Gypsum Use to Reduce P Loss From Agricultural Fields 2013

Bulletin No. 680
Alabama Agricultural Experiment Station, 2013
William Batchelor, Director
Auburn University
Auburn, AL

FGD Gypsum may be stockpiled at the edge of the field until ready to spread.

AUBURN
ALABAMA AGRICULTURAL EXPERIMENT STATION

In cooperation with the Alabama Cooperative Extension System
(Alabama A&M University and Auburn University)

Authors

D.B. Watts
Research Soil Scientist
USDA Soil Dynamics Laboratory
Auburn, AL 36832

H.A. Torbert
Supervisory Soil Scientist
USDA Soil Dynamics Laboratory
Auburn, AL 36832

C.C. Mitchell
Extension Agronomist & Professor
Agronomy and Soils
Auburn University, AL 36849

Table of Contents

Introduction

Public concern regarding agriculture's contribution to surface water quality impairment has increased in recent years. Specifically, phosphorus (P) has been identified as the most critical nutrient threatening surface water quality due to its role in eutrophication. As a result, controlling excessive P loss from agricultural fields has become an environmental priority. Therefore, efforts are underway to develop best management practices (BMPs) that can assist producers in making environmentally sound decisions to reduce agriculture's contribution of soluble P to surface waters.

Fertilizer and manure application rates that are greater than crop requirements can exacerbate P losses in runoff to surface water. This has led to increased scrutiny of current manure application practices. Traditionally, manure has been repeatedly applied to pastures and hayfields based on crop nitrogen (N) demands rather than P requirement, thereby contributing to a buildup of soil P. High soil P concentrations can contribute to soluble P losses in surface water runoff. In addition, initial runoff following manure applications may override the soil's natural ability to absorb P, resulting in a flush of P loss. Thus, BMPs are needed to abate edge-of-field P losses from high soil P concentrations as well as initial runoff following manure applications. Implementation of the Phosphorus Index is an attempt to estimate the risk of P runoff from the landscape. The Alabama P Index includes factors that are considered major risks in Alabama fields. Some factors can be modified using BMPs while others cannot (Table 1).

Table 1
Factors used in Alabama's current P Index.

Factors that cannot be modified	Factors affected by BMPs
Soil test P	P application rate
Underground outlet system	Nutrient application method
Hydrologic soil group	Grazing animals
Field slope	Erosion rate
Impaired or outstanding water	P application distance to water Filter strip width

Another promising BMP is the use of gypsum ($CaSO_4{\cdot}2H_2O$) as soil amendment to reduce P loss from agricultural fields. Gypsum is a calcium (Ca) and sulfur (S) fertilizer source often applied to peanuts during flowering to insure adequate Ca availability in the fruiting zone during pod development. Gypsum has been shown to react with P in soil and manure, resulting in the formation of insoluble Ca phosphate complexes and thereby decreasing the potential of P loss with surface water runoff. However, gypsum is not commonly used for pastures, hayfields and other row crop production systems due to cost considerations.

Flue gas desulfurization (FGD) gypsum, a by-product generated when S is removed from smoke stacks of coal burning power plants, may be a lower-cost alternative to mined gypsum. Presently, FGD gypsum is used primarily by the wallboard industry. 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 wallboard markets are not expected to be able to utilize all of the FGD gypsum produced. Additionally, FGD gypsum has a higher $CaSO_4{\cdot}2H_2O$ content, fewer impurities than commercially mined gypsum and contains much smaller, finer and more uniform particles (Dontsova et al, 2005; Srivastava and Jozewicz, 2001; Chen et al., Mitchell, 2010). Since FGD gypsum appears to be a viable fertilizer source for agricultural use that could potentially achieve reductions in P losses when used in conjunction with manure applications, research was conducted to evaluate FGD gypsum's impact on reducing soil P solubility and its potential as a best management practice.

Objectives and Procedures

Objective: The purpose of this study was to determine if FGD gypsum could be used as a soil amendment to reduce water-soluble P concentrations and P losses in surface water runoff from bermudagrass pastures in North and Central Alabama fertilized with poultry litter.

Procedures: Two experiments were conducted on established Coastal Bermudagrass (*Cynodon dactylon L.*) pastures used for hay production in Northeast and East-Central, Alabama. The Northeast Alabama experiment was conducted at the Sand Mountain Research and Extension Center in Crossville, AL, on a Hartsells fine sandy loam (fine-loamy, siliceous, subactive, thermic Typic Hapludults) from 2008 through 2009 to evaluate the effectiveness of different gypsum sources in reducing soluble P concentrations in soil. The East-Central Alabama experiment was conducted at the E.V. Smith Research and Extension Center Field Crops Unit in Shorter, AL on a Luverne sandy loam (fine, mixed, semi-active, thermic Typic Hapludults) from 2009 through 2011 to evaluate the effects of FGD gypsum in reducing soluble P loss to surface water runoff. Poultry litter was used as the fertility source for both experiments. Experiments were conducted on land where manure had not been applied to the agricultural fields within the last 10 years.

