

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

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1. Introduction

Crop potassium (K) requirement is greater than requirements for all nutrients except nitrogen (N). Whereas biological N fixation provides significant N inputs 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, increase food production will require a large proportional increase in K fertilizer user. Applications rates to soil 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 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 been leading to a great increase in K fertilizers consumption (Nachtigall and Raji, 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 sylvinitic deposits in the Amazon state (Lopes, 2005). In addition to that, they must stimulate research concerning the economical feasibility of potassium silicates and mineral byproduct, which are abundant all over Brazil, as source 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.

2. 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 (clay 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 $300 \text{ kg K}_2\text{O ha}^{-1}$), 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, content 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 presenting low concentrations of CaO and MgO, with low effective calcium carbonate (ECC) rating (Biotite schist: 3.20 % and RMS: 29.33 %). The equivalent rates applied to supply the levels of 75, 150 and $300 \text{ kg K}_2\text{O ha}^{-1}$ 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 $90 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$. 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 $1.0\text{-}1 \text{ ha}^{-1}$. The harvested biomass was weighed in the field and sampled for dry matter determinations. The sample was subsequently dried at $65 \text{ }^\circ\text{C}$ 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 $90 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ 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 ($P \leq 0.05$).



Fig 1. General aspects showing the Biotite schist applied on the soil surface (left) and pearl millet and soybean growing in the field (right).

3. 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 responses to alternatives sources (Biotite schist and RMS) and rates of K, compared to KCl, are show in Fig 1. Pear millet dry matter yields, range 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 (Fig 2). 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-K₂O ha⁻¹ supplied as RMS and KCl sources, which the dry matter production were statically similar, 4.00 and 3.60 t ha⁻¹, respectively.

For the Biotite schist a linear response, until 300-kg K₂O ha⁻¹, was observed (Fig 2a). 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 (Fig 2b). However, for all sources, the maximum dry matter yield was obtained with application of 150-kg K₂O ha⁻¹ (Fig 1b) and the production obtained with KCl (5.19 t ha⁻¹) was higher than RMS (3.70 t ha⁻¹) and Biotite schist (3.05 t ha⁻¹).

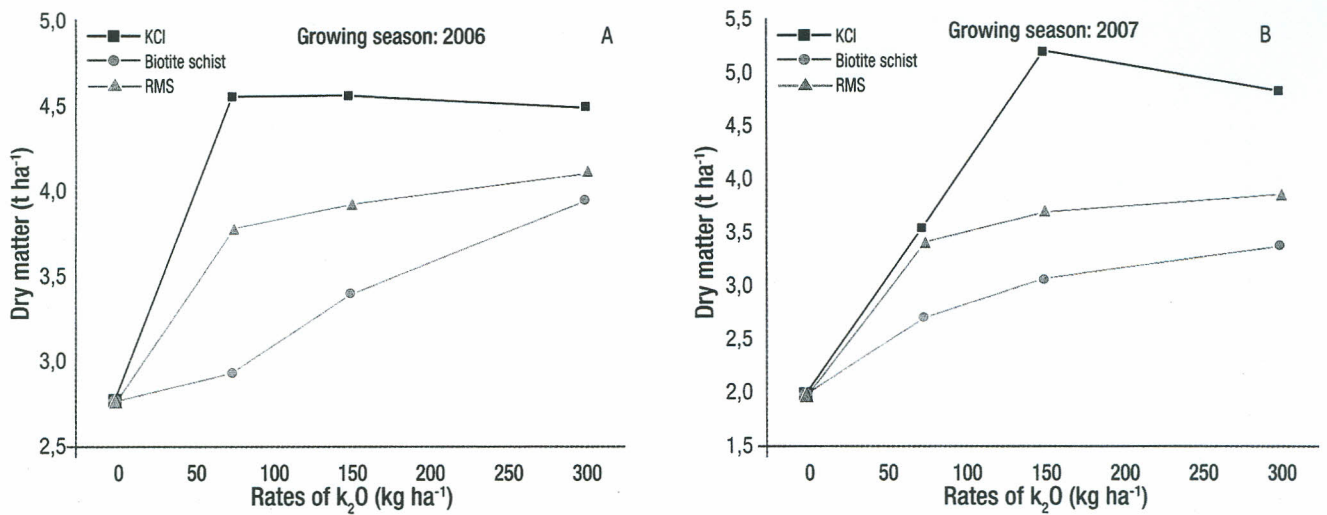


Fig 2. Pearl millet dry matter yields responses to sources and rates of K applications in 2006 and 2007 growing seasons.

