Decomposition of crop residues and availability of nutrients to bean plants as influenced by silicate and lime

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Abstract
The aim of this study was to evaluate the effect of calcium silicate and limestone on the decomposition of crop residues and the availability of bean plant nutrients. The treatments consisted of three species of covering plants: *Pennisetum americanum*, *Brachiaria brizantha* and *Cajanus cajan* L. and five doses of silicate (0, 25, 50, 75 and 100%) as the acidity corrective. Silicate did not interfere in the decomposition of covering plant residues, but it reduced magnesium content available in the soil and induced smaller Mg absorption by covering plants and availability after decomposition. The growth of bean plants was improved by silicate; the treatments with 25 to 75% silicate doses and brachiaria crop residues were the most efficient ones.

Key Words
Calcium silicate, brachiaria, millet, pigeon pea.

Introduction
Calcium silicate, as slag, has been used as acidity corrective and as Ca and Mg source for plants, increasing biomass production (Korndörfer *et al.* 2002). In the soil, silicate enables the reaction between silicic acid and o-diphenols, caffeic acid and esters, all compounds are precursors of lignin in plants; this results in complex polyphenolic compounds of highly stable Si (Inanaga and Okasaka 1995; Marschner 1995), making cell walls that are more resistant to degradation by microorganisms. This characteristic can allow more crop residue persistence on the soil surface, resulting in a more gradual release of nutrients. Thus, available Si from silicate may contribute to alternatives that provide higher crop residue persistence on the soil surface, mainly under the conditions of the Brazilian savannah. Therefore, this study aimed to evaluate the effect of silicate and limestone on the decomposition of crop residues and the availability of nutrients for bean plant development.

Methods
The experiment was carried out in greenhouse, using 20/dm^3 pots, in which 13/dm^3 was filled with soil and the first 7 /dm^3 were reserved for crop residues. Dystrophic Clayey Rhodic Hapludox (Embrapa 1999), collected from the 0-20 arable layer, was used. The initial chemical analysis, according to Raij *et al.* (2001) showed pH 4.2 in $CaCl_2$; 6 and 1 g/dm^3 of O.M. and P; Al, H+Al, K, Ca, Mg and CEC of 7; 21; 0.4; 6; 2 and 30 mmol$_c$/dm^3, 28% base saturation (BS) and 0.66 mg/dm^3 Si content in $CaCl_2$, following the method by Korndörfer *et al.* (1999). A 5x3 random block factorial scheme with 4 replications was used. The treatments consisted of three species of covering plants: millet (*Pennisetum americanum*), brachiaria (*Brachiaria brizantha*) and pigeon pea (*Cajanus cajan* L.) and five proportional doses of calcium silicate (0%, 25%, 50%, 75%, 100%) in the acidity corrective, applied in increasing doses of 0; 2.31; 4.63; 6.96 and 9.27g/pot, balanced with five decreasing doses of calcium carbonate and magnesium carbonate. Utilized silicate presented the following chemical characteristics: 39.8% of CaO, 12% of MgO, 100% of reactivity, 88% of neutralizing equivalent in $CaCO_3$, and 88% of relative efficiency. Utilized limestone was obtained from a mixture of $CaCO_3$ and $MgCO_3$ p.a., keeping the same proportions of these compounds in the calcium silicate. The utilized doses of acidity corrective were calculated to increase the base saturation to 70%, only varying the Si content in each treatment, which reached the values of 2.4; 4.2; 4.2; 5.4 and 6.4 mg/dm^3 of extracted Si in $CaCl_2$, 51; 53, 53, 45 and 42% for BS and pH 5.0; 5.1; 5.0; 4.6 and 4.6, after 30 days of incubation. Ca contents did not vary with the treatments: 15; 17; 17; 15 and 15 mmol$_c$/dm^3; there was a decrease of Mg contents as the silicate percentage increased: 9; 9; 8; 6 and 5 mmol$_c$/dm^3.

Before the sowing of covering plants (10/22/2006), fertilization was done with 15.4 kg/ha of P. Covering fertilizations were done in four applications: the first one at seven days after germination (dag) with 15.4

kg/ha of N and 15.4 kg/ha of K; the second one at 31 dag with 15.4 kg/ha of N; the third fertilization was at 45 dag with 15.4 kg/ha of N, and the fourth one at 52 dag with 200 mL/pot of Hoagland and Arnon micronutrient solution. At 90 dag, dissecation of covering species was done by cutting them into 10-12 cm pieces, adding 56.7 g/pot (6 t/ha) of each vegetal residue in the soil surface. Bean sowing (cv. Pérola) was done on 04/23/2007, and carried out until 60 days after sowing (das), corresponding to 50% of flowering, R6 crop stage, when all plants were collected for dry matter analysis. At 60 days after covering plant dissecation, i.e., when pot disassembling occurred, after the removal of bean plants, a second soil sampling was done for chemical analysis as mentioned before. Vegetal matter of covering plant aerial part was collected for chemical analysis (Malavolta *et al.* 1997) at 90 das. Crop residue persistence analysis was done when bean was harvested (65 days after cultivation) to quantify the remaining material and also for a chemical analysis of crop residues as previously described. The results were submitted to variance analysis using the Sisvar software, version 4.2. The treatment averages were compared using the t test (LSD) at 1 and 5% for covering plants and regression analysis for silicate doses.