Water Soluble P Concentrations in Soil

When evaluating the effectiveness of gypsum on reducing water-soluble soil P following poultry litter use in Northeast Alabama, three gypsum sources were used: commercially available mined gypsum, FGD gypsum from TVA power company and FGD gypsum + fly ash from TVA power company. Poultry litter was applied at a rate of 4 tons acre^{-1} (maximum one-time application rate for Alabama) to all plots on May 21, 2008 using a pull-behind John Deere Manure Spreader. Later the same day, gypsum from all sources was surface broadcast applied by hand. Gypsum was applied at three rates (1, 5, and 10 tons acre^{-1}), and compared to a control fertilized with poultry litter only. Soil samples for the first season were collected on August 14 and November 10, 2008 and April 30, 2009. During the second growing season poultry litter was applied on May 15 in 2009, but no additional gypsum was applied. Soil samples were taken on July 21 and October 15, 2009 to evaluate the residual gypsum effects on reducing water-soluble P following the 2009 poultry litter application. Samples were collected using a 1-inch soil probe at the 0-2 and 2–6 inch depth increments and analyzed for water-extractable P using a 1:5 ratio (soil/water).

Phosphorus Loss to Surface Runoff

Rainfall simulations were conducted in East Central Alabama to evaluate the effect FGD gypsum has on reducing soluble P loss in surface water runoff. Treatments consisted of four rates of FGD gypsum (0, 1, 2, and 4 tons acre^{-1}) surface-applied to the bermudagrass pasture fertilized with 6-ton acre^{-1} poultry litter. A 4-ton acre^{-1} FGD gypsum treatment with no poultry litter and a non-fertilized treatment (no litter or FGD gypsum) were utilized as controls. All treatments were applied to plots in May of 2009, 2010 and 2011. A rainfall rate of 3.5 inches per hour was applied to create surface water runoff. Once surface water runoff commenced, water was allowed to run off for 60 minutes. Surface water samples were collected at 10, 30 and 60 minute intervals during the runoff event and analyzed for soluble P loss. Three rainfall simulations were conducted to evaluate the effectiveness of using FGD gypsum to reduce P loss with surface water runoff. The series of rainfall simulations began in 2009, with the first evaluation of runoff beginning six weeks after treatment application. Two rainfall simulation studies were conducted in 2011, one immediately after treatment application and another six months after treatment application.

Results and Discussion

Soluble P Concentrations in Soil

Following poultry litter application, higher water-soluble P concentrations in soil were observed on the first soil sampling day following poultry litter application and tended to decrease over time (Figures 1–5). This suggests that the greatest impact for reducing water-soluble P is shortly after manure application. The greatest soluble P concentrations were observed at the 0–2 inch depth compared to the 2–6 inch depth. This was not surprising since previous studies have shown that P applied to agricultural fields generally adsorbs to the soil surface. Overall, gypsum additions significantly reduced water-extractable P in soil under the bermudagrass pasture compared to the control (P = 0.0052). A greater P reduction resulting from gypsum application was observed at the 0–2 inch depth compared to the 2–6 inch depth ($P<0.0001$), consistent with observed soil P concentrations. Regardless of gypsum type, as gypsum rates increased (commercial gypsum, FGD-gypsum, FGD-gypsum + fly-ash), water-extractable P concentrations in soil significantly decreased (P = 0.0103).

In year two, gypsum was not applied. Although modest reductions in water soluble P were observed following poultry litter application the second year (Figures 4–5), the greatest and most consistent reductions were observed the first year following poultry litter application. This suggests that gypsum should be applied at the time of manure application to achieve the greatest benefits of water-soluble P reduction in soil.

Phosphorus Loss to Surface Runoff

Soluble P losses for each of the three rainfall simulations are presented in Figures 6-8. Poultry litter application significantly increased soluble P concentration losses compared to the control (no litter or gypsum). Positive responses were observed for FGD gypsum additions, substantially reducing P loss from poultry litter fertilized pastures, regardless of rainfall simulation timing. Significant differences were also observed between gypsum rates, with P loss generally decreasing with increasing FGD gypsum rate. In this study, the poultry litter treatment without gypsum represented the worst case scenario for P loss and the control (no litter or gypsum) represented background levels. The addition of FGD gypsum at 4-ton $acre^{-1}$ to the unfertilized (no litter) pasture generally reduced soluble P concentrations in runoff to levels below background (data not shown). These results suggests that FGD gypsum additions could be used as an abatement practice to reduce soluble P loss from high soil test P soils as well as following manure applications.

The series of rainfall simulations were conducted on the same plots six weeks after treatment application in 2009, immediately after treatment application in 2011 and six months after treatment application in 2011. Conducting the rainfall simulations immediately after treatment application allowed us to determine FGD gypsum's effectiveness at reducing P loss when the loss potential is high (Figure 6). Conducting rainfall simulations three years after repeated treatment application allowed us to determine the FGD gypsum's long-term impact on reducing P loss (Figure 8). The greatest potential for reducing P loss was observed during the runoff event occurring immediately after poultry litter application (Figure 9). This indicates that controlling P in surface runoff during the first runoff event following poultry litter application is most important. Lower concentrations of P lost in subsequent runoff events was most likely because most of the soluble forms of P in the poultry litter had been released and had adsorbed to the soil or been lost to runoff during previous events. The effectiveness of gypsum was observed immediately after application, five weeks after application, and six months after application. This suggests that gypsum amendments could be effectively used as a BMP to reduce soluble P loss from bermudagrass pastures fertilized with poultry litter to prevent the initial flush of P loss, as well as subsequent losses in succeeding runoff events. However, if poultry litter is used for fertilization the following year, gypsum should be reapplied. It is also important to note that this study indicates that a rate of 2-ton $acre^{-1}$ would be optimal to get the most economical benefits from using gypsum to reduce P loss.

