VARIABLE RATE APPLICATION OF POTASSIUM FERTILIZER FOR SOYBEAN CROP GROWTH IN A NO-TILL SYSTEM

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ABSTRACT

Variable rate application of fertilizer has the potential to improve nutrient use efficiency, improve economic returns, and reduce negative environmental impacts. The objective of this study was to evaluate the variable rate application of potassium fertilizer to soybean crop in a no-till system. The study was conducted on a 13-ha soybean grain field in Carambeí, State of Paraná, Brazil in a Typic Hapludox. The area has been under no-tillage for more than 10 years growing grains (soybean, wheat and maize) in rotation with a cover crop (oat). Four treatments were used: control, 40, 80 and 120 kg ha^{-1} of K_2O applied as KCl. Narrow strip plots of 18 X 1,000 m were assigned in three blocks within the 13-ha field. In each strip plot grain yield was continuously evaluated at the harvest time with a combine equipped with yield monitoring and a real-time global positioning system unit (GPS) without differential correction. Data storage in geographical information system (GIS) was used to fit the kriged yield map. Soybean average yield was 3,838 kg ha^{-1}, and spatial differences in yield were observed with grain yields ranging form 2,100 to 6,583 kg ha^{-1}. These differences occurred where previous analysis showed soil texture variation. Maps of K exportation by grains indicated that the uniform rate fertilizer would not replace adequately the K fertilizer. These results showed that the recommendation map for variable rate of potassium fertilization can be accomplished by the yield maps from the past years. These results showed that VRT of potassium for this plot could be performed based on yield maps, and it could be used in reducing yield variability and maintaining profitability while optimizing K applications.

Keywords: spatial variation, Oxisol, no-tillage, soybean, potassium.

INTRODUCTION

Soybean is one of the main crops under no-tillage in Brazil and the succesful cultivation of this crop is also due to intensive research on soil chemistry, soil microbiology and soil fertility management. Providing an adequate supply of potassium is important for soybean production and is essential to maintain high quality and profitable yields (Tanaka et al. 1993) since high-yielding soybean removes large amounts of potassium from the field (Mascarenhas et. al. (1981). Therefore potassium and phosphorus are the most common nutrient input for this crop in the high weathered, low-fertile and acids soils of Brazilian tropical region.

However, soybean yield variation within an area is very common as agricultural fields are managed as uniform units. Previous results from Machado et al. (2002) and Bernardi et al. (2002) in a no-till farm in southern Brazil showed the spatial variability of soil parameters and plant nutrient concentrations and identified that potassium could be one of the main constraints to soybean yield. They confirmed that in the field scale variation in the tropics, soil fertility management without taking account of spatial variation within fields not only directly affects crop yield but also impede accurate protection of the environment.

Precision agriculture assists growers in making precise management decisions for different cropping systems (Koch and Khosla, 2003). According to Bianchi and Malarino (2002) yield monitor maps, differential global positioning system (DGPS) receivers in combines, and a strip-trial methodology can be used to evaluate the effects of VRT or other site-specific management practices (Oyarzabal et al., 1996; Colvin et al., 1997; Mallarino et al., 2001). Treatments may be applied to narrow (usually the width is a multiple of the equipment width used to apply the treatments) and long strips (generally the length of the field), and crops are harvested with combines equipped with yield monitors and DGPS receivers (Bianchi and Malarino, 2002).

Unlike the uniform application of fertilizers and lime, which can result in areas of applications above or below the dose required, the VRT promised to increase productivity and efficiency of nutrient use, while reducing the potential for environmental pollution (Robert, 1993, Mulla et al., 1992; Bongiovanni and Lowenberg-Deboer, 2004; Mulla and Schepers, 1997; Wollenhaupt et al., 1994).

Bongiovanni and Lowenberg-Deboer (2004), in an extensive literature review confirmed that the VRT can contribute to maintaining the sustainability of agriculture by applying fertilizer only at locations where and when the need arises. The benefits of precision agriculture in this application is accurate points and reducing losses due to excessive application of fertilizers. A major weakness identified by the authors was that few studies actually measured levels of environmental impact or used sensors, and most of the estimated environmental benefits indirectly, ie by measuring the reduced use of inputs.

