Performance evaluation of phonolite through mineral form and enrichment of filter cake in sugarcane ratoon

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Abstract

In order to evaluate the performance of phonolite as a source of potassium in fertilization management of sugarcane ratoon through mineral and organo-mineral forms, an experiment was installed in November of 2011 in Casa Branca, SP, Brazil, in soil type red-yellow Latosol Dystrophic medium texture, with variety SP 801816, in third yield, harvested mechanically with no fire. The experiment was designed using random blocks with four replications. The treatments were: T1-Control; T2- Mineral Phonolite 8.5% dose 70 kg ha-1 of K2O; T3- Mineral Phonolite 8.5% dose 100 kg ha-1 of K2O; T4- Mineral Phonolite 8.5% dose 130 kg ha-1 of K2O; T5- Mineral Phonolite 14% dose 100 kg ha-1 of K2O; T6- Mineral KCl 58% dose 100 kg ha-1 of K2O; T7- Organo-mineral KCl 58% dose 100 kg ha-1 of K2O; T8- Organo-mineral Phonolite 8.5% dose 70 kg ha-1 of K2O; T9- Organo-mineral Phonolite 8.5% dose 100 kg ha-1 of K2O; and T10- Organo-mineral Phonolite 8.5% dose 130 kg ha-1 of K2O. The following components were evaluated: sugarcane ratoon productivity, and potassium levels in soil and leaves. It was observed that productivity and potassium levels in soil and leaves were significantly affected by treatments.

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The treatments with potassium provided an average increase of productivity and potassium absorption of 21% and 59%, respectively, compared to the control treatment. Regarding the three sources of potassium, all were used in mineral form and in doses of 100 kg ha-1 of K2O (T3, T5 and T6). They did not show any significant difference in productivity. Regarding the organo-mineral form and the dose 100 kg ha-1 of K2O, a significant difference was observed between potassium sources. The filter cake enriched with phonolite 8.5% provided a productivity increase of 21% compared to the cake enriched with KCl. The three doses of potassium using phonolite 8.5% did not show significant increments in productivity with increased doses (70, 100 and 130 kg ha-1 of K2O), for both mineral and organo-mineral forms. However, the overall mean for the three doses used in organo-mineral form (T8+T9+T10) indicated a productivity increase of 15% compared to the mineral form.

Key words: cane ratoon; potassium sources; forms of dispersion.

Introduction

Sugarcane is one of the leading agro-industrial crops in Brazil. The southeast, and the state of São Paulo in particular, is responsible for 54% of the national production (CONAB, 2013). In order to move the extensive and complex production chain, which has more than 180 sugar and ethanol plants, and to ensure the Brazilian competitiveness in the ethanol and sugar energy sector, heavy investments are necessary in technology and inputs. Considering only the links of the production chain before the farm, the agriculture industry inputs moved more than 9 billion dollars in 2008, with 24.4% revenue generated from fertilizer sales alone (Neves et al., 2008). Potassium is the most extracted macronutrient by sugarcane plants that accumulate it in large quantities, even excessively as a “luxury consumption”, but without generating toxicity from its excessive presence (Rossetto et al., 2008). Oliveira (2008) has studied the extraction of macronutrients in 11 varieties of sugarcane and found the following results in kg ha-1: 196 of N; 29 of P2O5 and 376 of K2O. According to Malavolta (2006), the high demand for potassium in sugarcane is related to its important role in biochemical and other functions such as translocation of sugars, stomatal opening and closing, osmotic adjustment, and carbon fixation. In addition, it contributes to the quality of the raw material, increasing sucrose content in sugarcane culm and decreasing of fiber content.

Potassium salts represent the main source of K used in world agriculture, but the production of this raw material is restricted to few countries, such as Canada, Russia, Belarus-Russia, Germany, Israel, the United States, and Jordan, which together are responsible for 85% of the world's production. This means that Brazil imports more than 95% of all the potassium used.

