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Variable-Rate Application (VRA) of Potassium Fertilization for Soybean in Brazil

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Introduction

Potassium (K) and phosphorus (P) are the two most common nutrient inputs in the cultivation of soybean crop on the highly weathered, low-fertile and acid soils of tropical Brazil. Supplying adequate K is essential to maintain high quality and profitable yields (Tanaka *et al.*, 1993). Not only does soybean have a high K requirement for growth but large amounts of K are also removed from the field when harvesting high-yielding soybean crops (Mascarenhas *et al.*, 1981).

Soybean yield variation within a given area is very common as agricultural fields are managed as uniform units. Previous results from Bernardi *et al.* (2002) in a no-till farm in southern Brazil illustrated this variation within a commercial soybean crop, where yields ranged from 1,800 to 5,300 kg ha^{-1} over the same area that had been managed uniformly (Fig. 1). This evidence of spatial variation of yield must be regarded as a function of textural differences of the soil, as reported in a study of the same plot by Machado *et al.* (2006). In this work the authors examined spatial variability of soil clay content 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 which, according to Luchiari *et al.* (2000) and Machado *et al.* (2006), established the limits of the two management zones in this study (Fig. 2). The authors also related soil electric conductivity (EC) with soil clay content, and showed that an EC map adequately reflected the spatial variation in soil texture of the two management zones.

Study of the VRA of K

With the objective of detailing the spatial variability observed in this area, Machado *et al.* (2002) and Bernardi *et al.* (2002) studied how soil parameters and plant nutrient concentrations also varied within the commercial area. The average content of K determined by Machado *et al.* (2002) at the 0-5, 5-10, and 10-20 cm depth were considered medium to high (Fig. 3). Thus, the original existing exchangeable K levels in the soil were probably sufficient to meet the nutritional requirements of the crop.

Nevertheless, foliar diagnosis highlighted many regions with K levels below the adequate range for soybean (17 to 25 g kg^{-1}) under southern Brazilian growth conditions (Sfredo *et al.*, 1986; Fig. 4). These workers identified K as one of the main potential constraints to soybean yield. Their findings also indicated that soil fertility management has to take spatial variation within fields into account, not only because of a direct affect on crop yield but also for accurate protection of the environment. This is because the

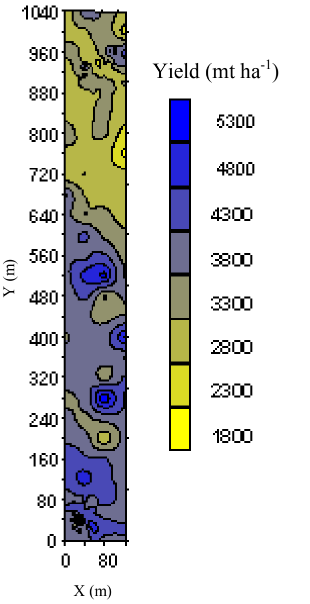

Fig. 1. Map of spatial variability of soybean yield in a no-till system in southern Brazil. *Source*: Bernardi *et al.*, 2002.

