RELATIVE EFFICIENCY OF DIFFERENT SOURCES OF POTASSIUM IN THE FERTILIZATION OF CROP SYTEM PEAR MILLET AND SOYBEAN

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Abstract

In 2008, the consumption of potassium (K) fertilizer in the Brazilian agriculture was seven million tons, of which 92 % was imported, representing a cost of US$ 5 billion. The objective of this study was to evaluate the efficiency of different sources of potassium in the fertilization of pearl millet (as cover crop) and soybean. Field experiments were conducted at the Embrapa Maize and Sorghum, Sete Lagoas, Minas Gerais state, in the 2006/2007 and 2007/2008 growing seasons, on a Dystroferric Red Latosol (clayey Oxisol), cultivated with pasture of brachiaria and had Mehlich1 extractable K concentration of 40 mg dm^{-3} in the top 20 cm. Pear millet (*Pennisetum glaucum*) was sown in September over the residues of brachiaria, and Soybean (*Glycine max*) was sown in the first week of December, in the two growing seasons. The treatments consisted of three sources of K (Potassium Chloride-KCl, Rock-Biotite schist, and Byproduct-RMS) and four rates (0, 75, 150 and 300 kg K_2O ha^{-1}), applied in the first year, broadcast on the soil surface and incorporated into the soil at 10 cm depth. The rock-Biotite schist occurs naturally in Minas Gerais state and, when crushed present gray color, with 5.0 % of total K insoluble in water. The RMS is a byproduct of the manganese extraction industry, presenting brown color, with 10.0 % of total K soluble in water. The experiment was in random blocks, using a split plot design with three replications. Pearl millet dry matter yield and soybean grain yield were significantly affected by sources and rates of K. Pearl millet and soybean presented greatest response to K fertilization rates of 150 and 300 kg K_2O ha^{-1}, respectively. The byproduct-RMS, when applied at equivalent rates, is almost as effective as KCl and both were superior to Biotite shist for pear millet and soybean production. Our hypothesis that the crop sequence pearl millet/cover crop-soybean could improve the efficiency of the less soluble source of K was not confirmed in this research.

Keywords : sources potassium, natural rock, byproduct, *Pennisetum glaucum, Glycine max.*

Introduction

Potassium (K) requirement of crops is greater than requirements for all other nutrients except nitrogen (N). Whereas biological N fixation provides significant N imputs to terrestrial ecosystems, there are no renewable sources of K in the biogeo-chemical cycle. Crop K uptake is therefore solely derived from existing soil reserves, recycled K in crop residues, and applied K fertilizer (Cassman, 1996). Because the native soil K supply is a fixed quantity, increased food production will require a large proportional increase in K fertilizer use. Application rates to soil which is already deficient must increase in proportion to higher yield levels, and, in addition, K application will be required in many areas where soils do not presently require K inputs to achieve the current yield levels.

The high K demand by crops contrast with the concentrations, in general insufficient, that occur in Brazilian soils (Coelho, 2005). This fact, associated the astounding growth of the Brazilian agricultural production in the past few years, has lead to a great increase in K fertilizers consumption (Nachtigall and Raij, 2005). In 2008, the consumption of potassium fertilizer in the Brazilian agriculture was seven million tons, of which 92 % was imported, representing a cost of US$ 5 billion. These data justify the implementation of governmental policies aiming to explore the canallite ore reserves in Sergipe state as well as the sylvinite deposits in the Amazon state (Lopes, 2005). In addition to that, they must stimulate research concerning the economical feasibility of potassium silicates and mineral byproducts, abundant all over Brazil, as sources of K fertilizer. The objective of this study was to evaluate the efficiency of alternative sources of potassium in the fertilization of pearl millet (as cover crop) and soybean.

