Rice yield affected by gypsum, lime and silicate application in no tillage system

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Abstract
The objective of this work was to evaluate the effects of combined silicate, lime and gypsum on acidity correction of the soil profile and on rice development. The experiment was carried out in Selvíria-MS, Brazil, at the College of Engineering, UNESP – Ilha Solteira-SP. The experimental design was the completely randomized block, with eight treatments and four replications. Treatments consisted of: control, gypsum, lime, silicate, lime+silicate, lime+gypsum, silicate+gypsum and lime+silicate+gypsum. Before and 12 months after the application, pH, H+Al, exchangeable Ca, Mg and K, SO_4^{2-} and extractable Si levels in soil were determined. Yield components and rice yields were measured. Some soil chemical attributes (pH, Ca, Mg, K, V%) were affected by the materials for acidity correction both applied separately and mixed. The number of panicles was increased by the superficial application of gypsum mixed with other materials, consequently affecting rice yield.

Key Words
Acidity correction, soil chemistry, *Oryza sativa*.

Introduction
The concept of no tillage system supports sowing without any kind of soil disturbance, including other aspects such as crop rotation with high dry matter production and the appropriate management of soil physical and chemical attributes. Soil fertility and acidity correction down the profile plays an important role in successfully establishing and consolidating no tillage system for many years. Soil acidity limits crop production in most areas under no tillage systems. Soil correction has been carried out with superficial liming, only leveling the material or with no incorporation at all. However, lime reactivity is usually restricted to the area where it was applied or incorporated. This material has low mobility and thus its use is questionable. Replacing part of the lime with other correction materials, such as some Ca and Mg silicates, may be a feasible option, since these are seven times more soluble than carbonates. Gypsum may also be used to enhance soil profile for better root growth. Therefore, some alternatives for acidity correction of the soil profile with no incorporation may contribute to make no tillage system viable. The objective of this work was to evaluate the effects of superficial application of combined silicate, lime and gypsum on acidity correction of the soil profile, rice nutrition, yield components and grain yield in no tillage system.

Methods
The experiment was carried out in Selvíria-MS, Brazil, at the College of Engineering, UNESP – Ilha Solteira-SP (51º 22' W, 20º 22' S, 335 m asl), in 2003/04 and 2004/05. Rice and bean were cropped in summer and winter, respectively, as crop rotation. Soil was a clayey Oxisol. Before the experiment, samples were taken for chemical analysis to estimate lime and gypsum necessity and to improve the area (Table 1). The experimental design was the completely randomized block, with eight treatments and four replications. Plots were 35 m^2 (5.0m x 7.0m). Treatments were: 1 – Control (no gypsum nor other materials), 2 – Gypsum (only gypsum application), 3 – Lime (only lime application), 4 – Silicate (only silicate application), 5 – Lime + Silicate (lime combined with silicate - LS, half dose of each), 6 – Lime + Gypsum (total dose of lime combined with the total dose of gypsum - LG), 7 – Silicate + Gypsum (total dose of silicate combined with the total dose of gypsum - SG) and 8 – Lime + Silicate + Gypsum (lime combined with silicate, half dose of each – and total dose of gypsum - LSG).

Doses for lime (2.1 t/ha) and silicate (2.2 t/ha) (Agrosilício®, Recmix Company) application were calculated to reach 70% of base saturation. Gypsum dose (3.0 t/ha) was calculated according to clay content in soil (500 g/kg). The products were combined using a cement mixer. Then, the materials were applied manually on soil surface, with no incorporation and just in the first year of the experiment, before rice sowing. The experiments were carried out under center pivot irrigation. Tensiometers were used for monitoring and to

Table 1. Soil chemical attributes before the experiment.

Depth (cm)	pH ($CaCl_2$)	O.M. g/dm^3	P (resin)	S-SO_4^{2-}	Si^A	Al	H+Al	K	Ca	Mg	CEC	V %
			(----------mg/dm^3---------)			(-------------mmol/dm^3-------------)						
0-20	5.1	27	20	16	5.9	0.0	40	1.5	19	12	72.5	45
0-5	5.1	28	22	14	6.2	0.0	40	3.3	18	14	75.3	47
5-10	5.1	25	28	14	5.4	0.0	40	0.7	16	10	66.7	40
10-20	5.2	26	16	16	5.7	0.0	37	0.6	18	13	68.9	46
20-40	5.3	23	8	40	4.7	0.0	34	0.6	12	9	55.6	39