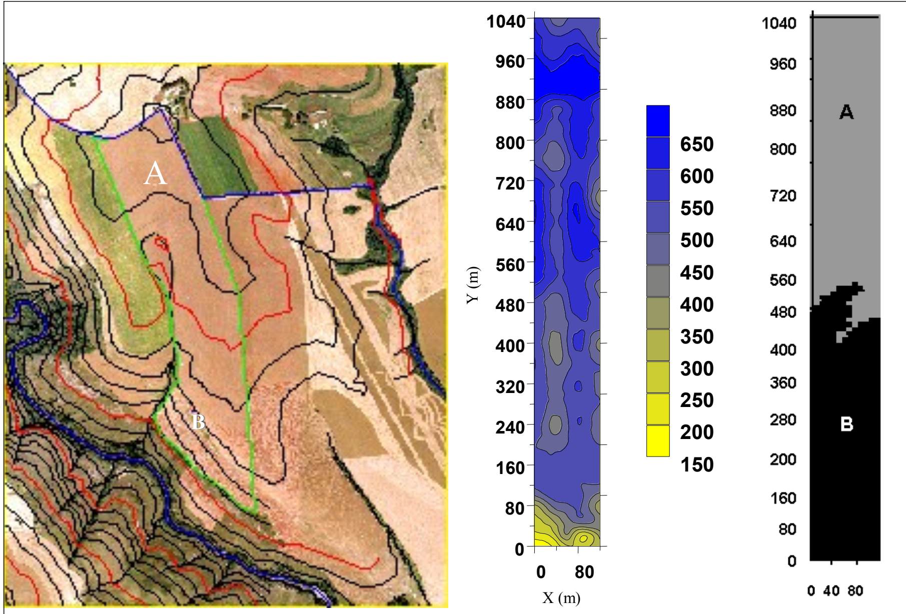

Fig. 2. Imaging of the study area and clay area spatial variability, kriged map of clay content (0-50 cm layer) and management zones. A = 612 to 667 g kg^{-1} of clay content; B = 362 to 442 g kg^{-1} of clay content. Adapted from Machado *et al.* (2006).

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uniform application of fertilizers and lime in areas with spatial variation in soil properties could result in points of fertilizer application above or below the required doses. The alternative, or control of the observed variability, could be a variable rate application (VRA) of nutrient supply.

Bongiovanni and Lowenberg-Deboer (2004), in an extensive literature review confirmed that VRA can contribute to maintaining agricultural sustainability by applying fertilizer only at locations where and when the need arises. The benefit of precision agriculture in this application is the usage of detailed data point (e.g. soil analysis) mapping which reduces losses caused by 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 were indirect, i.e. measuring the reduced use of inputs.

Since VRA of fertilizer has the potential to improve nutrient use efficiency, improve economic returns, and reduce negative environmental impacts (in the case of N and P fertilizers), Bernardi *et al.* (2010) evaluated the VRA of K fertilizer to the 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 (oats). Four treatments were used: control, 40, 80 and 120 kg ha^{-1} of K_2O applied as KCl at the V2 growth stage of soybean. Narrow strip plots of 18 x 1,000 m (Fig. 5 and 6) were assigned to three blocks within the field. In each strip, plot grain yield was continuously evaluated at harvest time with a combine equipped with yield monitoring and a real-time global positioning system (GPS) unit without differential correction. Data storage in a geographical information system (GIS) was used to fit the kriged yield map.

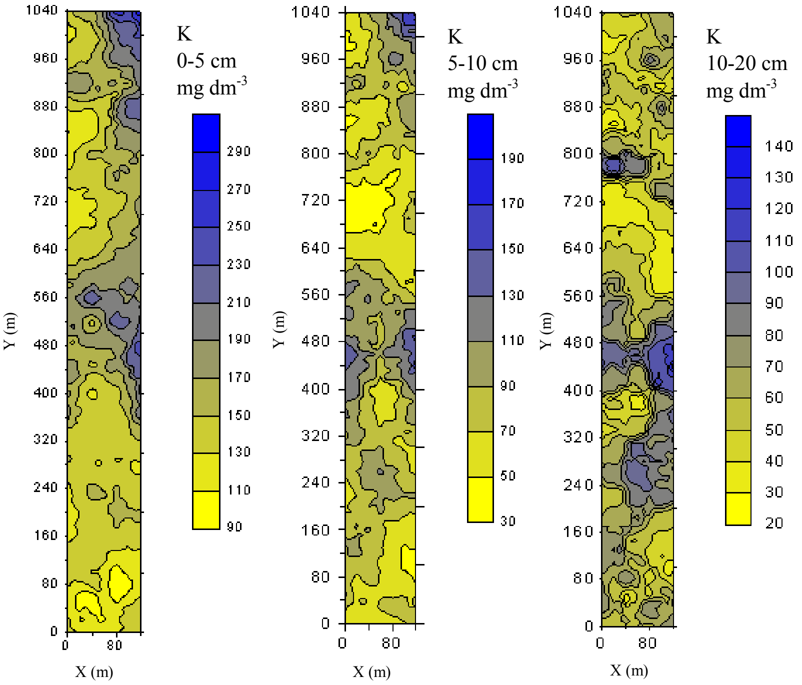

Fig. 3. Maps of spatial variability of soil exchangeable K in a soybean crop growth in a no-till system in southern Brazil. *Source*: Machado *et al.*, 2002.