Material and Methods

Field experiments were conducted at the Embrapa Maize and Sorghum, Sete Lagoas, Minas Gerais state, during the 2006-2007 and 2007-2008 growing seasons, on a Dystroferric Red Latosol (clayey Oxisol), cultivated with pasture of brachiaria. Soil test indicated a pH 5.8, organic matter content of 34.5 g dm^{-3}, P-Mehlich1 level at 7.3 mg dm^{-3} and K level at 40 mg dm^{-3} in the top 20 cm. The treatments consisted of three sources of potassium (Potassium Chloride-KCl, Rock-Biotite schist, and Byproduct-RMS) and four rates (0, 75, 150 and 300 kg K_2O ha^{-1}), applied in the first year, broadcast on the soil surface and incorporated into the soil at 10 cm depth. The experiment was in random blocks, using a split plot design with three replications. The main plots were sources of K and the split-plot factor consisted of the rates.

The rock-Biotite schist occurs naturally in Minas Gerais State. Sample of this rock was ground to pass a 2-mm screen and chemically characterized. It presents gray color, 5.0 % of total K insoluble in water. The RMS is a byproduct of the manganese extraction industry, presenting brown color, with a degree of fineness less than 2 mm (10 mesh) and a content of 10.0 % of total K soluble in water. Chemical analysis of both materials indicated that they have low concentrations of CaO and MgO, with low effective calcium carbonate (ECC) rating (Biotite shist: 3.20 % and RMS: 29.33 %). The equivalent rates applied to supply the levels of 75, 150 and 300 kg K_2O ha^{-1} were: Biotite schist 1.5, 3.0, and 6.0 t ha^{-1}; RMS 0.75, 1,5 and 3.0 t ha^{-1} and; KCl (60 % K_2O) 125, 250 and 500 kg ha^{-1}.

Pearl millet (*Pennisetum glaucum*), cultivar 'ADR 300', was sown in 3.5- by 6-m plots in 0.35-m rows at a rate of 10 kg ha^{-1} in September, and fertilized with 30 kg N ha^{-1} plus 90 kg P_2O_5 ha^{-1}. In both years, biomass of pearl millet was determined at bloom stage (50 days after sowing). Before harvest, pearl millet was desiccated with glyphosate at rate of 1.0 -l ha^{-1}. The harvested biomass was weighed in the field and sampled for dry matter determinations. The sample was subsequently dried at 65 °C in a forced draft oven, ground, and then analyzed for total N, P and K.

Fifteen days after pearl millet had been desiccated, soybean (*Glycine max*), cultivar 'Valiosa^{RR}', was sown in the first week of December at 0.35 m row spacing (250 thousand plants per hectare). In the first growing season (2006/07) soybean was not fertilized and the seeds were not inoculated with bacteria for N_2 fixation. In the second growing season (2007/08), soybean was fertilized with 30 -kg N ha^{-1} plus 90 -kg P_2O_5 ha^{-1} and, before planting, the seeds were inoculated with commercial powdered peat based granular *Brady Rhizobium*. Soybean grain yields were determined by hand harvesting six adjacent 5-m long rows (appropriately bordered) and reported based on a moisture content of 130-g kg^{-1}. After each harvest, plant and grain samples were collected and analyzed for total N, P and K. Data were analyzed by conventional analysis of variance procedures for split-plot design, using the PROC GLM of SAS (SAS Inst., 2001). Treatment means were compared by least significant difference ($P \leq 0.05$).

Results and Discussion

Pearl millet production in Brazil has recently been used as a soil improvement, cover crop for on two million ha of no-till production of soybeans (Bonamigo, 1999). In this system, where the pear millet biomass is not removed from the field, and if the soil fertility status is classified as optimum or higher, the application of fertilizers is not recommended (Pereira Filho *et al.*, 2005).