Production increases and reductions in fertilizer use associated with the practice of variable rates of nitrogen, phosphorus, and potassium have been reported for irrigated sorghum (Yang et al., 1999). In wheat and oats variable rates of P, K and N did not result in significant increases in productivity (Carr et al., 1991) or lower costs (Wibawa et al., 1993) when compared to uniform rates of application. Mallarino et al. (1999) found that variable rates of P sometimes helped reduce the total P applied, but rarely resulted in higher yields of corn or soybeans, even in areas with low levels of P in soil. Loweenberg and Aghib-Deboer (1999) observed that the varying rates of K helped to improve the distribution of fertilizers in the field, but did not provide positive economic balance in wheat, corn and soybeans. Wang et al. (2001) found that the rice yield increased from 5900 to 6400kg ha^{-1}, whereas the absorption of N, P and K increased from 8 to 14%, and agronomic efficiency of nitrogen use was 80% higher with site specific management.

The conflicting results with application to variable rates seen in the results described in the literature may be due to factors such as the discrepancy between the regional fertilizer recommendations and requirements for this new approach, lack of measurement of other factors limiting productivity as soil moisture, water stress, and other environmental factors, inadequate sampling strategies (Carr et al., 1991; Mallarino et al., 1999, Pierce and Warncke, 2000). Assessing the variable rates of fertilizer application, Swinton and Lowenberg-DeBoer (1998) concluded that this practice was economically viable for crops of high economic return. The main factor for these economic results was the high cost of sampling compared to the income provided by culture.

The objective of this study was to evaluate the variable rate application of potassium fertilizer to soybean crop in a no-till system in Brazil.

MATERIAL AND METHODS

The study site was located on a 12.5-ha soybean field in Carambeí, State of Paraná, Brazil (24º 51 45´´S, 50º 15´58´´W, 870 ASL). The climate is Cfb (Köppen) with mean annual temperature of 17.6º C and mean annual precipitation of 1560 mm, falling mostly in summer. The deep, well-drained soil is classified as a clayey, kaolinitic Typic Hapludox (Soil Taxonomy) and as Latosssolo Vermelho distroférrico in the Brazilian Soil Classification System (Bognola et al. (2004). Soil chemical properties of the study site were described by Machado et al. (2002).

Soybean was cultivated in rotation with wheat and black oat in winter, and after 2 summer growing seasons, with maize. No-tillage system has been used on this field since 1983. At the sowing time the soil was fertilized with 62.5 kg P_2O_5 ha^{-1}. No nitrogen fertilizer was applied as soybean seeds were inoculated with N_2-fixing bacteria *Bradyrhizobium* spp. Four treatments were used: control, 40, 80 and 120 kg ha^{-1} of K_2O applied as KCl at V2 growth stage of soybean (Figure 1). Broadcast fertilization treatments were applied to a 18 X 1,0000 m narrow strips

(Figure 2), respectively corresponding to a 2-times the equipment work area width used to apply the potassium fertilizer and to the length of the field.

Figure 1: Potassium broadcast fertilization at V2 soybean growth stage at studied area. Photo by A.C.C. Bernardi

At harvest time grain yield was continuously evaluated using a combine equipped with a yield monitor and real-time global positioning system unit (GPS) without differential correction. In each strip plot soybean grain yield was measured (Figure 3) using the Massey Fergusson Fieldstar system. The yield at each grid node was based on average yield (after checking for artifacts) over an area of 2 m^2 around the node. Potassium exportation were calculated based on Tanaka et al. (1993), considering that one ton of soybeans exported 18.7 kg K (or 22,5 kg of K_2O). Balance of potassium fertilization was calculated as: K_2O applied – K_2O exported.

Data were storage in geographical information system (GIS) used to fit the kriged yield, K exportation and K balance maps (Arch GIS - ESRI, Inc., Redlands, CA).

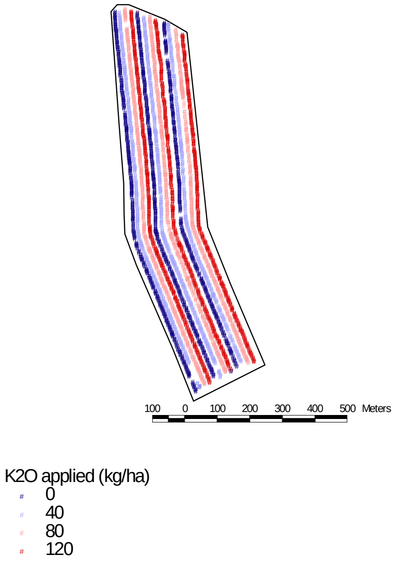

Figure 2: Potassium levels applied to soybean in study area.

Figure 3: Soybean harvest of fertilized narrow strips. Photo by P.L.O.A. Machado.

