FGD GYPSUM USE AS A SOIL AMENDMENT TO REDUCE SOLUBLE P IN SOIL

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ABSTRACT

Phosphorus loss from land-applied manure can be a major threat to water quality. Use of gypsum as a soil amendment could potentially minimize the water quality threat by reducing P loss from manured soils. Thus, a field study was conducted to evaluate if gypsum and lime amendment would reduce the extractability of P in soil. The study was located at the Sand Mountain Substation in the Appalachian Plateau region of Northeast Alabama, USA, on a Hartselle fine sandy loam (fine-loamy, siliceous, subactive, thermic Typic Hapludults). Poultry litter was applied at a rate of 4 tons acre^{-1}in an established bermudagrass pasture (*Cynodon dactylon* L.). Treatments consisted of commercial gypsum (1, 5, and 10 tons acre^{-1}), flue-gas desulfurization (FGD) gypsum (1, 5, and 10 tons acre^{-1}), FGD gypsum + fly ash (1, 5, and 10 tons acre^{-1}), lime (5 tons acre^{-1}), gypsum + lime (5 ton acre^{-1} gypsum and lime at an equivalent Ca content), and a control. Soil samples were collected at two depths (0-2 and 2-6 inches) and evaluated for water extractable P, Mehlich 3 extractable P, and Total P concentrations. Phosphorus concentrations in soil were the greatest in the first soil samples collected after poultry litter application. Also the greatest concentration of P was observed in the surface 0-2 inches of soil. Overall, the addition of all of the gypsum and lime treatments significantly reduced water extractable P concentrations in soil. No significant differences were observed between gypsum sources at the same rate. Averaged across gypsum sources (commercial gypsum, FGD gypsum, and FGD gypsum + fly ash), increases in application rates resulted in a greater reduction of soluble P. Similar results were achieved at the lower depths. No significant differences between treatments were observed for the Mehlich 3 P and total P concentrations. However, a trend was observed with the use of Mehlich 3. The Mehlich 3 extraction solution resulted in an increased P concentration with the gypsum sources and lime treatment additions. Information from this study may be useful in helping land managers and producers reduce the potential loss of P from agricultural fields.

INTRODUCTION

Concerns for environmental quality have prompted interest in recent years to develop agricultural practices that mitigate nutrient loss to the environment. This is of great concern, because in the southeastern USA, where the poultry industry is steadily increasing, management and disposal of poultry waste is becoming a top priority.

One approach to reduce runoff losses of P is to treat manure or the soil receiving manure with chemical amendments. Use of gypsum as a soil amendment seems promising. Studies have shown that the addition of gypsum can effectively reduce soluble P in runoff from soil with high soil test P (Stout et al., 1998) and from poultry litter additions (Watts and Torbert, 2009). Gypsum reduces P losses by decreasing the disaggregation of soil particles, thereby reducing the amount of P transported with sediment (McCray and Sumner, 1990). It is also suggested that a reduction in P losses can arise from the formation of an insoluble Ca phosphate complex when gypsum reacts with soluble phosphate (Brauer et al., 2005). This is a result of insouble hydroxyapatite and fluorapaptite forming when soluble P reacts with Ca (Linsday, 1979).

Mined Gypsum is often used as a calcium additive supplement for peanuts, but is not commonly used in hay and other row crop production systems due its high cost. Flue gas desulfurization (FGD) gypsum may be an alternative to mined gypsum. Use of FGD scrubbers to remove sulfur from the flue gas of coal-burning power plants for electricity production yields gypsum as a byproduct of the scrubber process. Presently, FGD gypsum is used primarily by the wallboard industries. However, installation of FGD scrubbers is expected to significantly increase in response to new and existing air pollution regulations, with a concomitant increase in FGD gypsum. The current wall board markets are not expected to be able to utilize all of the FGD gypsum produced. The beneficial uses of gypsum on agricultural land could provide an additional use for FGD gypsum, which represents a low cost alternative to commercially mined gypsum. Also, FGD gypsum has a higher $CaSO_4 \cdot 2H_2O$ content and fewer impurities than commercial mined gypsum and contains much smaller, finer, more uniform particle size (Dontsova et al, 2005; Srivastava and Jozewicz, 2001; Chen et al., 2008). Thus research is needed to evaluate FGD gypsum's impact on reducing the solubility of P in soil.