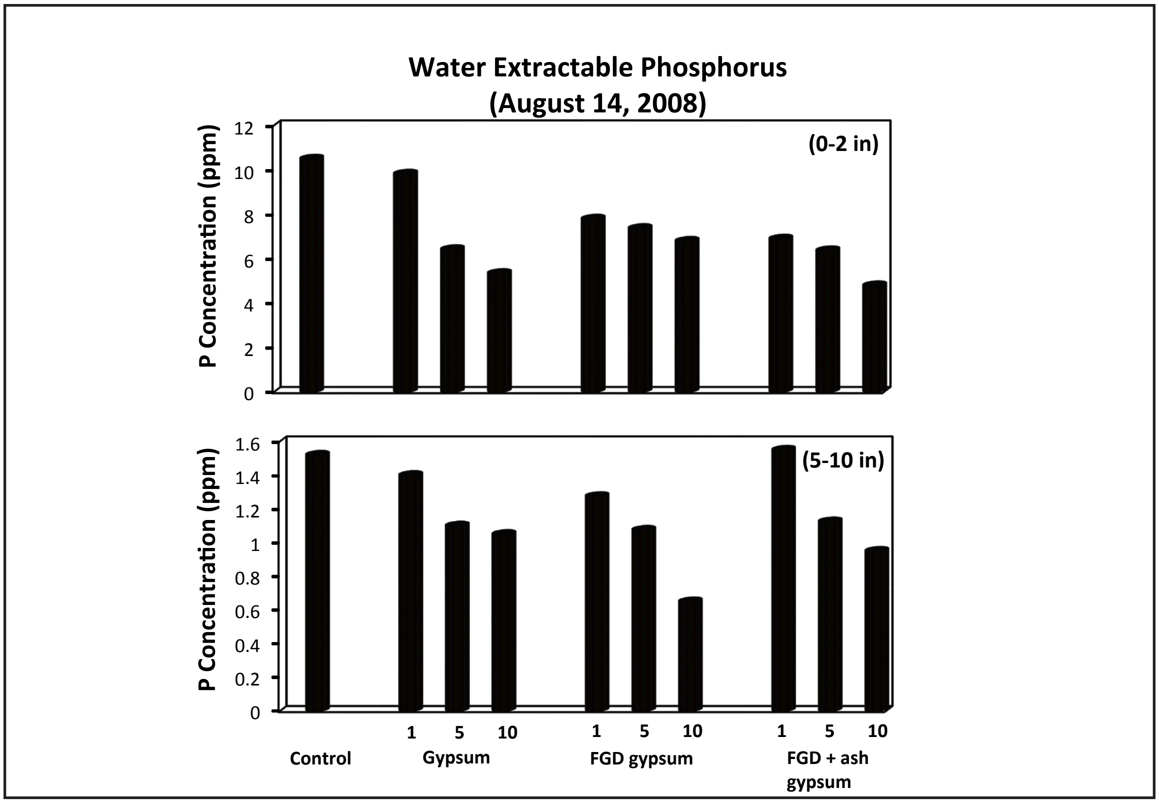

Figure 1. Water soluble P concentrations observed on August 14, 2008, in soil at two depths (0-2 and 2-6 inches) amended with gypsum, FGD gypsum, and FGD gypsum + fly ash applied at 1, 5 and 10 tons acre $^{-1}$ and compared to a poultry-litter-only control. Note difference in scale of the vertical axis between depths.