RESULTS AND DISCUSSION

The average content of K determined by Machado et al. (2002) at the 0-5, 5-10, and 10-20 cm depth are the Figure 4. These values were considered medium to high. Thus, the originally existing exchangeable K levels in soil was probably were sufficient to meet the nutritional requirements of the crop.

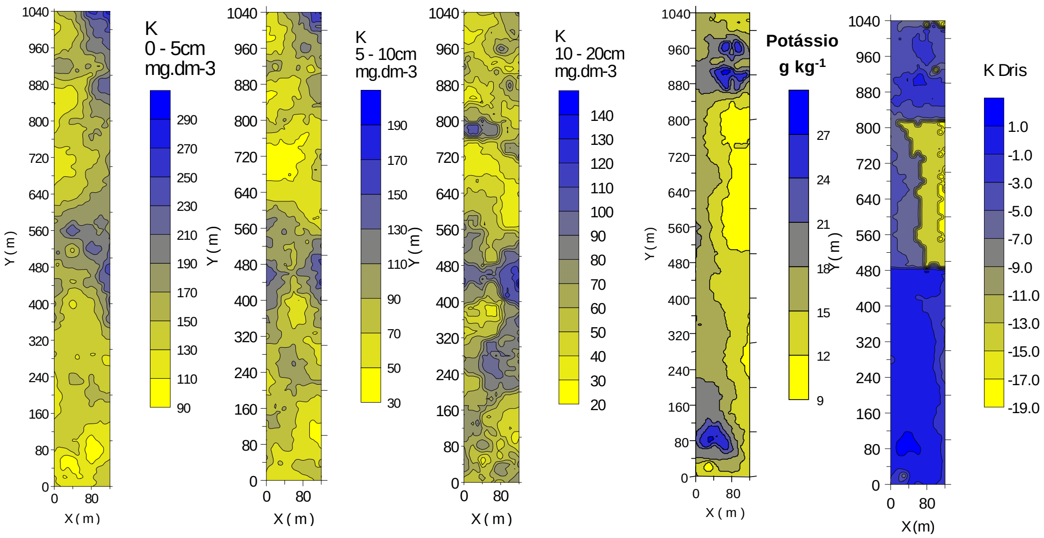

Figure 4: Kriged maps of soil exchangeable soil K at 0-5, 5-10 and 10-20 cm and K content in soybean leaves and DRIS indexes. Adapted form Bernardi et al. (2002) and Machado et al. (2002).

The average yield for the stand of the crop rated 3,838 kg ha^{-1}. From the data collected and stored in GIS was selected the sampling points located in each of the tracks and treatments, and then performed the calculation of income. Table 1 shows the performance data for the tracks. The results showed no response to potassium fertilizer application at tested doses

These results confirm the findings of previous studies in which there were increases in soyabean yield, even in soils with low levels of exchangeable K over successive crops (Mascarenhas et al. 1981, Palhano et al., 1983, Rosolem et al. 1988, Borkert et al. 1997a, Borkert et al. 1997b). In this sense, Rosolem et al. (1988) concluded that in addition to exchangeable potassium, there are other forms of K in the soil that can be released during the crop cycle, as the non-exchangeableK.

Table 1. Soybean yield according to the doses of potassium fertilizers used.

Repetition	**Treatments (kg ha^{-1} de K_2O)**				**Average**
	Control	**40**	**80**	**120**	
A	3863	3816	3780	3900	3832
B	3739	3907	3856	3857	3873
C	3831	3863	3826	3822	3837
Average	3811	3862	3821	3860	3838

Yield results are presented in Figure 5, which illustrates the levels of potassium fertilizer as a function of distances from the plot. Results indicate that there were values below the overall average yield (3,838 kg ha^{-1}) at the beginning of the plot and above average on the end of it. This is an indicating of spatial variation of results, which must be a function of textural differences observed during this study plot by Machado et al. (2006). The authors examined spatial variability of soil clay content for this same field at 0-20 cm depth, average clay contents ranged from 612 to 667 g kg^{-1} in Zone A, and from 362 to 442 g kg^{-1} in Zone B. The authors also related soil EC with soil clay content, and showed that EC map adequately reflected the spatial variation in soil texture for establishing the limits of management zones. Two management zones were established for this study area (Figure 6) according to Luchiari et al. (2000) and Machado et al. (2006). Krieged map of soybean yield confirms the tendency of higher yields at more clay soil region (Figure 7).

