16th WORLD FERTILIZER CONGRESS OF CIEC

TECHNOLOGICAL INNOVATION FOR A SUSTAINABLE TROPICAL AGRICULTURE

PROCEEDINGS

International Scientific Centre of Fertilizers (CIEC)

16th WORLD FERTILIZER CONGRESS OF CIEC

TECHNOLOGICAL INNOVATION FOR A SUSTAINABLE TROPICAL AGRICULTURE

October 20-24, 2014
Rio de Janeiro, RJ - Brazil

PROCEEDINGS

Vinicius de Melo Benites
Adilson de Oliveira Junior
Paulo Sergio Pavinato
Paulo César Teixeira
Milton Ferreira Moraes
Regina Maria Villas Bôas de Campos Leite
Ronaldo Pereira de Oliveira
Editors

Rio de Janeiro, RJ
2014

Electronic editing: Vanessa Fuzinatto Dall´Agnol
Front cover: Neia Sussai
Front cover photographs: Convention Bureau Rio de Janeiro / Stock Free images

1st edition
On line (2014)

The opinions expressed in this publication are the sole and entire responsibility of the authors and do not necessarily reflect the views of Brazilian Agricultural Research Corporation (Embrapa), University of São Paulo (USP) and International Scientific Centre of Fertilizers (CIEC).

World Fertilizer Congress of CIEC (*16. : 2014 : Rio de Janeiro, RJ*)

Technical innovation for a sustainable tropical agriculture : proceedings 16th World Fertilizer Congress of CIEC, Rio de Janeiro, RJ – Brazil, October 20-24, 2014 / edited by Vinicius de Melo Benites... [et al.]. – Rio de Janeiro: CIEC, 2014.

409 p.

ISBN 978-3-95547-013-5

Doi: 10.5073/jka.2014.448.000

1.Fertilizers. I.Oliveira Junior, Adilson de. II.Pavinato, Paulo Sergio. III.Teixeira, Paulo César. IV.Moraes, Milton Ferreira. V.Leite, Regina Maria Villas Bôas de Campos. VI.Oliveira, Ronaldo Pereira de. VII.Título.

631.8 CDD (21.ed.)

LONG TERM EXPERIMENTS WITH REACTIVE PHOSPHATE ROCKS FOR GRAIN CROPS IN CERRADO SOILS

DJALMA M. GOMES DE SOUSA, THOMAZ A. REIN, RAFAEL DE SOUZA NUNES, JOÃO DE DEUS G. S. JUNIOR

Embrapa Cerrados, PO Box 08223, Brasilia, DF, 73310-970, BRAZIL (djalma.sousa@embrapa.br)

Introduction

The Brazilian Cerrado (savannas) comprises aproximatelly 200 million ha in central Brazil with a large predominance of acid low-fertility soils, with Oxisols (Ferralsols) accounting for nearly 50% of the area. Considered waste land for agricultural purposes until the mid 1970s, with the widespread use of limestone and chemical fertilizers the Cerrado has become the country´s main producing region for grain crops and Brazil the largest soybean producer and exporter.

Under natural conditions phosphorus (P) deficiency is the most limiting factor for crop production in these soils, and P fertilizers are essential to achieve satisfactory yields. With the increasing costs of chemical fertilizers it has become more important to identify alternative sources with good agronomic and economic effectiveness. Products with such characteristics are the reactive phosphate rocks (RPR), used in Brazil since many decades. RPRs are of sedimentary origin exhibiting high degree of isomorphous substitutions, mainly PO_4^{3-} by CO_3^{2-} and F^-. Their reactivity expressed by solubility in extracting solutions, the dissolution rates in soils and P utilization by crops are directly associated with the degree of isomorphous substitutions.

In finely ground form as used in the past the first-year effectiveness of highly reactive phosphate rocks is nearly equivalent to water-soluble P sources for annual crops when broadcast and incorporated to Cerrado oxisols with pH below 6.0 (Sousa et al., 1999; Sousa and Lobato, 2004). Current interest and the subject of this work are the unground ("as received") RPRs marketed in Brazil since the beginning of the 1990s, with most particles between 0.15 mm and 0.50 mm. Studies with different crops have shown that unground RPRs exhibit satisfactory agronomic effectiveness in Cerrado soils, with the possibility of partially replacing water-soluble sources when properly used (Sousa et al., 1999, 2010; Sousa and Lobato, 2004).