MATERIAL AND METHODS

Site Description

The field study was conducted in 2008 at Auburn University's Sand Mountain Research and Extension Center located in the Appalachian Plateau region of Northeast Alabama on an established bermudagrass pasture. The soil was a Hartsells fine sandy loam (fine-loamy, siliceous, subactive, thermic Typic Hapludults), which consists of moderately deep, well drained moderately permeable soil that is formed from acid sandstone. The surface soil (6 inches) at the time of study initiation was characterized as 11.9 % clay, 28.9 % silt, and 59.6% sand with an average bulk density of 1.5 g cm^{-3}. Climate in this region is subtropical with no dry season; mean annual rainfall is 52 inches, and mean annual temperature is 61ºF (Shaw, 1982). Prior to initiation of the field study, no known history of fertilization had occurred since the establishment of the Research station in 1929.

Cultural Practices and Treatments

The bermudagrass pasture was cleared of any weeds or senesced plant material prior to establishment of plots. Experimental plots 12 ft wide and 20 ft long were arranged in a randomized complete block design with four replications. The experimental treatments consisted of three gypsum sources (commercially available bag gypsum, FGD-gypsum from TVA, and FGD-gypsum + fly ash from TVA) applied on May 21, 2008 at three different rates for the gypsum source (1, 5, and 10 tons $acre^{-1}$), and compared to lime at 5 tons $acre^{-1}$, mixture of commercial gypsum at 5 tons $acre^{-1}$ + lime at an equivalent Ca content, and control (fertilized with poultry litter only). Poultry litter was applied as the nitrogen source at a rate of 4 tons per acre (maximum 1 time application rate for Alabama) on all plots. Poultry litter was surface broadcasted using a pull behind John Deere Manure Spreader. Poultry litter used in this study was collected from a local poultry production facility and consisted of poultry manure and a bedding material mixture. Following the application of poultry litter, surface broadcast application of the gypsum sources and lime treatments were applied on top of the poultry litter. The bermudagrass was managed as a pasture used for hay production.

Soil Sampling

Soil samples were collected on 14 of August and 8 of November, 2008. Soil was sampled at 0-2 and 2-6 inch depth increments. Eight soil cores (1 inch dia) were collected per plot and composited by depth; surface plant residue was removed from the sample. After returning to the laboratory, soil samples were passed through a 0.08 inch sieve to remove root material. Soil mass was recorded and moisture content was determined gravimetrically. Sub-samples were stored at 39°F until use.

Laboratory Analysis

Laboratory analysis was performed by Ohio State University Soil Testing Laboratory. Specifically, soil pH was determined on 1:1 soil/water suspensions with a glass electrode pH meter. Total P was determined by perchloric/nitric acid digestion, acid extractable P was determined using a Mehlich 3 extracting solution, and water extractable P was determined using 1:5 ratio (soil/water). Both the total P and Mehlich 3 extractable P were analyzed using the ICP, and water extractable P was analyzed colorimetrically.

Statistics

The experimental design was a randomized complete block design, with the four blocks representing replicates. Statistical analysis was performed using a GLM procedure of SAS (SAS Institute, 1985). Statistical comparisons were made at a significance level of $\alpha < 0.10$ established *a priori*. Values that differed at the $0.10 < P < 0.25$ level were considered trends. The term *trend* is used to designate appreciable, but not significant, treatment effects.