The Curimbaba query (Mineração Curimbaba), located in Poços de Caldas, MG, Brazil, has large reserves of a rock called phonolite, which is a potassium silicate featuring the following chemical composition in % (mm-1), according to Teixeira et al. (2011): 52.44% of SiO2; 23.37% of Al2O3; 9.06% of K2O; 8.4% of Na2O; 3.85% of Fe2O3; 2.84% of CaO; 0.61% of TiO2; 0.13% of MnO; and 0.10% of P2O5. Due to the high biological demand of sugarcane crops for potassium, plus the fact that it is an input acquired more than 95% by import; it is of great importance to study national alternatives to the use of potassium chloride to reduce costs and external dependency. Therefore, the aim of this work was to evaluate phonolite's performance as a source of potassium in sugarcane ratoon, dispersed both in mineral form as well as in the enrichment of filter cake.

Methodology

The experiment was installed and conducted in the city of Casa Branca, SP, on the crop of 2011/2012, in an area of sugarcane ratoon (third yield) established with the variety SP 801816, which was mechanically harvested with no fire. The local soil was classified as red-yellow Dystrophic Latosol (Embrapa, 1999), medium texture. The chemical characteristics of layer 0 to 20 cm were determined before the experiment setup and they followed the methodology described by Raij et al. (2001), whose results were: organic matter, 16.5 g dm-3; pH (0.01 mol L-1 CaCl2), 4.2; Phosphorus (Resin), 15.7 mg dm-3; and K, Ca, Mg, H +Al, CTC and SB, 0.6, 17, 7, 21, 45.6 and 24 mmolc dm-3 respectively. Base saturation was 54%. The experiment was designed in entirely randomized blocks with four replications, totaling 40 experimental units.

Each parcel installed was composed of five lines 10 m long and 1.4 m away from each other. The useful area of the experiment was considered the three central lines, excluding the surrounding line of 2 m between the parcels. The treatments were composed of three sources of potassium (KCl- 58%, Phonolite- 8.5% and Potassium rock 14% of K2O, respectively), three doses (70, 100 and 120 kg ha-1 of K2O), and two forms of application, mineral and organo-mineral (Table 1).

The treatments' preparation was divided in two different phases: the first one was held in the courtyard where the plants were being composted at the Ferrari Power Plant, in Pirassununga, SP, aiming to reproduce the filter cake enrichment in commercial scale. For this purpose, criteria have been fixed regarding the use of in natura cake in sugarcane ratoon (5,000 kg ha-1 of original matter) and nitrogen. Thus, for an expected average productivity of 90 t ha-1 of culms, we adopted the relation 1.3 kg of N t-1 of culms, in a total of 117 kg ha-1 of nitrogen.

The cubic measurements and the parcel density estimations were made in the courtyard where the plants were composting. The result obtained was a relation of 1,254 kg of cake m-1 of the parcel (dry matter = 50%). Based on this value, it was calculated that 4 m was the parcel's necessary length to achieve 5,000 kg ha-1 of cake. The cake enrichment calculation with doses and sources of potassium and nitrogen adjustment was collected and sent to the soil laboratory of FZEA/USP for chemical characterization. The results shown in percentage of dry matter are 1.92 of N; 2.62 of P2O5 and 0.55 of K2O.

Table 1. Treatments employed in sugarcane ratoon (third harvest)

Treatments	Potassium Sources	N	P_2O_5	K_2O
			kg ha^{-1}	
T_1- Control		120	65,5	0
T_2- Mineral Phonolite 8,5% dose 70*		120	65,5	70
T_3- Mineral Phonolite 8,5% dose 100		120	65,5	100
T_4- Mineral Phonolite 8,5% dose 130		120	65,5	130
T_5- Mineral Potassium Rock 14% dose		120	65,5	100
100 T_6- Mineral KCL 58% dose 100		120	65,5	100

T_7- Organomineral KCL 58% dose 100	120	65,5	100
T_8- Organomineral Phonolite 8,5% dose 70	120	65,5	70
T_9- Organomineral Phonolite 8,5% dose 100	120	65,5	100
T_{10}- Organomineral Phonolite 8,5% dose 130	120	65,5	130

*Doses in kg ha^{-1} of K_2O

The doses of K for cake enrichment were calculated from the results mentioned above. The nitrogen adjustment used was the Ajifer (7.5% N) at a dose of 960 L ha-1. For product application the parcels were divided in four segments of 4 m and were separated by 10 m between each other, as a border line. The calculated doses of Ajifer, phonolite and KCl were applied manually in each segment. Right after, the materials were homogenized using a mechanical composter Civemasa CRO 4.0. Before the treatment application in the field, one composite sample of each treatment of enriched cake was collected in order to determine the moisture content and make the corrections of the values to be weighed and applied in each treatment.