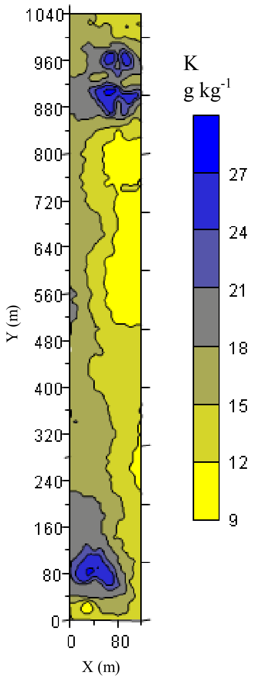

Fig. 4. Spatial variability of leaf K in a no-till soybean crop in southern Brazil. *Source*: Bernardi *et al.*, 2002.

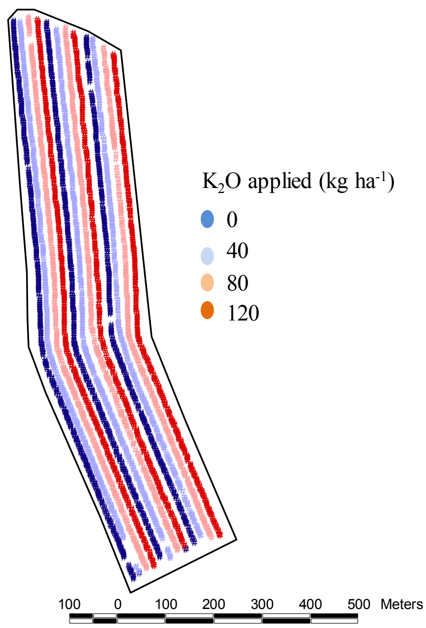

Fig. 5. K levels applied to soybean in a no-till soybean crop in southern Brazil.

Yield results (Bernardi *et al.*, 2010) are presented in Fig. 6, which illustrate the levels of K fertilizer as a function of distance from the plot and the kriged map of soybean yield. Soybean average yield was 3,838 kg ha^{-1}, and spatial differences in yield were observed with

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grain yields ranging from 2,100 to 6,583 kg ha^{-1}. These differences occurred where Machado *et al.* (2006) had shown soil texture variation. The results indicated no response to K fertilizer application at the tested doses.

These results confirm the findings of previous studies in which there were increases in soybean 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). From these findings, Rosolem *et al.* (1988) concluded that in addition to exchangeable K, there are other forms of K in the soil that can be released during the crop cycle, including non-exchangeable K.

According to Bernardi *et al.* (2010), an alternative for the producer would be to apply fertilizer in amounts to restore nutrients exported at harvest. In this respect, harvesting one tonne of soybean removes 18.7 kg K (Tanaka *et al.*, 1993), or 22.5 kg of K_2O from the soil. The results given in Fig. 7, showing exportation of K by soybean grains, have to be considered in relation to these values. If the amount of K removed at harvest was not properly restored, some K mining would be expected to occur. The balance of K fertilization (K_2O applied - K_2O exported) indicates that a positive balance can only be achieved by supplying 80 to 120 kg of K_2O ha^{-1}. The average fertilization (80 kg K_2O ha^{-1}) used by the producer in this area could still lead to a small deficit of K supply. These findings are also in agreement with those reported by Bongiovanni and Lowenberg-Deboer (2004), that VRA of K improved fertilizer distribution.