Results

Covering plants presented different chemical compositions with significant effect for N, Ca, Mg, K, S and Si (Table 1). Pigeon pea plant, a leguminous plant, enables N biological fixation, presenting higher content of this nutrient; the higher Ca absorption by the pigeon pea may be related to the higher root CEC, providing bigger affinity in bivalent cation absorption by this leguminous when compared to grasses. High contents of Si and lignin presented the lower C/N relation, favoring pigeon pea decomposition when compared to millet and brachiaria.

Table 1. Chemical composition of vegetal tissue of covering plant aerial part.

Covering plants	N	P	K	Ca	Mg	S	Si	Lignin	C/N
	(----------------------------			g/kg		-------------------)	%	g/kg	
Brachiaria	15.4b	2.6	10.2b	4.1b	4.2a	1.4c	0.62b	38.2b	32a
Pigeon pea	35.5a	3.1	17.1a	11.1a	2.1b	2.5a	0.92a	83.4a	14b
Millet	14.2b	2.8	8.2b	4.4b	4.4a	2.0b	0.47c	28.3c	35a

Averages followed by different letters differ among themselves.

Pigeon pea presented the highest K absorption when compared to the two grasses, and it was the only covering plant that presented a significant effect in relation to the silicate percentage increase in the acidity corrective. It showed increasing quadratic behavior until 64% (Figure 1a), which may be related to the lower Mg absorption (Figure 1b). The three covering species presented reduction in Mg content of the aerial part vegetal issue (Figure 1b), which is compatible to the decrease of Mg content in the soil with increasing doses of silicate, from 9 to 5 $mmol_c/dm^3$, possibly associated to the magnesium compound solubility in the silicate. The silicate percentage increase resulted in different lignin contents in the covering plant aerial parts, with significant effect for pigeon pea and millet (Figure 1c); pigeon pea presented the highest contents.

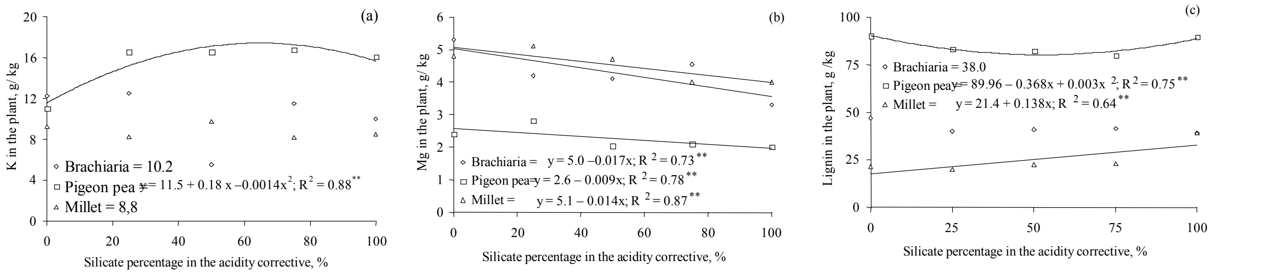

Figure 1. K (a), Mg (b) and lignin (c) content in the aerial part of brachiaria, pigeon pea and millet in function of calcium silicate percentage in the acidity corrective.

Table 2. Amount of macronutrients released in the soil and contents of Si, lignin and remaining dry mass in the vegetal residues of the covering plant aerial part.

Covering plants	N	P	K	Ca	Mg	S	Si	Lignin	R.D.M.
	(----------------------			mg/pot		----------------)	%	g/kg	%
Brachiaria	487 b	88 b	525 b	41 b	173 a	32 b	1.44 a	10.7 b	42.90 a
Pigeon pea	1784 a	148 a	838 a	407 a	103 b	102 a	1.24 b	8.4 c	20.15 b
Millet	394 b	90 b	432 c	53 b	173 a	48 b	1.39 a	12.3 a	47.70 a

Averages followed by different letters differ among themselves.