RESULTS AND DISCUSSION

The goal of this study was to evaluate the impact commercial gypsum, FGD-gypsum and FGD-gypsum + fly ash have on reducing soluble P in soil resulting from poultry litter application. Higher P concentrations in soil were observed on the first soil sampling day compared to the second sampling time. Also, soils collected from the 0-2 inch depth had significantly higher P compared to the 2-6 cm depth. This was not surprising because the P that is applied to agricultural fields tends to be adsorbed on the soil surface.

Mean water extractable P concentrations as affected by treatment addition are shown in Figure1. Overall, treatment additions of gypsum and lime significantly reduced water extractable P concentrations in the bermudagrass pasture soil compared to the control (P = 0.0052). The greatest reduction of P resulting from gypsum and lime addition was observed in the 0-2 inch depth compared to the 2-6 inch depth (P<0.0001). This was to be expected since the soil surface contained greater concentrations of P. As gypsum rates increased, regardless of gypsum type (commerical gypsum, FGD-gypsum, FGD-gypsum+fly-ash), water extractable P concentrations in soil significantly decreased (P = 0.0103). On August 14, 86 days after poultry litter fertilization, an average 10 ppm water extractable P concentration (control treatment) was observed in the surface 0-2 inches of soil. Averaged across the three gypsum treatments (commercial gypsum, FGD-gypsum, FGD-gypsum+fly ash), water extractable P concentration in soil decreased significantly to 8.5, 6.7, and 5.7 ppm with the addition of 1, 5, 10 lbs acre^{-1} of the gypsum treatment, respectively.

Mehlich 3 extractable P, which is often used as a plant available P index for eastern U.S. soils, resulted in higher concentration of P compared to the water soluble P. This was expected since the Mehlich 3 extraction solution is an acid, which is more effective at releasing P from soil particles. However, the use of this extractant was less sensitive in differentiating between treatments. The only significant differences observed for Mehlich 3 P concentrations was depth (P = 0.006). A trend was observed between treatments and application rates. Addition of gypsum sources and lime tended to increase the amount of Mehlich 3 extractable P in soil compared to control (P = 0.2319). Increases in Mehlich 3 extractable P in comparison to the control may be attributed to the technique used to measure the P concentration. The Mehlich 3 soil extracts were analyzed using the ICP. Unlike colorimetric procedures for analyzing P, the ICP can measure both inorganic and organic P fractions. Thus, if the P-containing particulates (colloidal materials) were not removed during the filtering process and/or the presence of soluble P complexes with iron (Fe), Aluminum (Al) and/or calcium (Ca) measurement of some fraction of these soluble or suspended P components that would not be measured using colorimetric procedures.

In general, Mehlich 3 P tended to increase in concentration from the 1 to 5 ton acre^{-1} rate and decrease from the 5 to 10 ton acre^{-1} rate for all three gypsum treatments. This was probably attributed to addition of a large quantity of material resulting in a dilution of soil P at the 10 ton acre^{-1}rate. Significant differences were observed between sampling dates. Similar to the water soluble P, concentrations of Mehlich 3 extractable P in soil decreased in November compared to the August sampling date.

No significant differences were observed in total P concentrations. However, similar patterns between treatments and rates were observed between the Mehlich 3 and the total P concentrations. This suggests that the Mehlich 3 P concentrations from the soil extract could have contained some soluble as well as organic fractions. Further research is needed to evaluate the impact of gypsum treatment on reducing soluble P losses from agricultural fields, and to determine how often and optimum rate of application needed to reduce P solubility in soil.

CONCLUSIONS

The addition of gypsum to soil as an amendment has the potential for reducing the amount of water soluble P. Greater water soluble P reductions from soil were also observed with increasing rates. Our data, although short-term, suggest that adding gypsum to manure amended soil would reduce the potential loss and export of P in surface water runoff.