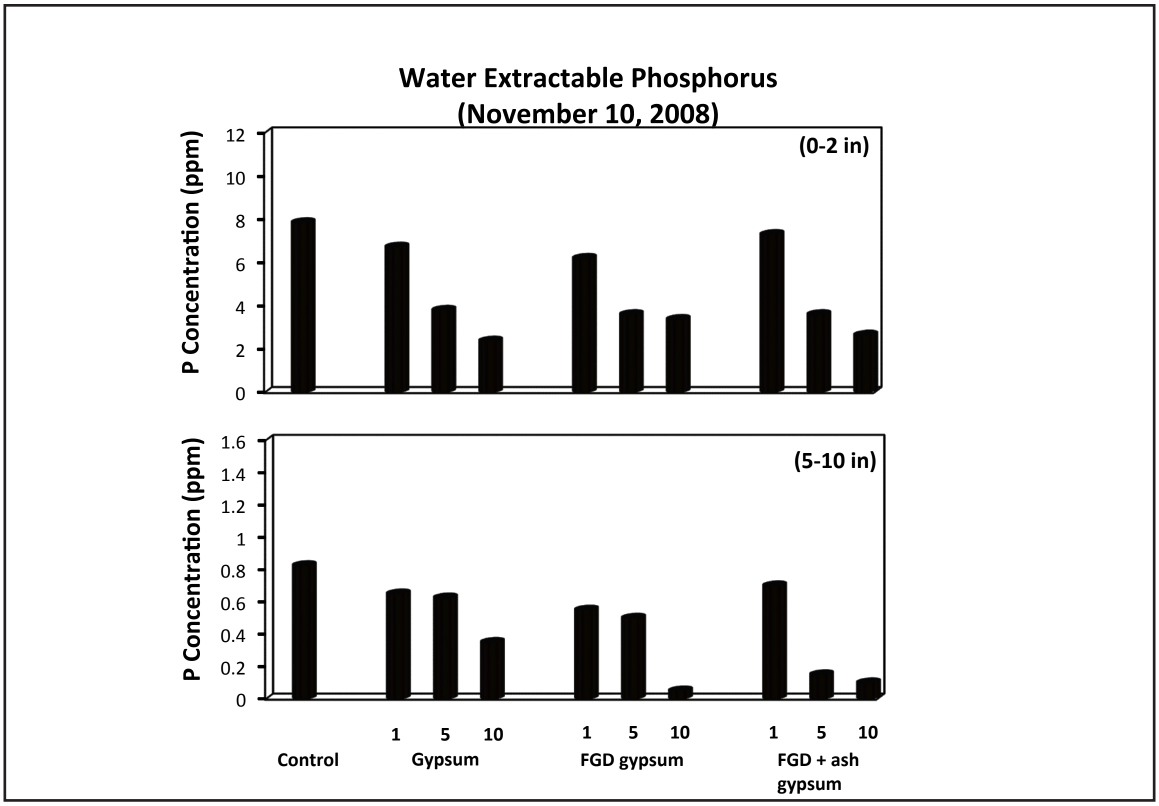

Figure 2. Water soluble P concentrations observed on November 10, 2008, in soil at two depths (0-2 and 2-6 inches) amended with gypsum, FGD gypsum, and FGD gypsum + fly ash applied at 1, 5 and 10 tons acre $^{-1}$ and compared to a poultry-litter only-control. Note difference in scale of the vertical axis between depths.

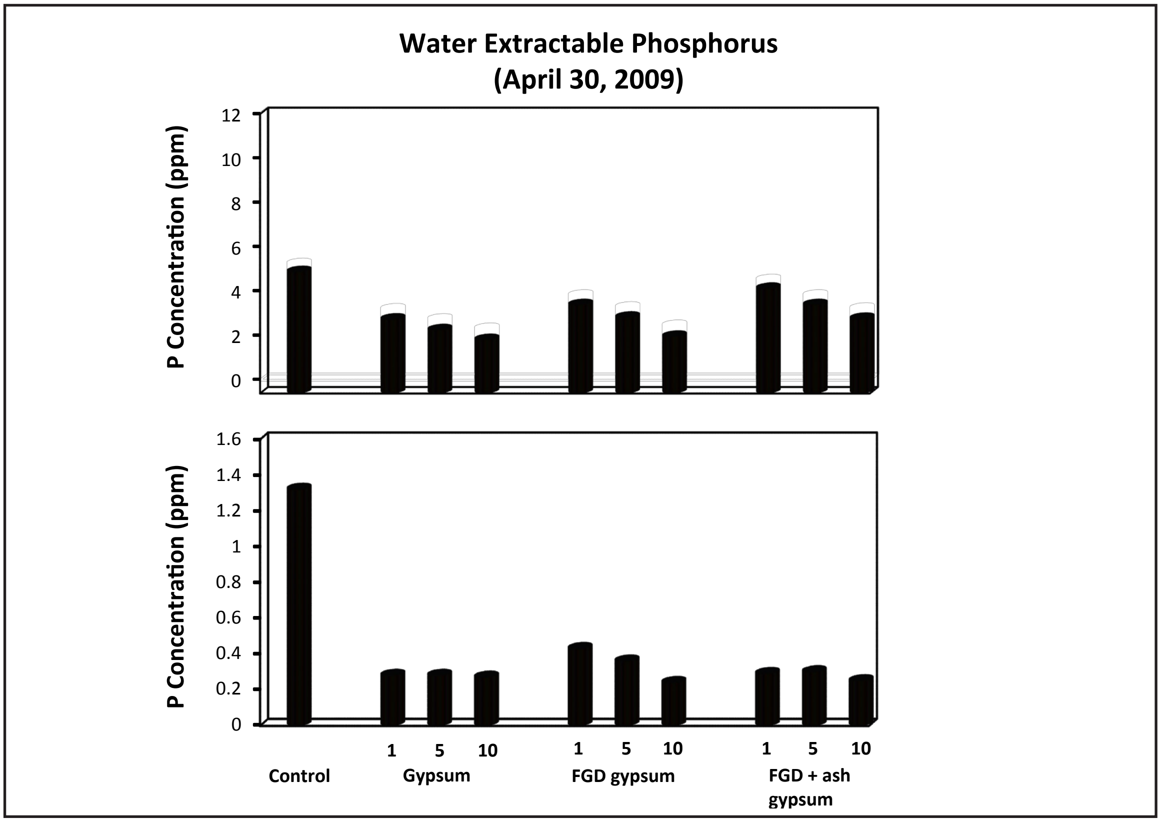

Figure 3. Water soluble P concentrations observed on April 30, 2009, in soil at two depths (0-2 and 2-6 inches) amended with gypsum, FGD gypsum, and FGD gypsum + fly ash applied at 1, 5 and 10 tons acre $^{-1}$ and compared to a poultry-litter only-control. Note difference in scale of the vertical axis between depths.