Solubility and agronomic effectiveness

Figure 1a shows the relationship between the relative agronomic effectiveness (RAE) of seven unground RPRs evaluated for soybeans in a clayey Cerrado oxisol and the solubility of finely ground samples (< 0.063 mm) in 2% citric acid (1/100 w/v) (Sousa et al., 2009). Granular triple superphosphate (TSP) was the reference source (RAE=100%). The fertilizers were broadcast and incorporated at 240 kg/ha total P_2O_5 in the first year, and their residual effect evaluated for five years. Average RAE for the seven RPRs increased from the first to the fourth year. RAE was directly related to the citric acid solubility for the first three years, but no relationship was found in the fourth year when the average RAE was nearly 125% (higher residual effect compared to TSP). In the fifth and sixth years inverse relationships were found, with the lowest soluble sources exhibiting higher residual effects. Cumulative yields of the six soybean crops were similar for the seven RPRs and the TSP treatments, 11.26 t/ha on average, whereas the cumulative yield of the control (-P) treatment was 1.05 t/ha. The relationships between agronomic effectiveness and solubility in two extractants are also shown for RAE calculated from the cumulative yields of the first three crops (Figure 1b).

Therefore, solubility can be used to predict the fresh and residual effects of RPRs in Cerrado soils. Because of the good relationships observed, any of these extractants can be used as an indication of RPR effectiveness in the early years.

Management of reactive phosphate rocks in soils

When broadcast and incorporated at high doses the RPRs currently marketed in Brazil (unground form) exhibit RAE of roughly 50% in the first year increasing to nearly 100% or above in the following one or two years compared to fresh and residual effects of water-soluble P sources. Since the performance of the RPRs quickly increase with time, these products are suitable alternatives to water-soluble sources for corrective ("build up") P fertilization. Sousa et al. (unpublished data) performed a benefit-cost analysis of the corrective fertilization with RPR and TSP broadcast and incorporated at 240 kg/ha P_2O_5 in the first year of an ongoing experiment in a clayey Oxisol under no-tillage. Soybeans and corn were grown for a period of 15 years with millet as winter cover crop. TSP was applied in the seed furrow at 80 kg/ha/year P_2O_5 as maintenance fertilization. The accumulated yield of soybeans and corn was 95.7 t/ha without corrective fertilization. With corrective fertilization using TSP and RPR the accumulated yields were, respectively, 99.2 and 101.0 t/ha, with benefit/cost ratios of 4.4/1 and 7.6/1 considering the unit cost of RPR P_2O_5 as 75% compared to TSP.

Considering the use of RPRs for maintenance fertilization, since short term agronomic effectiveness is very low for band application in the seed furrow or surface broadcast in the case of no-till systems (Sousa and Lobato, 2004; Sousa et al., 1999, 2010), these products are not recommended for soils responsive to P. This was shown in a soybean experiment with TSP and Gafsa phosphate rock broadcast and applied in the seed furrow at 80 kg/ha/year P_2O_5 in a clayey oxisol under conventional tillage and no-till systems (Figure 2). Annual plowing, by incorporating broadcast RPR before planting or thoroughly mixing unreacted RPR previously applied in the seed furrow increases the fresh and residual effects, whereas under no tillage soybean yields with either broadcast or banded RPR were significantly lower compared to TSP for the first five crops.

On the other hand, if maintenance fertilization with RPR is anticipated (pre-applied) to the winter cover crop, RAE for the following cash crop (not fertilized with P) can be improved. This was shown in the 15-year not-till experiment previously mentioned, for treatments starting with adequate (near critical level) soil P. When TSP was applied at 80 kg/ha/year of P_2O_5 in the seed furrow of the cash crops, cumulative grain yield was 99.2 t/ha (average yields of 3.6 t/ha for soybeans and 11.2 t/ha for corn). With RPR applied the same way cumulative yield was 94.9 t/ha (average yields of 3.3 t/ha for soybeans and 10.9 t/ha for corn). On the other hand, when the maintenance application of RPR was anticipated, banded in the seed furrow of the millet cover crop, cumulative yields were equivalent to that of TSP applied to the cash crops (99.2 t/ha, with average yields of 3.6 t/ha for soybeans and 11.2 t/ha for corn).

