Report for 2002SD4B: Establishing a Relationship Between Soil Test P and Runoff P for a South Dakota Soil Using Simulated Rainfall

- Other Publications:
  - Guidry, A.R., F.V. Schindler, D. R. German, R. H. Gelderman, and J.R. Gerwing. 2004. Influence of Soil Test Phosphorus on Phosphorus Runoff Losses from South Dakota Soils. 34th Annual North Central Extension-Industry Soil Fertility Conference. Volume 20 pp 27-34. Des Moines, Iowa. Nov. 17-18, 2004.
  - Guidry, A.R., D. R. German, R. H. Gelderman, J.R. Gerwing, and F.V. Schindler. 2004. Evaluating phosphorus loss from Midwestern soils Using Simulated Rainfall. ASA, CSSA, SSSA Annual Meetings. Oct. 31-Nov.4, 2004. Seattle, Washington, abstract No. 3277.
  - German, D.R., A.R. Guidry, R. H. Gelderman, F.V. Schindler, and J.R. Gerwing, 2004. Soil and runoff P relationships: Implications for lake and watershed management. ASA, CSSA, SSSA Annual Meetings. Oct. 31-Nov.4, 2004. Seattle, Washington, abstract No. 4732.
  - Guidry, A.R., F.V. Schindler, D. R. German, R. H. Gelderman, and J.R. Gerwing. 2005. Estimating Phosphorus Loss From Benchmark Eastern South Dakota Soils. 8th Annual Student Research Poster Session funded by the South Dakota Board of Regents, South Dakota NSF-EPSCoR Program, and the South Dakota Academy of Science. February 15, 2005. State Capitol Rotunda, Pierre, South Dakota, abstract No. 89.
  - Guidry, A., Schindler, F., Gelderman, R., German, D., and J. Gerwing. 2005. Use of Indoor Rainfall Simulations as a Tool to Predict Outdoor Plot Runoff. In preparation.
  - Schindler, F.V., A.R. Guidry, D.R. German, R.H. Gelderman, and J.R. Gerwing. 2005. Relationship between Soil Test Phosphorus and Phosphorus in Runoff from South Dakota Soils. In preparation.

Report Follows

Annual Progress Report

State Water Resources Institute Program (SWRIP)
March 2004 to February 2005

PART I.

Title: Establishing the relationship between soil test phosphorus and runoff phosphorus for South Dakota soils

Investigators: Dr. Ronald H. Gelderman, Plant Science Department
Dr. Frank V. Schindler, Dept. of Chemistry and Biochemistry
Mr. David R. German, Water Resources Institute

The following report discusses the results and progression of the research project titled "Establishing the relationship between soil test phosphorus and runoff phosphorus for South Dakota soils" during the funding period of March 2004 through February 2005. This project is part of an ongoing P study to evaluate the relationships that exist between surface runoff and soil P. The information gathered from this project will provide the South Dakota Dept. of Environment and Natural Resources sound scientific data in which to base their regulations of manure and fertilizer P application to agricultural land. This reporting period is the result of a no-cost extension granted through February 2005. The extension was granted to assist in the financial support of our graduate student. The specific objectives of this project are as follows:

Objective 1: Establish correlations between STP and runoff P for South Dakota soils by conducting *in situ* rainfall simulation in the field.

Objective 2: Evaluate P sorption saturation of South Dakota soil and STP relationship to runoff P by conducting controlled, laboratory rainfall simulation.

Objective 3: Use the research results to develop educational brochures, field day demonstration events, and offer manure management education to extension educators and area animal producers

Methodology:

Field Studies: The protocol for the National Research Project for simulated rainfall-surface runoff studies was used in this study (1). Ten conventionally tilled cropland areas were identified for the Poinsett and Barnes soil series. These areas possessed similar slope and topography and were chosen based on their range in soil test phosphorus (STP) (i.e., low to high agronomic STP). The Poinsett and Barnes sites were identified in the upper Big Sioux Watershed near Watertown, SD. Rainfall simulation was conducted on each site for three consecutive days: one at field moist conditions, and two at field capacity. Rainfall was applied at an intensity of 2.5 in hr^{-1}. Runoff collection began after 2.5 min of continuous runoff, and was collected in toto for 30 min. Runoff was weighed to determine runoff volume, and a composite sample was taken for analysis. Surface runoff water was analyzed for Total Dissolved P (organic and inorganic P species minus sediment associated P), and Total P (total dissolved plus sediment associated P) by the South Dakota

Analytical Services Laboratory. Composite soil samples were collected after raining and analyzed for STP and other select chemical parameters by the South Dakota Soil and Plant Testing Laboratory. The relationship between total dissolved P in surface runoff and STP was determined.