Other factors besides the content of soil-K or K-fertilization could influence the crop response because the effect of fertilization was reduced, as already showed. Ebehar et al. (2001) also didn’t obtained significant response to K-fertilization of maize and soybean, even with significant increases in nutrients levels in plants.

Just as occurred in the intervention made in the study area, the evaluation of only the fertilizer, as the only limiting factor of crop production, has not explained the observed variations in grain production (Mulla and Schepers, 1997; Everett and Pierce, 1996).

To properly evaluate and implement precision farming practices in order to apply fertilizer at variable rates, more information is needed on other factors affecting the yield, but yield map can be an alternative since it integrates all these factors.

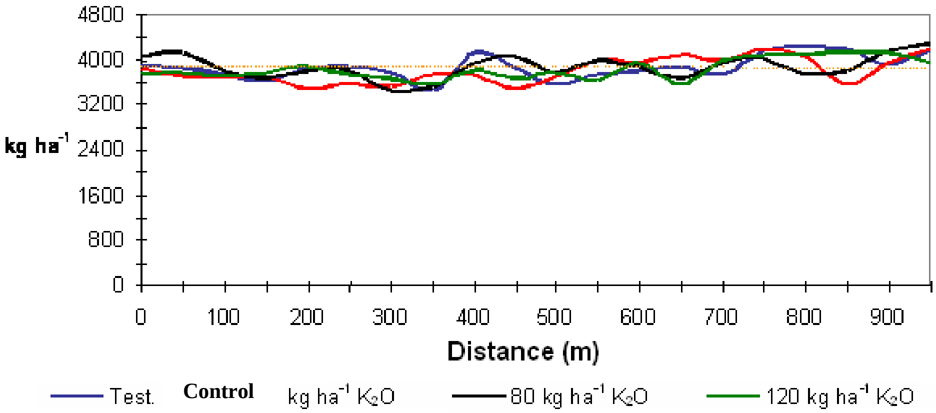

Figure 5. Variation of soybean yield due distances and K levels.

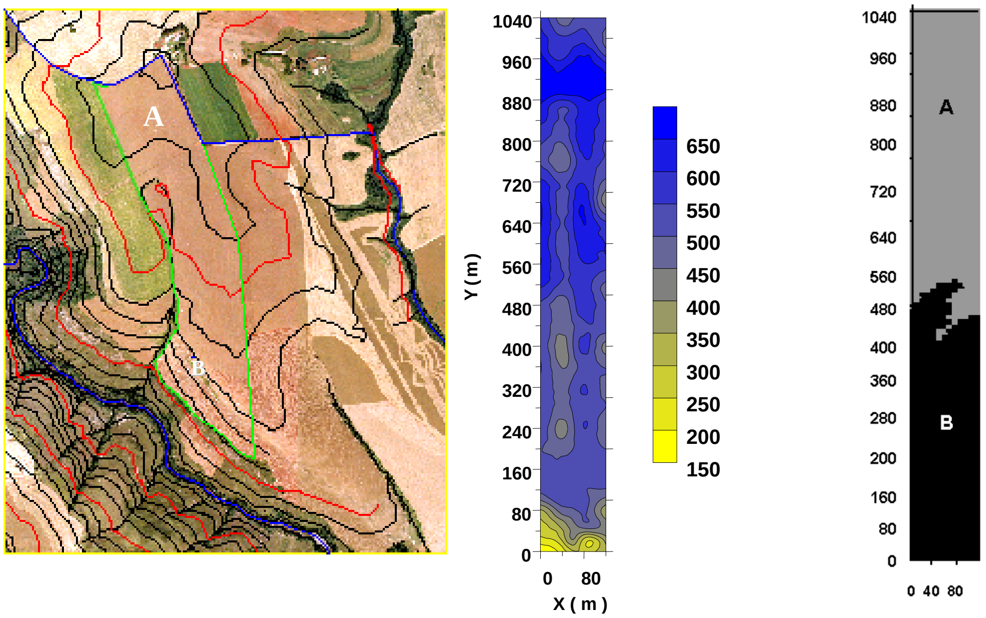

Figure 6. Imaging of the study area and clay area spatial variability, kriged map of clay content (0-50cm layer) and management zones established of studied area. Adapted from Machado et (2006).