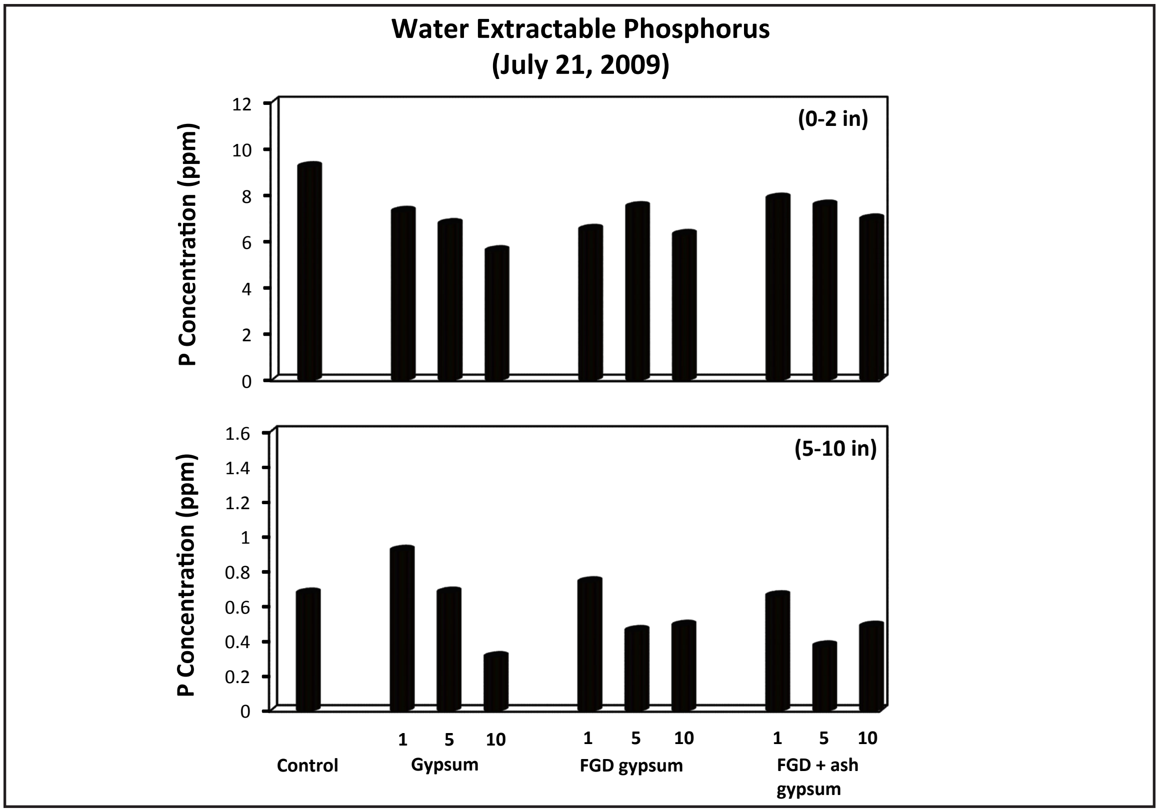

Figure 4. Water soluble P concentrations observed on July 21, 2009, in soil at two depths (0-2 and 2-6 inches) amended with gypsum, FGD gypsum, and FGD gypsum + fly ash applied at 1, 5 and 10 tons acre $^{-1}$ and compared to a poultry-litter only-control. Note difference in scale of the vertical axis between depths.