The data of total K accumulation in dry matter of pearl millet are showing in the 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 for the Biotite schist treatment was significant less than other sources treatments, which are consistent with the degree of solubility of the K in the sources (Table 1). When a more soluble source (KCl) was applied, a large quantity of K was uptake, which is consistent with luxury uptake of K. Since that pearl millet was used as cover crop, a large amount of K ($40 - 190 \text{ kg ha}^{-1}$) were 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 $\text{K}_2\text{O} - \text{kg ha}^{-1}$	K-uptake – 2006		K-uptake – 2007	
		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 schist	75	14.6	41.33	9.6	25.83
Biotite schist	150	16.4	55.93	9.6	29.23
Biotite schist	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 Fig 3. Grain yields range from 824 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 K₂O ha⁻¹ (Fig 3). The relative low yields obtained in 2006-07 (Fig 3a) were caused by the fact that area never had been cultivated with soybean and the seeds were not inoculated with bacteria for N₂ fixation.

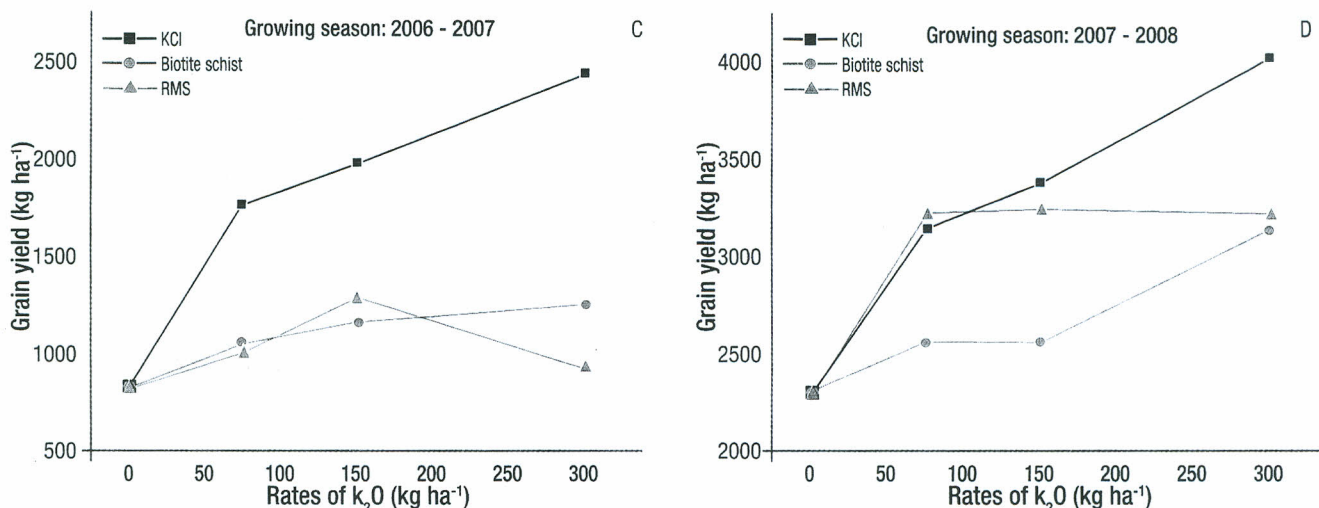


Fig 3. Soybean grain yields responses to sources and rates of K application in 2006-07 and 2007-08 growing seasons.

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 schist and RMS, with a linear response until the rate the 300-kg K₂O ha⁻¹ (Fig 3a). However, in the second growing season (2007-08), while a linear response was obtained to rates applied of the KCl and Biotite schist, 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 K₂O ha⁻¹ (Fig 3b). 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.

4. 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 K₂O ha⁻¹, respectively. This research also shown that byproduct-RMS, when applied at equivalent rates, is almost as effective as KCl and both were superior to Biotite schist 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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