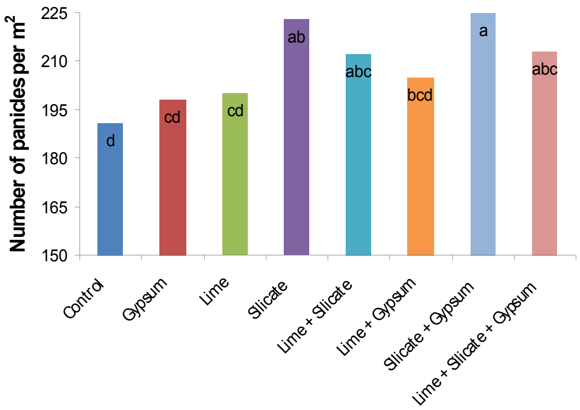
^{A}calcium chloride extractant

indicate need for water application, maintaining 0.058 MPa (vegetative and maturation stage) and 0.033 MPa (reproductive stage). Upland rice cultivar Primavera was sown in a 0.36 m row spacing. Density was 80 viable seeds per meter. Each plot consisted of 12 rows with 7 m length. The 4 central rows were the useful area, except 0.5 m in the extremity of each. Fertilization in both growing seasons consisted of 200 kg/ha of the NPK formula 08-28-16 + 0,4% of Zn applied in the furrows, and 60 kg/ha of urea for N supply. Samples were taken 12 months after the application of the materials in the depths 0-0.05, 0.05-0.10, 0.10-0.20 and 0.20-0.40 m. At random, eight simple samples per plot from each depth were taken to form a composite sample. These were dried, sieved (2 mm) and submitted to chemical analysis of pH ($CaCl_2$ 0.01 mol/L), potential acidity (H+Al), exchangeable Ca, Mg and K, and base saturation (V%), according to Raij *et al.* (2001). SO_4^{2-} levels were determined through calcium phosphate extraction. Si levels were evaluated according to Korndörfer *et al.* (1999). Yield components (number of panicles per m^2, total number of spikelets per panicle, spikelet fertility, weight of 1000 grains) and rice yield were also determined.Data was submitted to variance analysis and means were compared by the Tukey test at a probability level of 10%.

Results

Superficial application of lime, silicate and gypsum influenced the number of panicles per m^2 (Figure 1). The number of panicles per m^2 was higher than the control for silicate mixed with gypsum. Nevertheless, it did not differ from the others that were mixed with silicate, inferring the effects of Si on the number of panicles per m^2. The role of Si in the number of panicles per m^2 is not well described. According to Ma *et al.* (1989), Si hardly affected the vegetative stage. The other yield components did not differ statistically. Means were 183, 81% and 23,8 g for spikelets per panicle, spikelet fertility and weight of 1000 grains, respectively. Grain yield (Figure 1) was significantly increased by the materials and mixtures (LS, LG, SG and LSG) compared to the control. The treatment SG showed the higher yield (4,362 kg/ha). Either the combinations LS and LSG or each product applied separately showed similar effects.

According to Figure 2, pH was affected by the treatments only down to 0-0.05 m. In general, there were no effects either for the products applied separately (lime and silicate) or mixed (Figure 2). Therefore, although silicate is more soluble than lime, it was not more effective in neutralizing soil acidity in deeper layers. Gypsum application increased S-SO_4^{-2} levels down the whole profile, although higher accumulation was found in the depths 0.10-0.20 and 0.20-0.40 m, corroborating the results observed by Caires *et al.* (2003) and Soratto and Crusciol (2008). Lime and silicate, applied either separately or mixed, also increased sulphate levels in deeper layers, reaching higher values in the depth 0.20-0.40 m. K levels were decreased significantly by the treatments in the depths 0-0.05 m and 0.20-0.40 m. The application of lime and



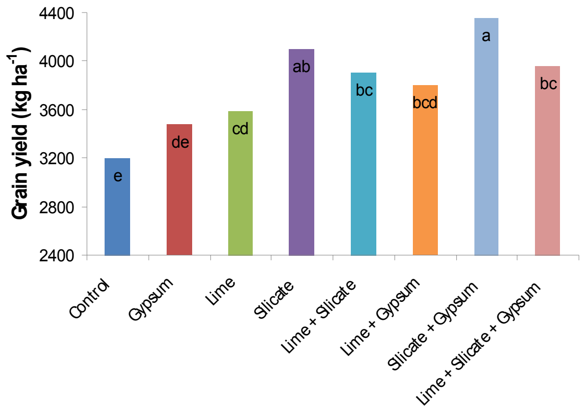


Figure 1. Number of panicles per m^2 and rice yield as affected by materials for acidity correction and gypsum under no tillage system. Average of 2003/04 and 2004/05.