Pear millet dry matter yields responded to alternatives sources (Biotite schist and RMS) and rates of K, compared to KCl (Figure 1). Pear millet dry matter yields ranged from 2.0 to 5.0 t ha^{-1}, with average of 3.48 t ha^{-1}, and large responses to applied K were observed. In the first growing season (2006) the dry matter yield responses showed significant differences ($P \leq$ 0,05) for sources and rates of K application, but the interaction (K sources x rates) was not significant. The maximum dry matter yield was achieved with 75 kg-K_2O ha^{-1} supplied as RMS and KCl, which exhibited statistically similar dry matter, 4.00 and 3.60 t ha^{-1}, respectively. For the Biotite shist a linear response, until 300 kg K_2O ha^{-1}, was observed (Figure 1a). These results agree with the content and solubility of the K previously determined in the sources. For the second year (2007), similar results were observed (Figure 1b). However, for all sources, the maximum dry matter yield was obtained with application of 150 kg K_2O ha^{-1} (Figure 1b) and the production obtained with KCl (5.19 t ha^{-1}) was higher than the one obtained with RMS (3.70 t ha^{-1}) or Biotite shist (3.05 t ha^{-1}).

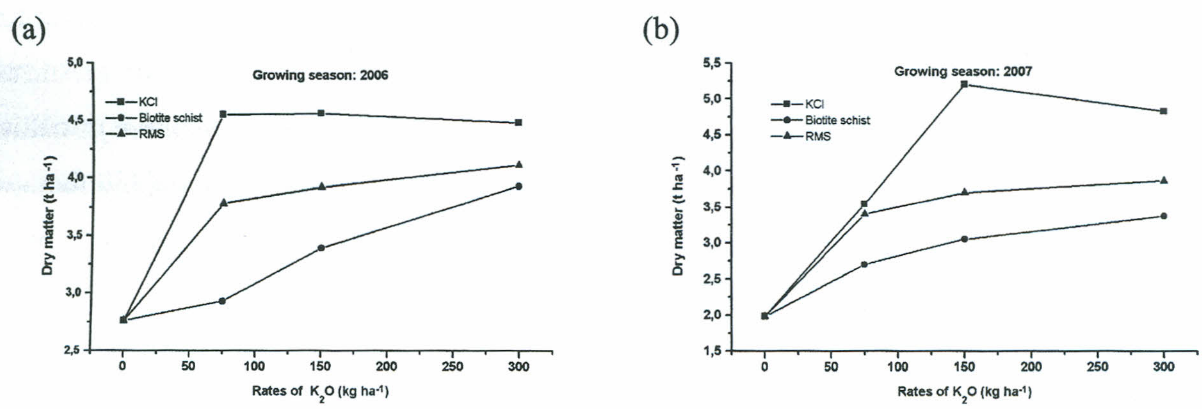

Figure 1: Pearl millet dry matter yields at different rates of K applied in various K sources in 2006 and 2007 growing seasons.

Total K accumulation in dry matter of pearl millet are shown in Table 1. The trends in K uptake in 2006 were similar to those in 2007. Although the sources were applied at equivalent rates, significant ($P \leq 0.05$) differences among rates and sources were observed in the K uptake by pearl millet and they were all greater than the control (Table 1). The K uptake from the Biotite shist treatment was significantly less than from the other sources, which is consistent with the degree of solubility of the K in the sources (Table 1). Upon application of a more soluble source (KCl), a large quantity of K was taken up, which is consistent with luxury uptake of K. Since pearl millet was used as cover crop, a large amount of K (40 - 190 kg ha^{-1}) was cycled from the plant back into the soil (Table 1).

Table 1: Total potassium accumulation in dry matter of pearl millet during the growing seasons.