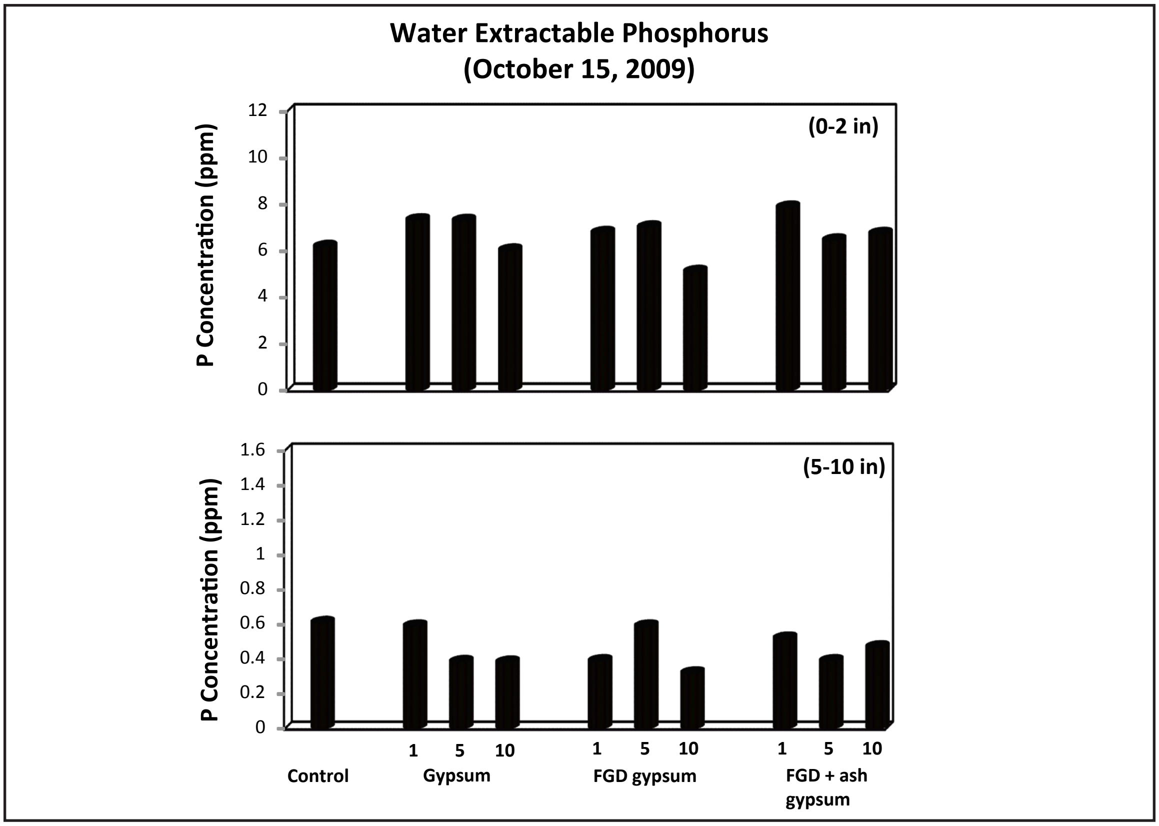

Figure 5. Water soluble P concentrations observed on July 21, 2009, in soil at two depths (0-2 and 2-6 inches) amended with gypsum, FGD gypsum, and FGD gypsum + fly ash applied at 1, 5 and 10 tons acre $^{-1}$ and compared to a poultry-litter only-control. Note difference in scale of the vertical axis between depths.

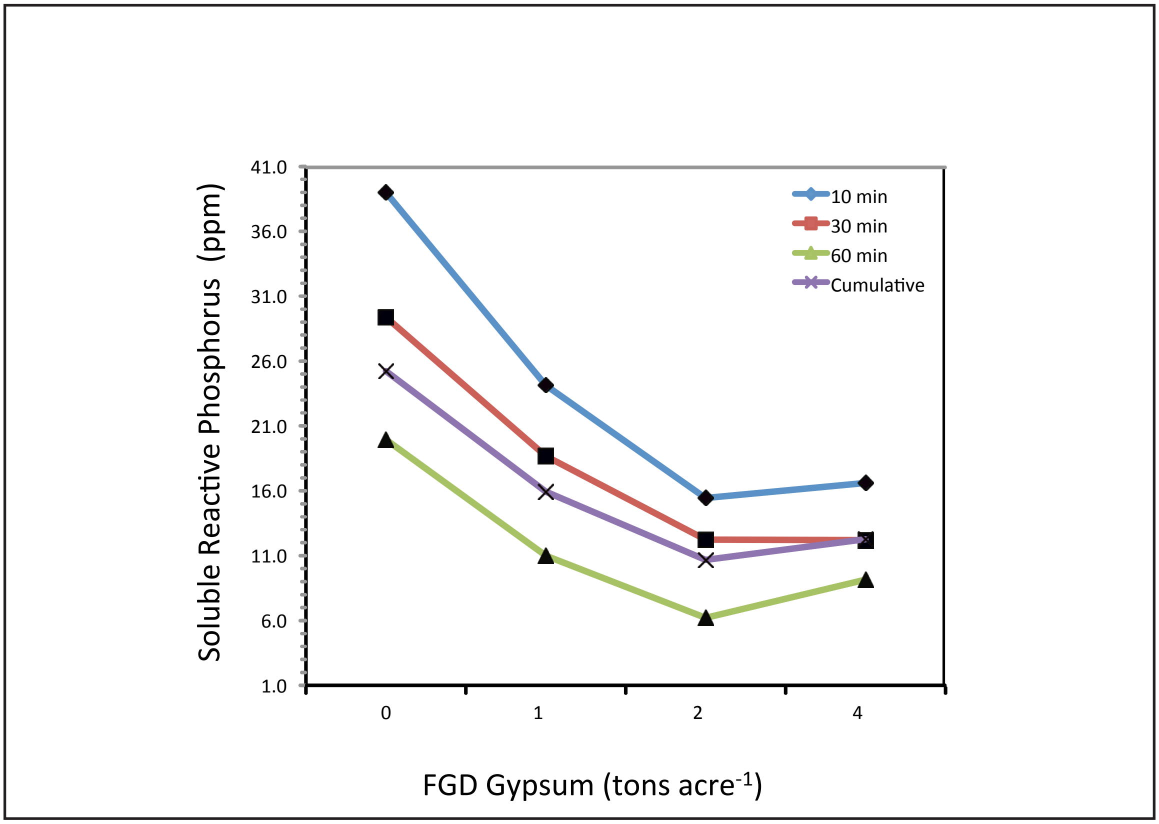

Figure 6. Regression lines describing the relationship of FGD gypsum application rates at 0, 1, 2 and 4 ton acre^{-1} to runoff of SRP concentration during the 10, 30 and 60 minute sampling intervals and cumulative sampling, immediately after poultry litter application.