The second phase of the experiment consisted of the preparations of mineral treatments, made in order to maintain the same concentrations of nitrogen and phosphorus that were applied in the field via 5,000 kg of enriched cake, for example, 120 kg ha-1 of N and 65.5 kg ha-1 of P2O5. Ammonium nitrate (31% N) was used as a source of N, and MAP (11-52-00) was used as a source of P2O5. The treatments were applied in the field on 11/15/2011, in the form of a continuous thread of products on the line of cane ratoon. After a period of four months (03/15/2013), five leaves (leaf +3) were collected in each of the three lines of sugarcane that made up the utile area of the parcels.

Right after harvesting the sugarcane, two samples were taken from each of the three lines of the working area; at 0 cm and 20 cm. Analytical, routines for the quantification of macronutrient levels in soil and leaves were made according to the recommendations described by Raij et al. (2001). The sugarcane harvest took place on 10/10/2012, twelve months after the application of treatments. The results were submitted to analysis of variance using the program SAS-9.2 and significance level of 5% of probability for f-test.

The Tukey test was used to compare the mean of the dependent variables (productivity, potassium content of soil and leaves) and it was also used in orthogonal contrasts for groups of treatments of the same nature, also using the significance level of 5% of probability for f-test.

Results and Discussion

Tables 2 and 3 present the results of variance analysis for the treatments, the mean comparison of treatments, the contrasts between the means of interest treatment groups for the variables productivity, potassium content in the soil and in the leaves of sugarcane ratoon (third harvest) in relation to each treatment.

Table 2. Variance analysis and classification of the mean variables: productivity, potassium content in the soil and in the leaves of sugarcane ratoon (third harvest) in relation to each treatment.

Sources of Variation	Productivity	K-soil	K-leaf
		P-value	
Blocs	$0{,}0061^{**}$	$0{,}0135^{**}$	$0{,}0329^{*}$
Treatments	$0{,}0001^{**}$	$0{,}0206^{*}$	$0{,}0001^{**}$
Sources of Variation	Produtivity	K-soil	K-leaf
Treatments	TCH	$mmol_c\, dm^{-3}$	$mg\ kg^{-1}$
T_1	$55{,}7^{c}$	$1{,}03^{b}$	$12{,}72^{d}$
T_2	$59{,}7^{bc}$	$1{,}23^{ab}$	$16{,}79^{c}$
T_3	$64{,}2^{abc}$	$1{,}10^{b}$	$18{,}22^{bc}$
T_4	$67{,}1^{abc}$	$1{,}00^{b}$	$18{,}34^{bc}$
T_5	$67{,}7^{abc}$	$1{,}15^{b}$	$19{,}72^{abc}$
T_6	$66{,}1^{abc}$	$1{,}40^{a}$	$19{,}97^{abc}$
T_7	$61{,}5^{abc}$	$1{,}20^{ab}$	$21{,}47^{ab}$
T_8	$67{,}8^{abc}$	$1{,}08^{b}$	$21{,}72^{ab}$
T_9	$74{,}4^{ab}$	$1{,}03^{b}$	$22{,}72^{a}$
T_{10}	$77{,}8^{a}$	$1{,}18^{ab}$	$22{,}97^{a}$
DMS	16,70	0,25	3,70
CV(%)	10,35	9,00	7,81

* e ** significant at 1 and 5%, respectively by f-test

Table 3. Contrasts between the means of interest treatment groups for the variables productivity, potassium content in the soil and in the leaves of sugarcane ratoon (third harvest) in relation to each treatment.