Source	Rate	K-uptake - 2006		K-uptake - 2007	
	K_2O - kg ha^{-1}	g kg^{-1}	kg ha^{-1}	g kg^{-1}	kg ha^{-1}
KCl	75	20.4	92.74	19.8	70.60
KCl	150	38.2	174.50	21.3	109.71
KCl	300	42.7	189.91	22.6	109.32
Biotite shist	75	14.6	41.33	9.6	25.83
Biotite shist	150	16.4	55.93	9.6	29.23
Biotite shist	300	19.2	73.37	15.7	54.10
RMS	75	24.7	91.30	18.6	61.73
RMS	150	30.6	116.12	22.7	87.42
RMS	300	34.9	148.68	24.7	98.73
Control	0	12.0	32.96	12.3	25.68
Mean		23.1	90.23	16.8	60.31
CV, %		21.0	29.4	38.3	48.7

Soybean grain yields as affected by sources and rates of K application are showing in the Figure 2. Grain yields range from 820 to 2,400 kg ha^{-1} in 2006-07 and from 2,300 to 4,000 kg ha^{-1} in 2007-08 as K was increased from 0 to 300 kg K_2O ha^{-1} (Figure 2). The relative low yields obtained in 2006-07 (Figure 2a) were caused by the fact that the area never had been cultivated with soybean and the seeds were not inoculated with bacteria for N_2 fixation.

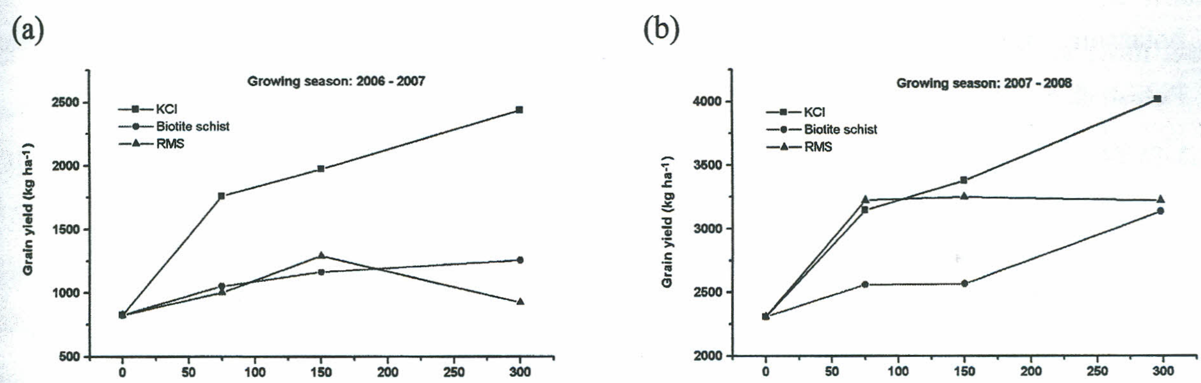

Figure 2: Soybean grain yields at different rates of K applied as various K sources in 2006-07 and 2007-08 growing seasons.

In the first growing season (2006-07), sources, rates and interactions treatments all had a significant effect ($P \leq 0.05$) on soybean grain yield. The treatments with the soluble source (KCl) yielded significantly more than the sources Biotite shist and RMS, with a linear response until the rate the 300-kg K_2O ha^{-1} (Figure 2a). However, in the second growing season (2007-08), while a linear response was obtained to rates applied as KCl and Biotite shist, a linear-plateau response was verified to the RMS with the maximum grain yield (3.200 kg ha^{-1})

obtained with application of 75 kg K_2O ha^{-1} (Figure 2b). These results indicated that the source RMS presented some detrimental effect, limiting soybean grain yield. On the other hand, our hypothesis that the crop sequence pearl millet/cover crop-soybean could improve the efficiency of the less soluble source of K was not confirmed in this research.

Conclusions

The results of this study show that pearl millet dry matter yield and soybean grain yield were significantly affected by sources and rates of K. Pearl millet and soybean presented greatest response to K fertilization rates of 150 and 300 kg K_2O ha^{-1}, respectively. This research also shows that byproduct-RMS, when applied at equivalent rates, is almost as effective as KCl and both were superior to Biotite shist for pear millet and soybean production. Our hypothesis that the crop sequence pearl millet/cover crop-soybean could improve the efficiency of the less soluble source of K was not confirmed in this research.

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