Lower agronomic effectiveness of surface broadcast RPR compared to band application in the seed furrow has been observed during the first two years after surface application of limestone in no-till systems. The high soil pH of the surface layer, around 7, should decrease the dissolution of RPR. Therefore, in such situation it is recommended maintenance application in the seed furrow rather than surface broadcast.

Soil testing

One aspect that should be considered when using RPRs is soil testing since these sources react slowly in the soil, even when broadcast and incorporated. Mehlich-1 extractant (0.0125 mol/L H_2SO_4 + 0.05 mol/L HCl) adopted by most of the laboratories in the region partially dissolves unreacted phosphate rocks in soil samples taken the year after application, overestimating the availability of soil P for the subsequent crop. Bray-1 (0.03 mol/L NH_4F + 0.025 mol/L HCl) and resin extractants, the later routinely used in many soil testing laboratories in Brazil, could be a solution to this problem, not dissolving less soluble ("non-reactive") phosphate rocks in soil samples (Sousa and Lobato, 2004).

The suitability of soil P extractants was evaluated in a clayey oxisol under no-tillage with soybeans fertilized with RPR and TSP at 80 kg/ha/year P_2O_5 during five years (Sousa et al., 2010). The relationships between grain yields and soil P were not satisfactory for Mehlich-1 as well as for resin methods as used in Brazil, which overestimated soil P availability when fertilized with RPR. This did not occur with Bray-1 extractant, although the prediction of soil P availability was also not very satisfactory, apparently slightly underestimated in the presence of RPR. It makes knowledge of the fertilization history even more important when interpreting soil analysis results and making recommendations for RPR fertilized systems.

- The agronomic effectiveness of RPRs during the first years after broadcast application with incorporation in

Cerrado oxisols is directly related to the solubility in citric and formic acids. In the medium term (>3 years), the residual effects of the least soluble RPRs are equivalent or even slightly higher than water-soluble sources and the most soluble RPRs.

• RPRs are suitable for corrective (build up) fertilization of Cerrado soils. RPRs can also be recommended for maintenance fertilization of grain crops in soils with adequate (near or above critical level) P, being more effective under conventional tillage. The agronomic effectiveness is enhanced when the application of RPR is anticipated to the winter cover crop in no-till grain production systems.

• Mehlich-1 and resin extractants as used in Brazil overestimate the availability of soil P when RPRs are used, which does not occur with the Bray 1 extractant.

References

SOUSA, D.M.G.; LOBATO, E. Adubação fosfatada em solos da região do Cerrado. In: Simpósio sobre fósforo na agricultura brasileira. In: YAMADA, T.; ABDALLA, S.R., eds. Fósforo na Agricultura Brasileira. Piracicaba, Associação Brasileira para Pesquisa da Potassa e do Fosfato, 2004. p.157-200.

SOUSA, D.M.G., REIN, T.A.; GOEDERT, W.; LOBATO, E.; NUNES, R.S. Fósforo. In: PROCHNOW, L. I.; CASARIN, V.; STIPP, S.R., eds. Boas práticas para uso eficiente de fertilizantes: nutrientes, v.2. Piracicaba, IPNI, 2010. p.71-132.

SOUSA, D.M.G.; REIN, T.A.; LOBATO, E. Solubilidade e eficiência agronômica de fosfatos naturais reativos avaliados com a cultura da soja em um latossolo de Cerrado. In: FALEIRO, F.G.; FARIAS NETO, A.L. Simpósio Nacional sobre o Cerrado, 9 / Simpósio Internacional sobre Savanas Tropicais, 2. Menções honrosas. Planaltina, Embrapa Cerrados; Brasília, Embrapa Informação Tecnológica, 2009. p.232-237.

SOUSA, D.M.G.; REIN, T.A.; LOBATO, E.; SOARES, W.V. Eficiência agronômica de fosfatos naturais reativos na região dos cerrados. In: CONGRESSO BRASILEIRO DE CIÊNCIA DO SOLO, 27, Brasília, 1999. Annals... Planaltina, Embrapa Cerrados, 1999. CD-ROM.