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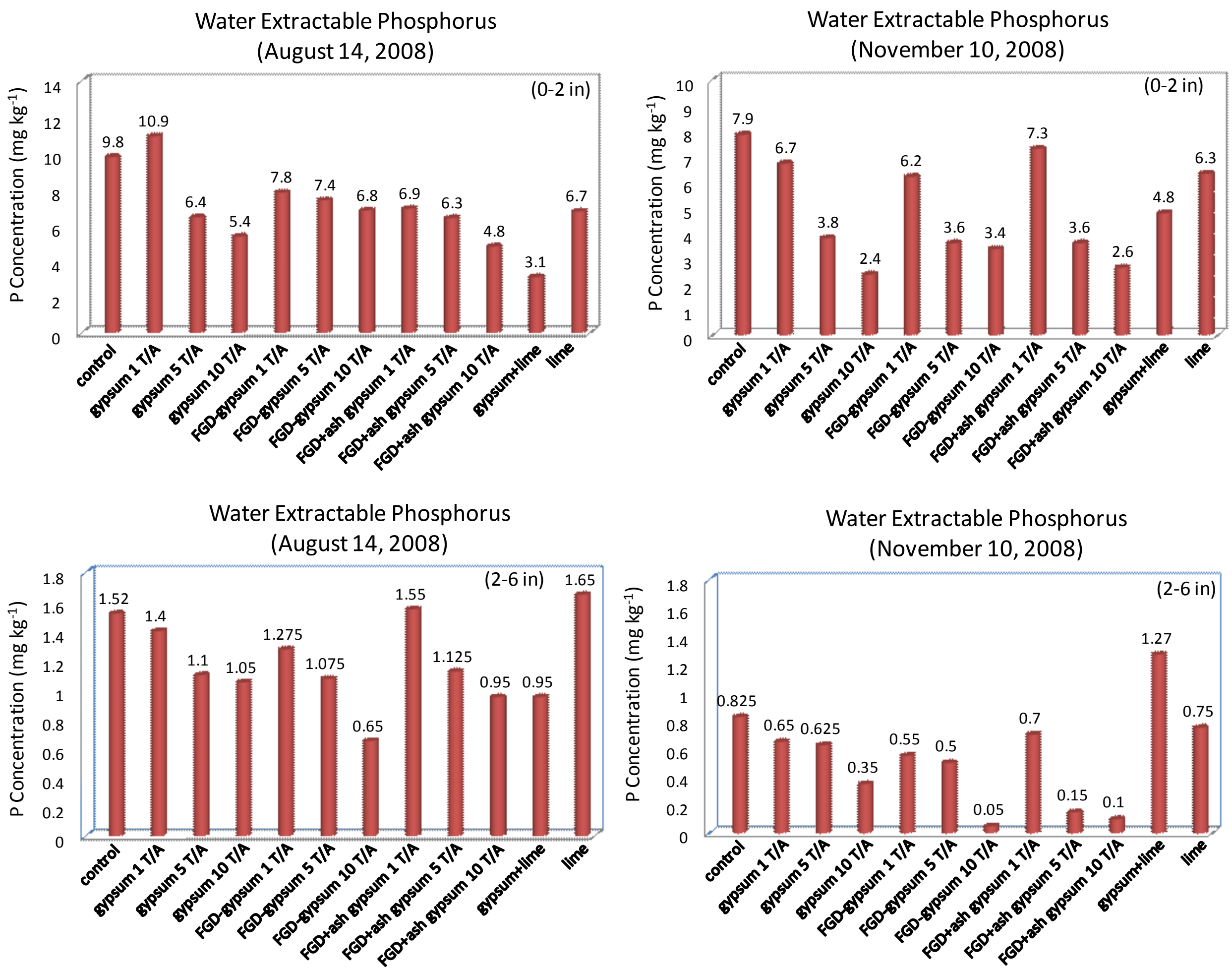

Figure 1. Water soluble P concentrations in soils amended with different gypsum sources and lime treatments at two depths (0-2 and 2-6 inches) from August and November's soil sampling.