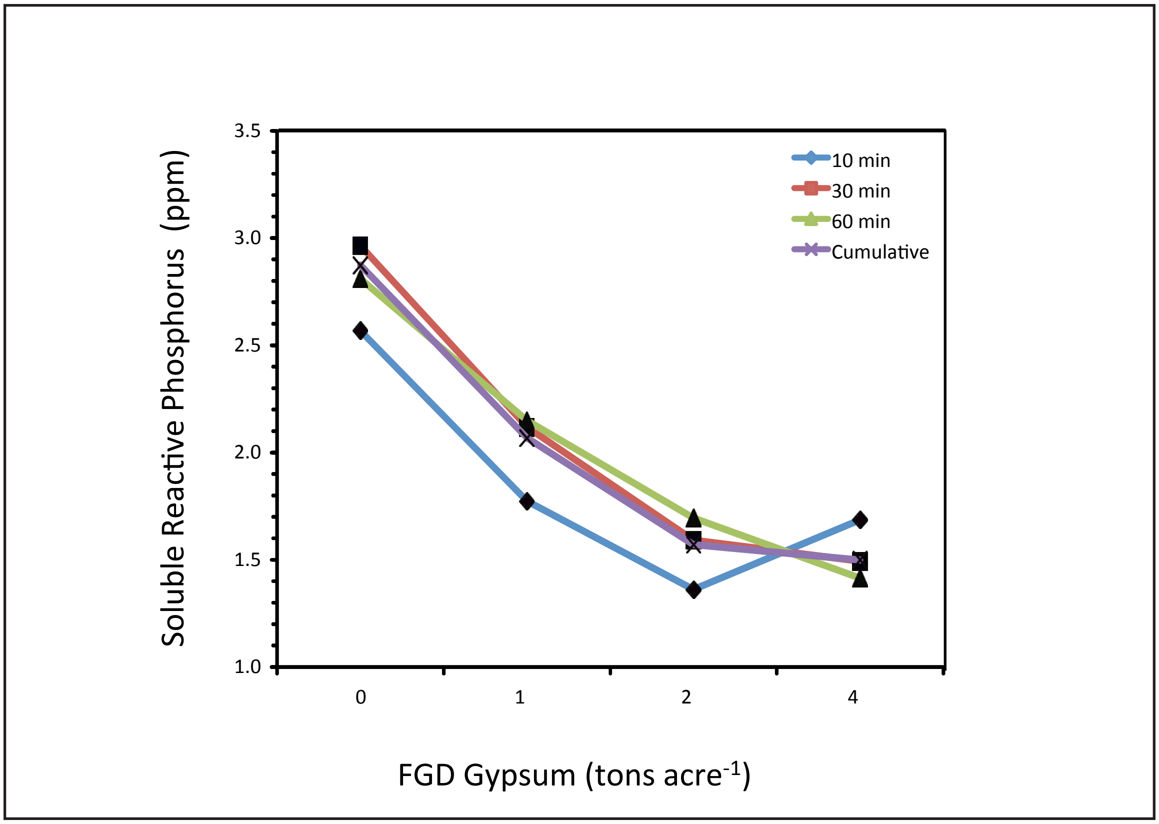

Figure 7. Regression lines describing the relationship of FGD gypsum application rates at 0, 1, 2 and 4 ton acre^{-1} to runoff of SRP concentration during the 10, 30 and 60 minute sampling intervals and cumulative sampling, five weeks after poultry litter application.

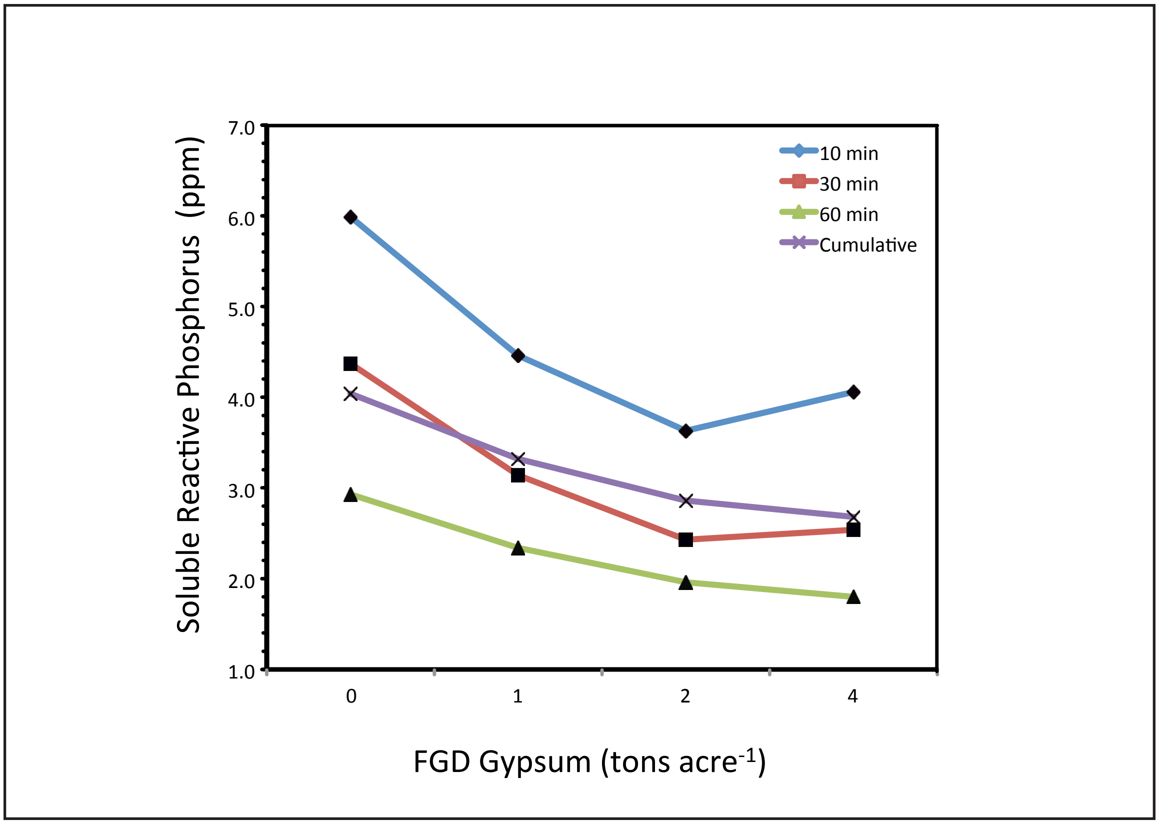

Figure 8. Regression lines describing the relationship of FGD gypsum application rates at 0, 1, 2 and 4 ton acre^{-1} to runoff of SRP concentration during the 10, 30 and 60 minute sampling intervals and cumulative sampling, seven months after poultry litter application.