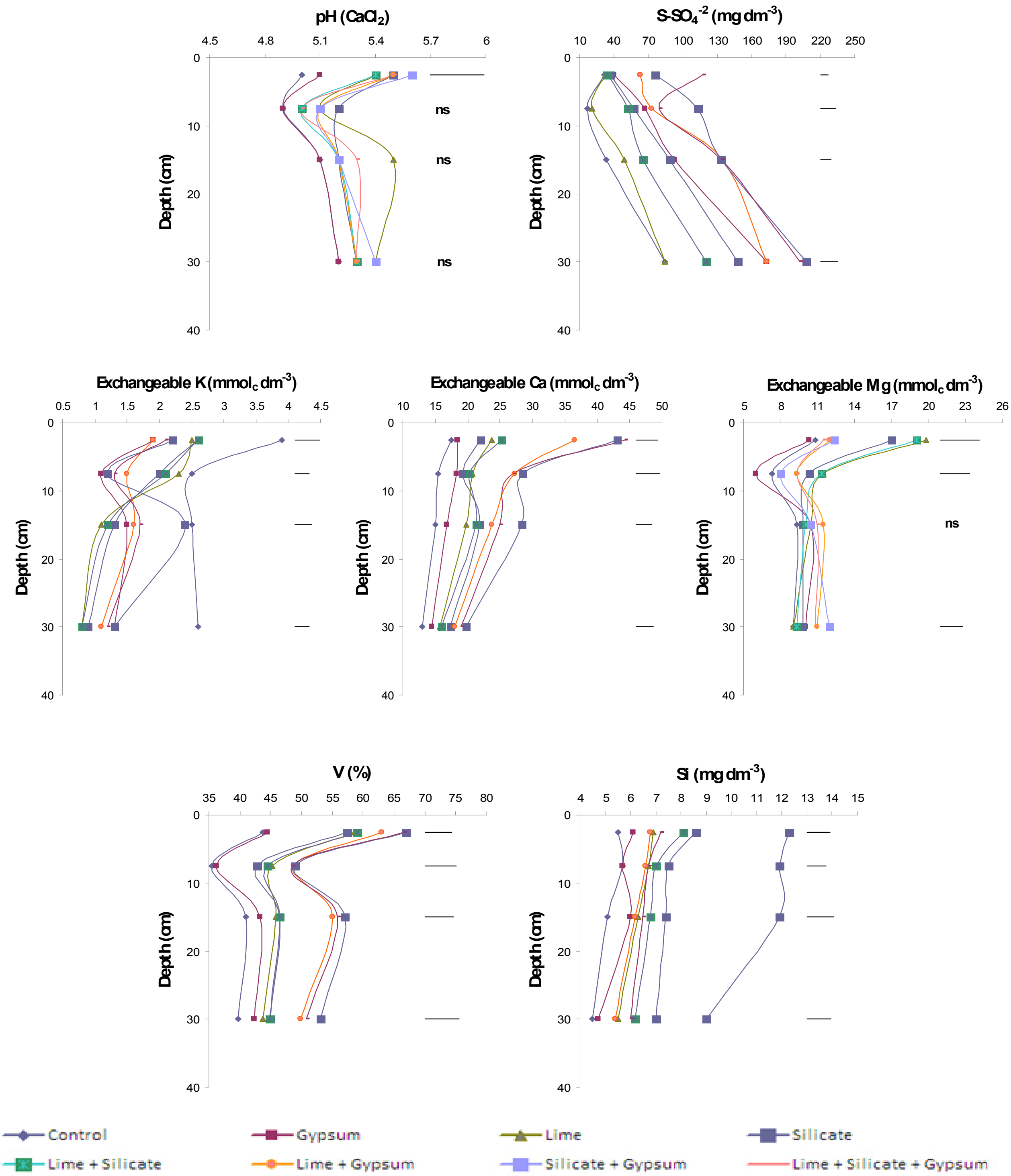


Figure 2. pH, H+Al, S-SO_4^{-2}, exchangeable K, Ca and Mg, base saturation (V%) and Si levels in soil as affected by materials for acidity correction and gypsum under no tillage system 12 months after superficial application.

silicate+gypsum, in the depths 0.05-0.10 and 0.10-0.20 m respectively, were similar to the control. The influence of materials for acidity correction on K leaching is clearly explained by the decrease in K levels compared to the control. Leaching can be a result of SO_4^{2-} and NO_3^- working as accompanying ions. Also, there is the influence of mass in K mobility, due to Ca and Mg added by the products, which compete for the same sorption sites.

Whenever gypsum was added to any of the other products, higher Ca levels were found in all depths (Figure 2). Lime and silicate applied either separately or mixed (LS) showed intermediary values, between the results with gypsum separately or mixed to other materials and the control. Silicate + gypsum greatly influenced Ca levels due to a higher solubility of both products compared to lime. Ca leaching probably occurred due to

SO_4^{2-} and NO_3^- leaching, since both can be accompanying íons for this cation. Considerable mobility of Mg to deeper layers was observed whenever gypsum was mixed with other products, mainly silicate. The application of the materials for correction either separately or mixed (LS) resulted in lower Mg leaching and thus higher levels of this nutrient were found in upper layers (0-0.05 m and 0.05-0.10 m). Base saturation (Figure 2) was influenced indirectly by the treatments due to higher levels of K, Ca and Mg, i.e., the products affected V% in all depths mainly because of Ca and Mg increase. Higher levels were found in the upper layer (0-0.05 m); however, the aimed base saturation was not reached (70%). Better results in all depths were obtained whenever gypsum was added to the other materials. This is a promising alternative for soil acidity correction down the profile in no tillage system with no incorporation. Silicate applied separately (23% of SiO_2) increased Si levels in all depths. Similar results were observed for liming.

Conclusion

Superficial application of silicate in a no tillage system was no better than lime in neutralizing soil acidity down the profile, showing similar efficiency. Some soil chemical attributes (pH, Ca, Mg, K, V%) were affected by the materials used for acidity correction both applied separately and mixed. The number of panicles per m^2 and, consequently, rice yield, were affected by the superficial application of gypsum mixed with other materials for acidity correction.

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