After 60 days of dissecation and covering plant aerial plant tillage on the soil surface, it was verified that pigeon pea was the species that enabled most macronutrient availability, except for Mg, (Table 2); that can be related to the lower C/N relation of this leguminous when compared to the two grasses (Table 1). Increase of silicate percentage in the acidity corrective did not change N, P, Ca and S mineralization of soil covering plants, but it influenced the amount of Mg and K released by vegetal residues. Mg availability, regardless the covering plant, decreased in the presence of calcium silicate in the acidity corrective (Figure 2a), which is compatible to the lowest absorption of this nutrient by covering plants because of Mg content reduction in the soil. Regarding K release, only pigeon pea presented a statistical difference, having an increasing behavior up to the 64% dose (Figure 2b). The increase of K availability by pigeon pea may be the result of a higher absorption of this nutrient by this plant with silicate application (Figure 1a).
Comparing the data from Tables 1 and 2, it is verified that Si was accumulated in the crop residue during the decomposition process of the three covering plants. While crop residues mineralize, the most soluble elements are exudated by the plant, and just the less soluble ones remain, as the Si compounds. Even with the highest Si accumulation in vegetal residues, when only 50% of the silicate was applied, the content of this element was lower (Figure 2c) due to its lower concentration when compared to the 100% dose of silicate. It is probable that there is an increase in Si solubility in the soil when it is applied with $CaCO_3$ and $MgCO_3$, and the higher anion concentration may increase the availability of this element and, consequently, its absorption by covering plants.

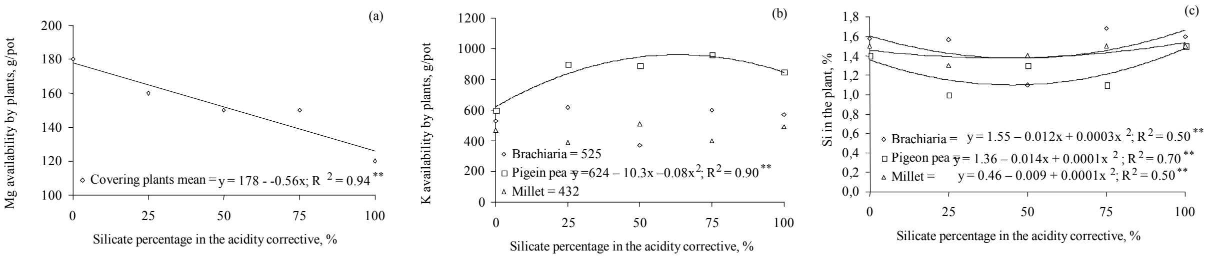

Figure 2. Mg (a) and K (b) availability by covering plants and Si contents in vegetal residues in the covering plant aerial part (c) in function of the silicate percentage increase in the acidity corrective.

The application of increasing doses of silicate resulted in higher lignin contents in the pigeon pea aerial part up to the 100% dose and up to 52% dose in the brachiaria, but in the millet there was a reduction of lignin content up to the 63% silicate dose (Figure 3a). Because the pigeon pea crop residue presented the greatest reduction of lignin content in the aerial part after 60 days of dissecation, this characteristic also contributed to the highest decomposition rate in relation to the millet and brachiaria, having values of 20% remaining dry matter when compared to 43 and 48%, respectively. Besides the reduction of lignin content, the highest decomposition by the leguminous can be explained by its smaller C/N relation in the beginning of the bean sowing (Table 1).

Dry biomass of the bean aerial part was provided by the silicate application in the acidity corrective, with different results for each species of covering plant (Figure 3b); it is important to note that for the 100% silicate dose all crop residues presented similar results. Brachiaria was the crop residue that provided the best bean development, and the 55% silicate dose was the most efficient. Even presenting the best results for nutrient content in the aerial parts, except for Mg in both situations, dry biomass of the bean aerial part for pigeon pea was inferior to millet and brachiaria in silicate doses inferior to 100%. That can be related to the lower availability of Mg in the soil, which probably conditioned a smaller growth of bean plants. Based on this information it can be inferred that when sowed under pigeon pea crop residue, bean has to have silicate application instead of limestone.

Millet presented the best intermediate results for bean dry biomass between 0 and 75% silicate doses when compared to brachiaria and pigeon pea,. Zero dose and 75% was the most efficient treatment for this variable and the highest biomass value for this crop residue was obtained with the 62% dose. There was no difference when limestone or silicate was used for plant sowing under millet crop residue.

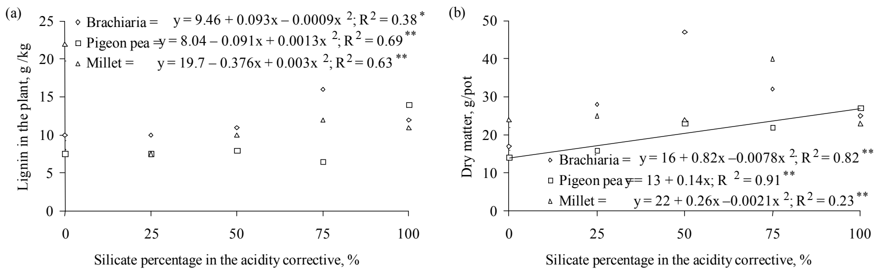

Figure 3. Lignin content in covering plant aerial part (a) and dry matter mass of bean aerial part in function of brachiaria, pigeon pea and millet covering plants and silicate percentage in the acidity corrective.

Conclusions

Calcium silicate application did not interfere in the brachiaria, pigeon pea and millet crop residue decomposition. Bean growth was provided by the silicate application and the treatments with 25 to 75% doses with brachiaria crop residue were the most efficient.

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