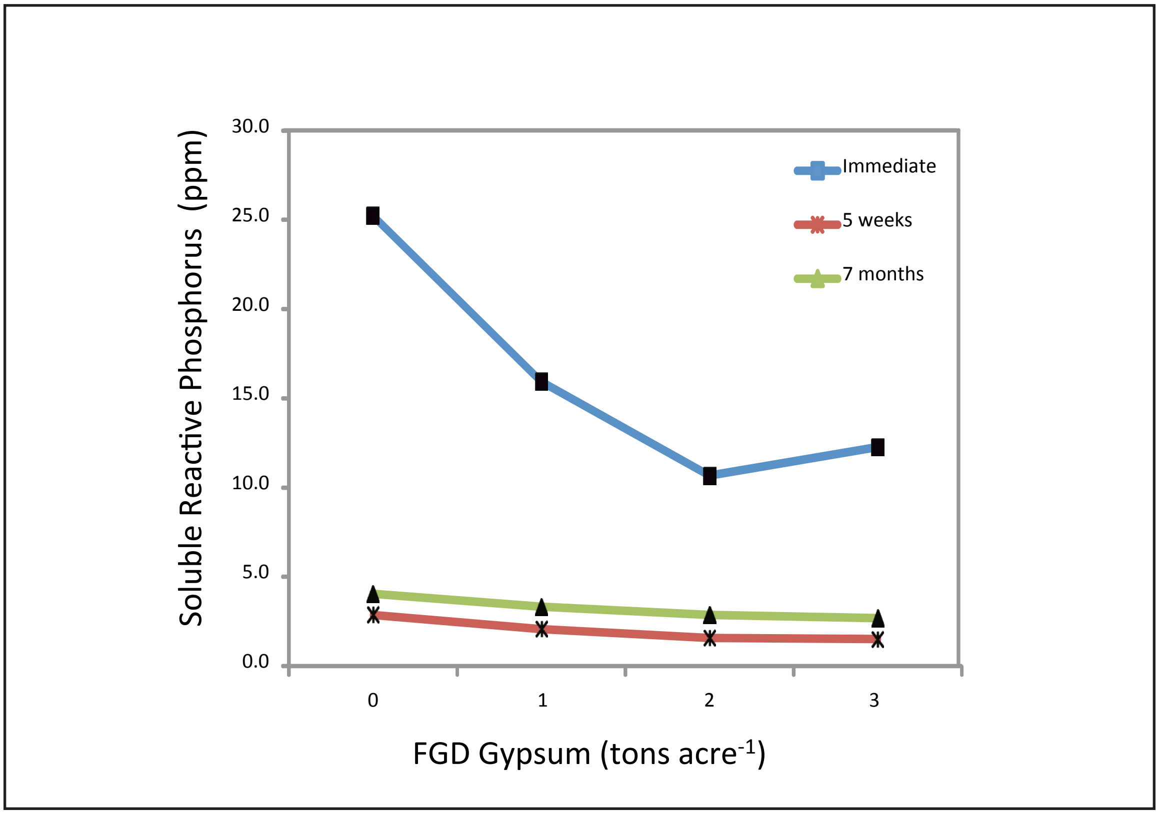

Figure 9. Regression lines describing the relationship of FGD gypsum application rates at 0, 1, 2 and 4 ton acre^{-1} to runoff of SRP concentration. Lines represent cumulative SRP losses after 1-hour runoff event following immediately, five weeks, and seven months after poultry litter application.

Conclusions and Recommendations

Conclusions

Repeated manure use on agricultural fields at agronomic N rates has created a redistribution of P in soils which increases the risk of P contribution to surface waters. If manure use continues at current rates, refined prescriptions will be needed to reduce and prevent P losses from deteriorating surface water quality. Gypsum use as a soil amendment seems promising as a BMP to reduce P losses from agricultural fields. The current study provides valuable information needed to fine-tune current prescriptions for BMPs needed to maintain environmental sustainability.

Recommendations

Where P application rate or P application method will create an unacceptable risk for runoff according to the Alabama P index, either agricultural or FGD gypsum may be used as a BMP at the time of P application. A recommended rate of 2-ton acre^{-1} is needed to obtain the greatest benefit of reducing the threat of P loss from pastures fertilized with poultry litter.

Works Cited

Dontsova K., Lee, Y. B., Slater, B. K., & Bigham, J. M. (2005). Gypsum for agricultural use in ohio—sources and quality of available products. *Ohio State University Extension Fact Sheet, ANR 20*(5). http://ohioline.osu.edu/anr-fact/0020.html (Verified 26 September 2013).

Srivastava, R.K., & Jozewicz, W. (2001). Flue gas desulfurization: The state of the art. *Journal of the Air and Waste Management Association, 51*, 1676–1688.

Chen, L., Kost, D., & Dick, W.A. (2008). Flue gas desulfurization products as sulfur sources for corn. *Soil Science Society of America Journal 72*, 1464-1470.

Mitchell, C.C. (2010). FGD gypsum on alabama fields. *Timely Information: Alabama Agricultural Extension System, s(*01), 10. http://aces.edu/timelyinfo/Ag%20Soil/2010/March/S-01-10.pdf (Verified 26 September 2013).