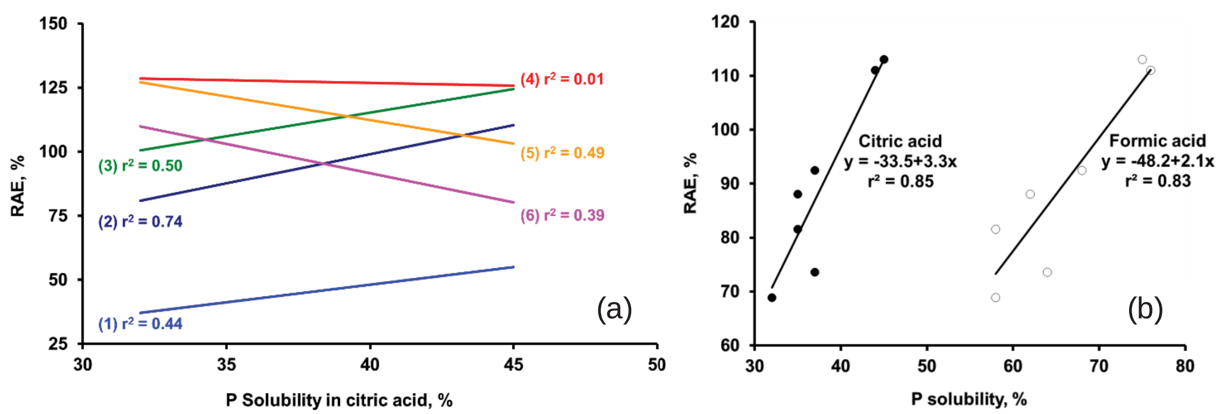

Figure 1. (a) Relationship between the 2% citric acid solubility of seven RPRs broadcast and incorporated in the first year and their relative agronomic effectiveness (RAE) during six years with soybeans. (b) Relationship between RAE calculated from the cumulative yields during the first three years and solubility in 2% citric and formic acids (Source: adapted from Sousa et al., 2009).

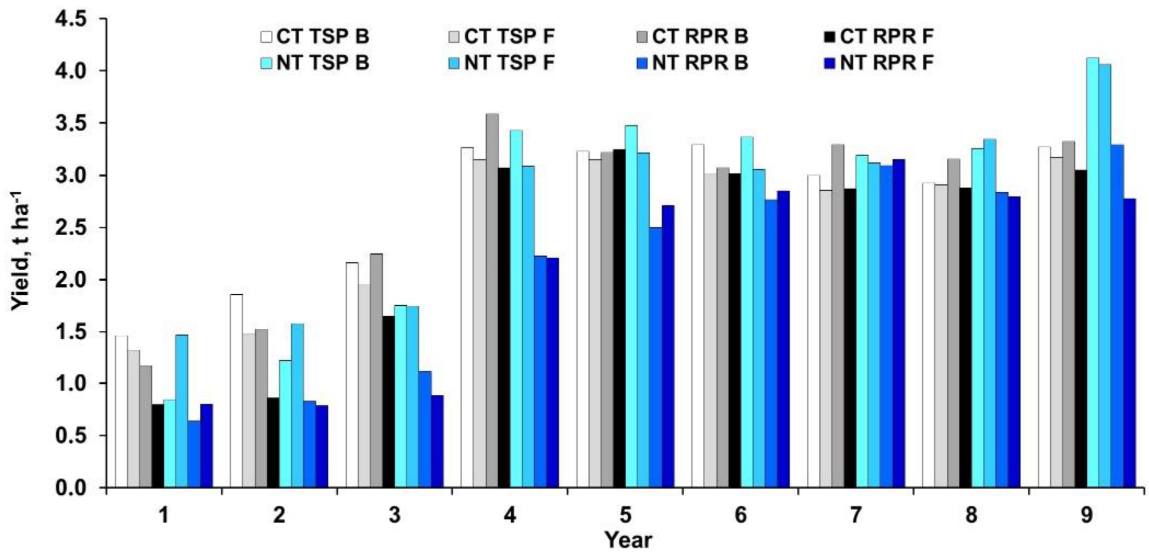

Figure 2. Soybean yields in response to triple superphosphate (TSP) and Gafsa phosphate rock (RPR) broadcast (B) or applied in the seed furrow (F) at 80 kg/ha/year P_2O_5 during nine years in a clayey oxisol under conventional tillage (CT) and no-till (NT) systems (Source: D.M.G. Sousa and R.S. Nunes, unpublished data).