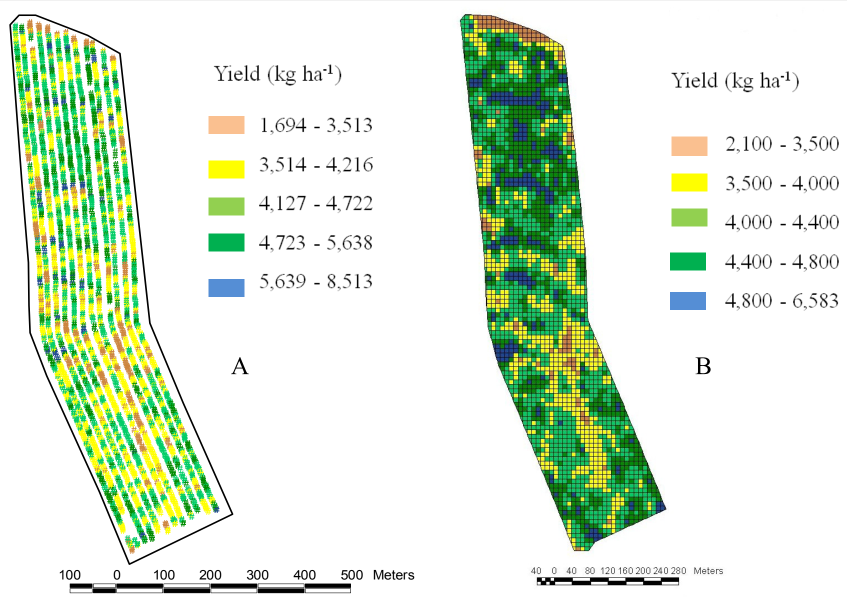

Fig. 6. Soybean yield in each narrow strip (A) and kriged yield of yield map (B). *Source*: Bernardi *et al.*, 2010.

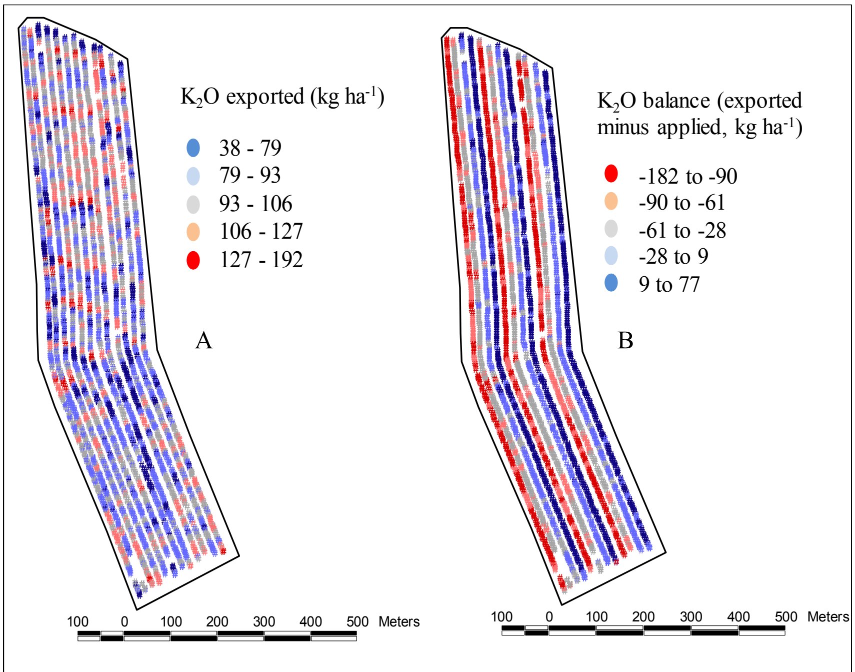

Fig 7. K exportation (A) and balance of K fertilization (B) (K_2O applied - K_2O exported). *Source*: Bernardi *et al.*, 2010.

Conclusions

These results showed that the recommended map for variable rate of K fertilization can be accomplished by using yield maps from previous years. With this information, VRA of K for this plot could be performed, and used to reduce yield variability and maintain profitability while optimizing K applications.

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