

Sustainable management of calcareous Histosols for crop production

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Abstract

Elemental S is used as an amendment for Everglades Agricultural Area soils of south Florida to decrease pH and increase P availability to crops. Our objectives were to determine how S application altered phosphorus availability and microbial activity in organic soils under sugarcane cultivation. Sulfur application had minimal effect on soil pH and thus generally failed to increase P supply to sugarcane during the entire growing season at the application rates tested due to the high soil buffering capacity against acidification. Yet, a significant reduction in soil pH did increase P concentrations in labile P and Fe-Al bound P fractions at 2 months for the highest S rate. The size of the Ca-P fraction remained unchanged during the early season but significantly decreased at the end of the growing season. Humic-fulvic acid P fluctuated seasonally, averaging 143, 172, 139, and 181 mg P/kg for 2, 6, 9, and 13 months, respectively. Residual P fluctuated in a contrasting pattern to humic-fulvic acid P and contributed approximately 50% to the total P. Sulfur had minimal effect on enzyme activity and microbial biomass beyond a short-term enhancement at 2 months. Considering the entire range of S application, S did not result in a large P accumulation in labile pools, thus it not appear to enhance potential P export from fields to the environment.

Introduction

The Everglades Agricultural Area (EAA) in south Florida consists primarily of Histosols that were drained in the early 1900s and converted to sugarcane and vegetable cropping. These soils contain low P and micronutrient concentrations that require supplemental fertilization (Snyder 2005; Castillo and Wright 2008). Underlying these organic soils is limestone, and due to the conversion of land from seasonally-flooded wetlands to agricultural use, oxidation has occurred at 1.5 cm/y (Shih *et al.* 1998). The depth of the soil has declined considerably to the point of causing significant interaction with the underlying bedrock. Cultivation of these drained peatlands, specifically the use of tillage, has resulted in incorporation of bedrock CaCO₃ into soil, which has increased the pH from the historic 5.0-5.5 to approximately 7.0-7.5 today (Snyder 2005; Gabriel *et al.* 2008). Subsequently, these soil pH increases have decreased P and micronutrient availability to crops and necessitated new fertilizer management practices or use of soil pH amendments. The Everglades wetlands of south Florida are traditionally P limited and sensitive to small increases in P loading. Reducing P export from the EAA is critical to fulfilling the emerging interests of protecting water quality and restoring south Florida ecosystems. Due to the increases in pH and the decreasing depth to bedrock of soils in the EAA, use of S application to counteract the rising pH may increase in the future. Therefore, a better understanding of how S influences pH and P distribution and availability is the objective of this study.

Materials and methods

The experimental site is located in the central EAA on Dania muck (euic, hyperthermic, shallow Lithic Haplosaprist) with a depth to bedrock of approximately 45 cm. The experimental design was a randomized complete block with four S application rates and four field replications. Each field plot measures 9 m x 13 m and consists of 6 rows of sugarcane (*Saccharum sp.*). Elemental granular S (90%) was applied at rates of 0, 112, 224, and 448 kg S/ha to the furrow and covered after planting sugarcane in the furrow. Other fertilization was provided using typical guidelines for this region (Rice *et al.* 2006). Sugarcane was planted in November 2007 and harvested in February 2009. Soil samples were collected before planting and fertilizer application and then in January 2008, May 2008, August 2008, and December 2008, corresponding to approximately 0, 2, 6, 9, and 13 months after planting, respectively. Twelve soil (0-15 cm) cores (2.54 cm diameter) were randomly collected from rows within each field plot and composited. Soil chemical, physical, and microbial properties were analyzed.

Results and discussion

Overall, S application within the range of 0 to 448 kg S/ha did not significantly reduce soil pH. Labile P is commonly considered the most biological available form of P and consistently represented the smallest fraction of total P throughout the growing season, decreasing from 1.1% to 0.3% from 2 to 13 months.

Labile P was significantly higher in soils receiving 448 kg S/ha (13 mg P/kg) compared to soils receiving 112 (6 mg P/kg) and 224 kg S/ha (6 mg P/kg). Phosphorus concentrations in the Fe-Al bound fraction displayed a clear declining pattern during the growing season. Phosphorus stocks in the Ca-bound fraction were much higher than those of labile and Fe-Al fractions, contributing 28-35% of the total P as a result of high Ca concentrations in the soil. Residual P was the most abundant P fraction for all sampling times, accounting for 47-51% of the total P. Sulfur application at 448 kg S/ha promoted P accumulation in labile P and Fe-Al-P fractions, suggesting increased P availability to crops and as well as potential increased risk of P export at this high rate since these fractions are the most prone to contribute P to soil solution.

Sulfur application also had effects of enzyme activities in the short-term. The S application effect on phosphatase activity was significant, yet the effect was only observed at 2 months after S application. Glucosidase activity significantly increased at 2 months, averaging 15, 56, 58, and 99 mg MUF/kg/h for the increasing S application rates. Microbial biomass C and N were not altered as a result of S amendment, but did fluctuate during the growing season dependent on temperature patterns. Microbial biomass P increased significantly at 2 months at the highest S rate (177 mg/kg), which was about 3 times higher than for lower S application rates. Soil oxidation rates, and N and P mineralization, did not differ between soils receiving variable S application rates.

Conclusions

Application of elemental S at 448 kg S/ha increased P availability at 2 months, which subsequently stimulated some enzyme activities and simultaneously promoted labile P to be immobilized in microbial biomass. However, these effects were temporary and not observed beyond 2 months. Organic P was the major form of P in this soil, averaging 63% of total P, while the Ca-P fraction dominated the inorganic pools, contributing 32% of total P. Total P concentrations in the surface soil decreased significantly at the end of growing season as a result of considerable reduction in inorganic P, especially labile P and Fe-Al-P, which comprised of the majority of available P for crops. Under current sugarcane production, organic P in this soil is susceptible to oxidation and a potential source for P loss. Application of S at rates up to 448 kg S/ha introduced limited effects on reduction in soil pH, yet it promoted P accumulation in labile and Fe-Al bound fractions, which increased P availability and as well as the risk of P export from these two fractions. The pool of Ca-P was relatively stable under current S application guideline and rates. Higher S rates than currently recommended may overcome the soil's buffering capacity and consequently release large amounts of P from the Ca-bound pool and pose an environmental hazard, so it must be well evaluated.

References

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