Contrasts	Produtivity	K-soil	K-leaf
	P-value		
Y_1: Control vs Other treatments	0,0035**	0,1945ns	0,0001**
Y_2: Dose 100 Mineral: T_3, T_5 and T_6	0,7766ns	0,0134*	0,0010**
Y_3: Dose 100 Organomineral: T_7 vs T_9	0,0138*	0,0940ns	0,1747ns
$Y_{4:}$ $T_2+T_3+T_4$ vs $T_8+T_9+T_{10}$	0,0020**	0,6710ns	0,0001**
Y_5: T_2 T_3 T_4 - Effect level 1	0,1427ns	0,2257ns	0,2122ns
Y_6: T_2 T_3 T_4 - Effect level 2	0,8507ns	0,6710ns	0,5511ns
Y_7: T_8 T_9 T_{10} - Effect level 1	0,0508ns	0,8061ns	0,2555ns
Y_8: T_8 T_9 T_{10} - Effect level 2	0,7123ns	0,6710ns	0,0168*

* e ** significant at 1 and 5%, respectively, by f-test. Means followed by the same letter do not have any difference between each other at 5% level of probability by Tukey test.

According to the results obtained, there was a significant response for the treatments regarding productivity and potassium content of soil and leaves (Table 2). Analyzing the variables from interest treatment groups, it was found that the average productivity of sugarcane ratoon increased significantly (p=0.0035) with the use of potassium, disregarding the dose, source and the form of application (Table 3, contrast Y1). When the overall productivity mean of the treatments that received potassium (T2+...+T10) was compared to the control treatment, an increase of 21% was noticed (Fig. 1a).

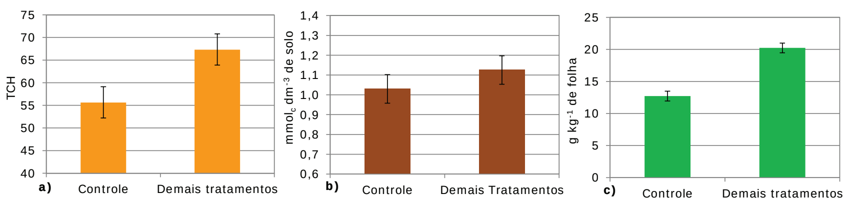

Figure 1. (a) Average productivity, (b) residual content of potassium in soil, (c) potassium content in leaves of sugarcane ratoon (third harvest) by each treatment that received or did not receive potassium doses.

Regarding the residual contents of potassium in soil, there was no significant difference (p=0.1945) between the control and other treatments (Fig. 1b). However, there was a difference (p=0.001) in the content found in the leaves (Fig. 1c) of 59% higher on average in treatments that provided potassium. Both results of productivity and potassium absorption by leaves are expected because of their important metabolic role and the large amount of potassium extracted by sugarcane. Regarding the potassium sources, both applied in a mineral form and in doses of 100 kg ha-1 of K2O (Table 3, contrast Y2), significant differences (p=0.7766) in productivity were shown (Fig. 2a).

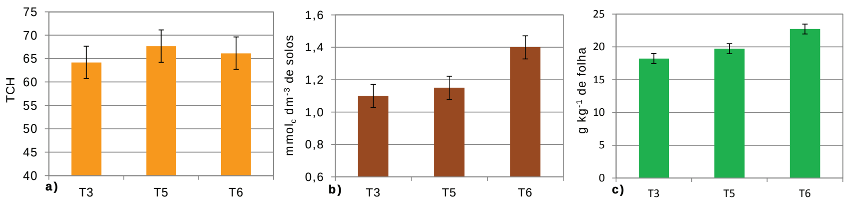

Figure 2. (a) Average productivity, (b) residual content of potassium in soil, (c) potassium content in leaves of sugarcane ratoon (third harvest) from different doses of potassium applied as mineral form in the dose of 100 kg ha-1 of K2O.

Barão et al. (2010) studied the effects of two sources of potassium (KCl 58% of K2O and the phonolite 11% of K2O) and four doses (0, 20, 40 and 80 kg ha-1 of K2O) on the components of soy bean production and concluded that the treatments were not influenced by the sources of potassium. Regarding the potassium content in soil, there was significant difference between the sources (p=0.0134). The T6 showed the highest residual value (1.4 mmolc dm-3 of soil) when compared to T3 and T5 (Fig. 2b). However, both treatments did show contents within the range suggested by Malavolta et al. (1997) for sugar cane ratoon (13 to 15 g kg-1 of leaf).

The leaves' content did also show significant differences (p=0.0010) with the potassium sources, and the highest value observed was for the treatment T6 (22.72 g kg-1 of leaf), while the treatments T3 and T5 did not show any difference in value among themselves (Fig. 2c).

Both cases did show contents within the range considered adequate by Malavolta et al. (1997) for sugarcane ratoon (13 to 15 g kg-1 of leaf).