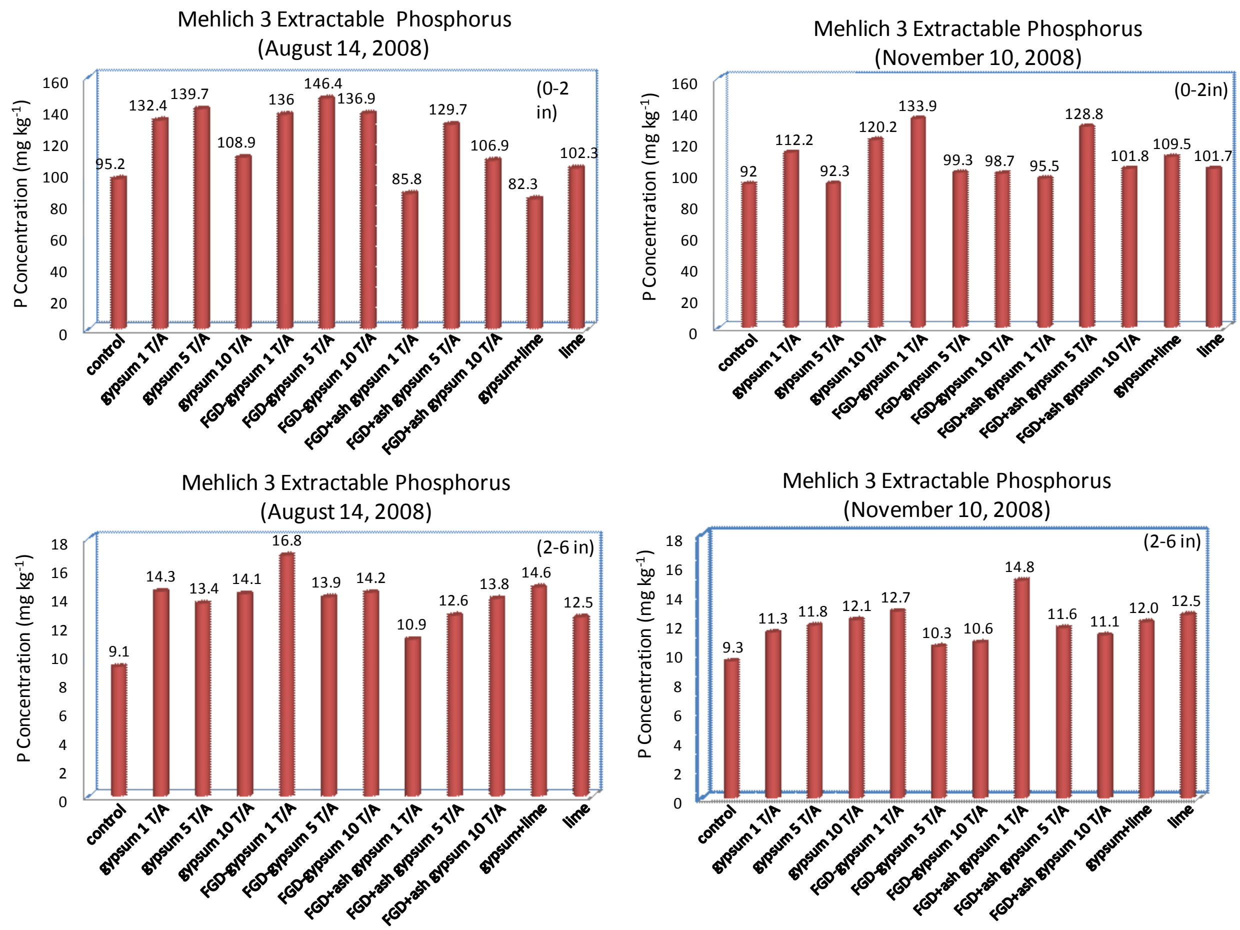

Figure 2. Mehlich 3 P concentrations in soils amended with different gypsum sources and lime treatments at two depths (0-2 and 2-6 inches) from August and November's soil sampling.