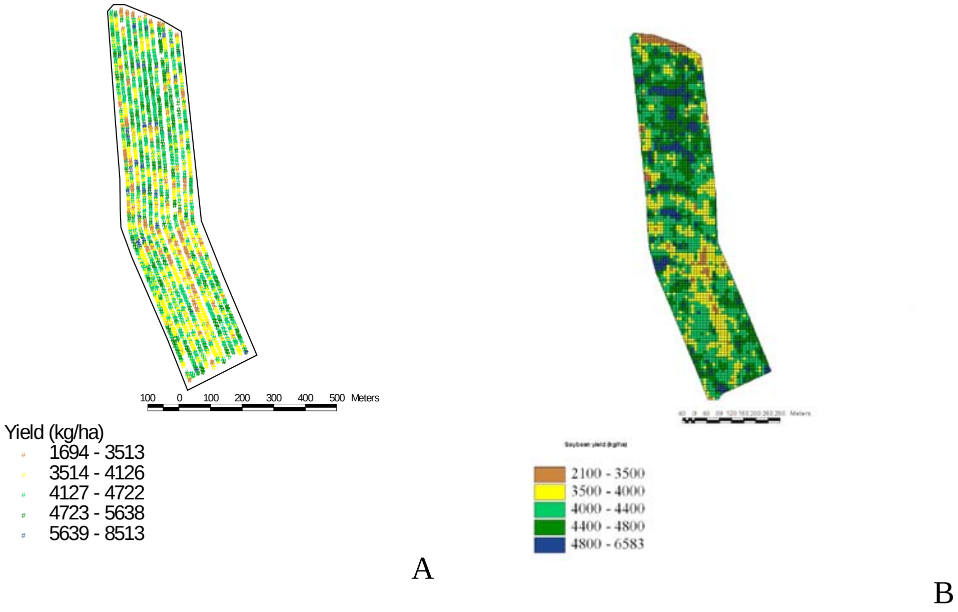

Figure 7. Soybean yield in each narrow strip (A) and kriged yield of yield map (B).

An alternative to the producer would be to use a fertilizer in order to restore the nutrient exported. Thus, considering that one ton of soybeans exported 18.7 kg K (Tanaka et al., 1993), or 22.5 kg of K_2O, Figure 8 showed that exportation o K by soybean grains. If this amount were not properly restored some K mining could occur in this area. The balance of potassium fertilization (K_2O applied – K_2O exported) indicated that a positive balance only could be obtained from 80 to 120 kg of K_2O. The average fertilization used by the producer in this area is 80 kg ha^{-1} de K_2O, that still could lead to a small deficit of potassium supply. These findings are also in agreement with those related by Loweenberg and Aghib-Deboer (1999) that VRT of K improved the fertilizers distribution.

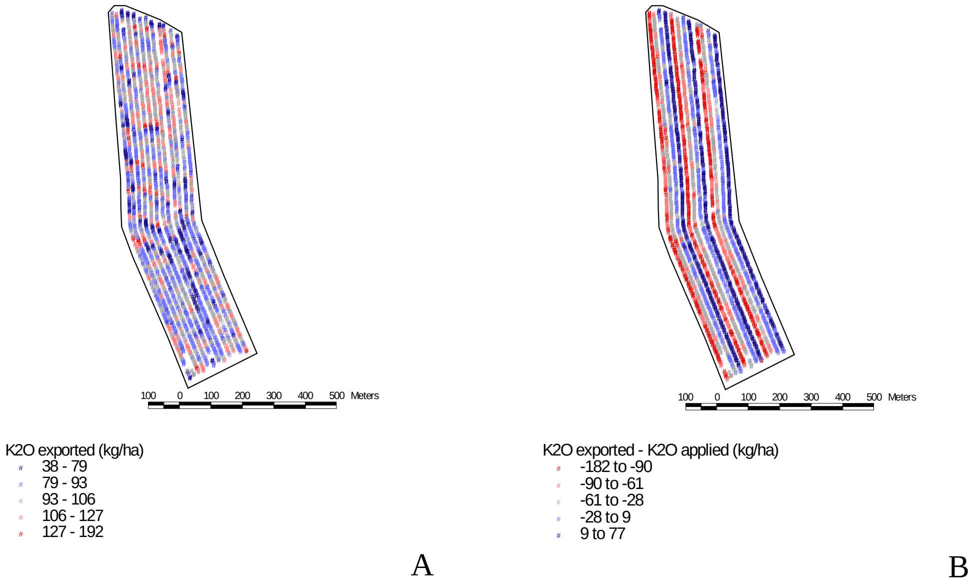

Figure 8. Potassium exportation (A) and balance of potassium fertilization (K_2O applied – K_2O exported)

CONCLUSIONS

These results showed that VRT of potassium for this plot could be performed based on yield maps, and it could be used in reducing yield variability and maintaining profitability while optimizing K applications.

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