The organo-mineral form of application in the dose of 100 kg ha-1 of K2O (Table 3, contrast Y3) did show significant differences (P=0.0138) among the potassium sources. One cake filter was enriched with Phonolite 8.5%, and another was enriched with KCl 58%. The filter enriched with Phonolite 8.5% was 20 percent more productive than the filter enriched with KCl 58% (Fig. 3a). This fact may be related to the lower solubility of phonolite that could have reduced the loss of K+ by rainwater washing the lines during the composting process. There was no significant difference between potassium contents in leaves (p=0.1747) and in soil (p=0.0940) (Figs. 3b and 3c).

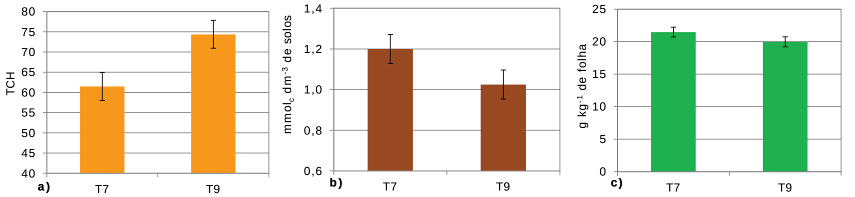

Figure 3. (a) Average productivity, (b) residual content of potassium in soil, (c) potassium content in leaves of sugarcane ratoon (third harvest) by different doses of potassium applied as organo-mineral form in the dose of 100 kg ha-1 of K2O.

In the case of Phonolite 8.5% (Table 3, contrast Y5, Y6, Y7 and Y8) as a potassium source, there were no significant increments in productivity observed as the doses increased for both mineral and organo-mineral forms. However, there was a significant difference when it was contrasted with the general average productivity of the three doses applied in mineral form (T2+T3+T4) with the overall mean of the three doses applied as organo-mineral form (T8+T9+T10). The organo-mineral form provided an increase of 15% compared to mineral form (Fig. 4a). This response is related to the benefits provided by the high content of organic matter in the composition of the cake enriched with phonolite.

According to Luz et al. (2011), the organic and/or organo-minerals fertilizers feature nutrients such as nitrogen, phosphorus and sulfur associated with organic composts, which gives them gradual solubility.

This fact allows such elements to be released gradually over the time, beginning with lower availability and increasing along with plant development, allowing greater efficiency of nutrient use.

In addition, the high cationic exchange capacity of the cake may have contributed to the retention of K+ soluble ions, releasing them gradually in the course of the crop development. These results reflected significantly in the accumulation of potassium by leaves (p=0.0001), which happened to be higher for treatments that applied the organo-mineral form (Fig. 4c). The residual potassium contents in the soil did not show any significant difference (p=0.6710) among the two group of treatments (Fig. 4b).

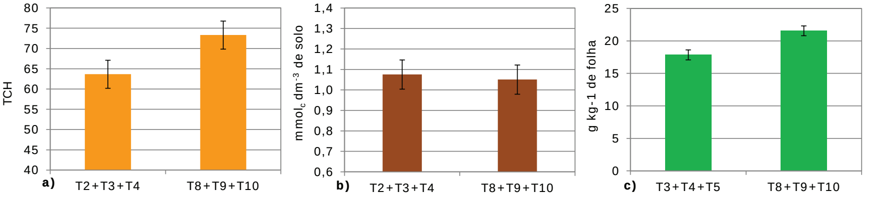

Figure 4. (a) Average productivity, (b) potassium content in soil, (c) potassium content in leaves of sugarcane ratoon (third harvest) by different doses and forms of application of potassium.

Conclusões

The experiment's results allow us to conclude that the phonolite and the potassium rock dust applied as a mineral form in doses of 100 kg ha-1 of K2O did show potential as a potassium source for sugarcane crops with similar performance to potassium chloride.

There was no significant difference in the productivity of sugarcane ratoon in the three tested doses of K2O ha-1 using phonolite as a source. However, the overall mean of the three tested doses when applied in the organo-mineral form was superior to the mineral form, showing the potential of this source and its form of application in the nutrition of sugarcane plants.

The phonolite proved to be a source of potassium technically viable for organo-mineral compound production.

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