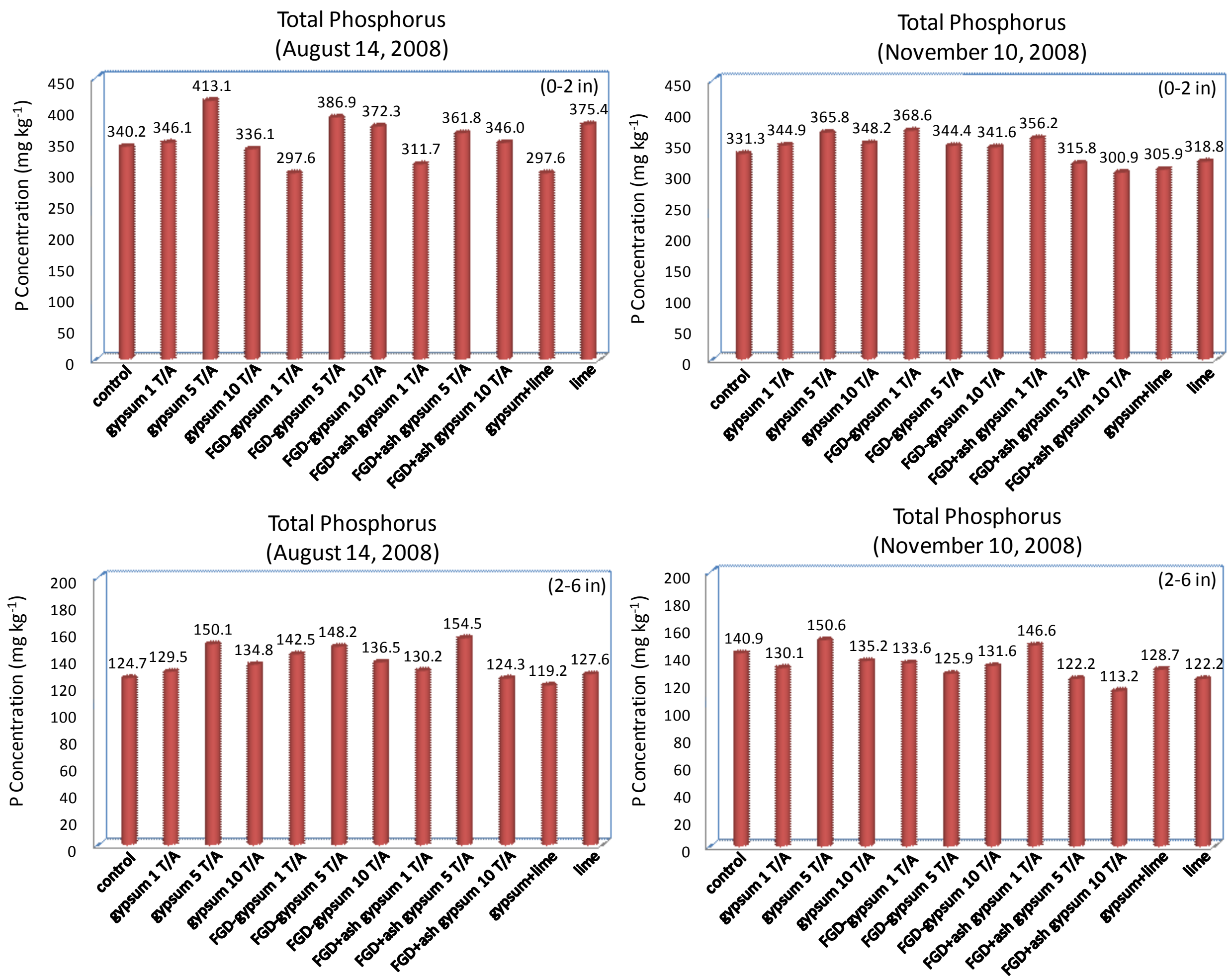

Figure 3. Total P concentrations in soils amended with different gypsum sources and lime treatments at two depths (0-2 and 2-6 inches) from August and November's soil sampling.