypsum application (d).

For Al³⁺ saturation in the CEC at soil pH, the values in the soil surface range from 0 to 35 % (data not showed). The subsoil (20 - 40 cm) presented high acidity, with values of Al³⁺ saturation ranging from 20 to 58 % in almost all field (Figure 1c). Thus, according to criteria for gypsum recommendation, in 70 ha of the field, there is the opportunity for gypsum application at maximum rate of the 1.0 t ha⁻¹ (Figure 1d). Research reported by Prado (2001) showed for some corn hybrids, that grain yield was reduced by 47 % in an oxisol with Al³⁺ saturation of 23 % in the topsoil (0-20 cm). The results presented and discussed here, show that the conventional approach to soil testing, based on average, was inadequate for characterizing spatial variation of soil acidity. However, only the economic conspire against it, because of the need to analysis the soil for nutrients at least 99 points at two depths, and the cost of that in any one year could be more than the farmer can expect to gain in greater efficiency. In the Table 1, are showing the annual costs for application of lime and gypsum at variable rate for a 100-hectare field.

Table 1: Annual information costs for application of lime and gypsum at variable rate for a 100 hectare field, with a 4-year soil sampling cycle.

Activities	Price (US\$/ha)	Amount (US\$)	%
Soil sampling labor 0-20 cm depth(1ha grid)	5.00	500.00	8.42
Soil sampling labor 20-40 cm depth (1ha grid)	5.00	500.00	8.42
Soil test lab analyses (198 samples) ^{1/}	10.00	1,980.00	33.35
Constructing soil test results maps with GIS	4.00	400.00	6.74
Lime application (72 ha)	18.00	1,296.00	21.83
Gypsum application (70 ha)	18.00	1,260.00	21.23
Total variable cost		5,936.00	100.00
Cost of capital (discount rate 6 % a.a.)		356.16	
Depreciation (4 years)		1,484.00	
Annualized cost for 100-hectare field		1,840.16	
Annualized cost per hectare		18.40	

^{1/}Assumes a composite sample for each hectare. Cost of soil test lab analyses US\$10,00 per sample for analyses of pH, Al, H+Al, Ca, Mg, P, K and organic matter.

The total variable cost (Table 1), for grid soil sampling, laboratory analyses, building soil maps and, application of lime and gypsum for 100 ha field was US\$ 5,936.00, which represent a cost of the US\$ 59.36 ha⁻¹. However, according to National Research Council (1997), the information gained from sampling and mapping soil phosphorus, potassium and, soil acidity, is often used for three to five years, allowing sampling and analysis cost to be amortized over several growing seasons. Thus, allocating the cost of soil acidity management over a useful lifetime of four years, the cost of this technological package become relatively reasonable, US\$ 18.40 ha⁻¹ (Table 1). It is important to remember that this cost was obtained for an intensive grid soil sampling of 1 ha and, collecting samples from two depths. According to Hennessy *et al.* (1996), optimal sampling depends on trade-offs between potential savings in input expenditures, potential gains from increased yields due to improved management, and sampling costs.

Conclusions

The conventional approach to soil testing, based on averages, was inadequate for characterizing spatial variation of soil acidity. Intensive grid sampling conducted for precision farming studies showed that the indicators of the soil acidity levels within field are variable and can be mapped into management units suitable for variable rate application technology. The annualized cost (US\$ 18.40 per hectare) of intensive grid sampling was economically feasible. Since this study is ongoing, little information is available to describe the long-term effects on soil productivity. Innovative soil fertility manager should consider field heterogeneity as a

potential alternative to conventional strategies and a way to improve fertilizer profitability, particularly if appropriate yield goals and fertilizer recommendation can be developed.

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