Laboratory Studies: Bulk 0-2 inch soil samples were collected from the ten field sites following field simulation. Soils were dried at low temperatures, sieved, and packed, in triplicate, into soil runoff boxes according to the National Research Project protocol (1). Rainfall application, runoff collection, and sample analyses for the indoor simulation were the same as described for the field studies. Representative soils samples were collected during runoff box preparation. Soil samples were crushed and passed through a 2 mm sieve. Soil P sorption saturation was determined as water extractable soil P content (mg kg^{-1}) divided by P_{MAX} (mg kg^{-1}) and multiplied by 100 (2). The P_{MAX} is the maximum amount of P that could be adsorbed by the soil and is defined as

$$P_{MAX} = (PSI + 51.9)/0.5 \qquad (1)$$

where PSI is a single-point P sorption index described by (3). The PSI is calculated as

$$PSI = X(\log P_F)^{-1} \qquad (2)$$

where X is P sorbed (mg kg^{-1}) = $[(P_I)(V) - (P_F)(V)]$ (kg of soil)$^{-1}$, P_I is initial P concentration in sorption solution (mg L^{-1}), V is the volume of P sorption solution (L), and P_F is the final P concentration in solution (mg L^{-1}).

Principal Findings and Significance:

Objective 1: Figure 1 shows the STP and runoff P relationships developed for the Poinsett soil at the 0-2 and 0-6 soil depth using in-field simulated rainfall. The reported R^2 values at each soil depth for the Poinsett soil indicate that STP does a fair job of estimating the P concentration in runoff. Unlike the other soils studied, however, e.g., Moody, Vienna, and Kranzburg soils, the Poinsett soil exhibited a lower relative R^2 at either soil depth (Fig.1). A stepwise regression analysis indicates a significant increase in the amount of variation explained in surface runoff P concentrations when Olsen P, clay, and clay x Olsen P are added to the regression model (Table 1).

Based on the field runoff results, the Poinsett soil did not exhibit a STP threshold. However, the linearity that existed between STP and runoff P for the Poinsett soil suggests that continued manure or fertilizer P applications will eventually lead to deleterious surface water P enrichments. Livestock and crop producers will not be able to apply infinite amounts of manure or fertilizer P to soil without concern for water quality.

No field runoff evaluations were performed on the Barnes soil during this reporting period. All Barnes investigations will be performed in April through June 2005 and will be included in the final report.

It must be noted, that the relationships developed in these studies say nothing about total or dissolved P loss from the field site, but rather give only an indication of the P concentration in runoff as a function of STP. STP alone can not predict total P loss because it is a single soil parameter and does not account for climatic, topographic or agronomic influences on P loss to sensitive water bodies. These runoff relationships, when evaluated in conjunction with climate, topography and various agronomic strategies will aid state water quality experts in determining the critical level of P in surface runoff considered problematic for water resource eutrophication. Livestock and crop producers will benefit from this information in terms of being able to develop more comprehensive nutrient management plans that safeguard South Dakota's water quality.

The next phase of our ongoing P runoff research will evaluate P loss on a watershed basis and relate P loss on a microplot scale to that of a larger, watershed scale. These studies are scheduled to being in the summer of 2005 and are funded, in part, by the South Dakota Dept. of Environment and Natural Resources and the USGS State Water Resources Institute Program.
Objective 2: Relationships between P-sorption saturation and Olsen-P and total dissolved P concentrations of indoor surface runoff for the Poinsett soil are shown in Figs. 2 and 3, respectively. As indicated, very strong linear relationships exist suggesting both Olsen-P and P saturation percentage are good predictors of total dissolved P levels in surface runoff. Note the indoor relationships are much stronger than that of the outdoor (Fig. 1). The outdoor relationships are developed under the more variable field conditions, whereas the indoor relationships are developed under a more controlled environment. Indoor soils are more uniformly packed and are subject to less surface disruptions, e.g., earthworm activity, compared to the field soils. Controlled variability enhances the relationship explained by the predictor variables, i.e, Olsen-P and P-sorption saturation.

These data suggest that the Olsen-P, which is a routine and simple P extraction method, may prove to be a very useful environmental predictor of P loss potential for South Dakota. This information is critical to developing simple, but effective P management strategies for South Dakota.

Similar to objective one, above, no indoor P runoff and P saturation determinations were performed on the Barnes soil during this reporting period. All indoor and laboratory investigations related to the Barnes soil will be performed in April through June 2005 and will be included in the final report.

Objective 3: The progress and/or products of objective 3 are discussed in the "Information Transfer Program" section of PART II, below.

References:

1. Southern Extension-Research Activity. 2004. National phosphorus research project: runoff simulation protocol. [Online]. Available at http://www.soil.ncsu.edu/sera17/publications/National_P/National_P_protocol%20.pdf. (verified 22 Sept. 2004).

2. Pote, D.H., T.C. Daniel, D.J. Nichols, A.N. Sharpley, P.A. Moore, D.M. Miller, and D.R. Edwards. 1999. Relationship between phosphorus levels in three Ultisols and phosphorus concentrations in runoff. J. Enivron. Qual. 28:170-175.

3. Sharpley, A.N., T.C. Daniel, J.T. Sims, and D.H. Pote. 1996. Determining environmentally sound soil P levels. J. Soil Water Cons. 51(2):160-166.

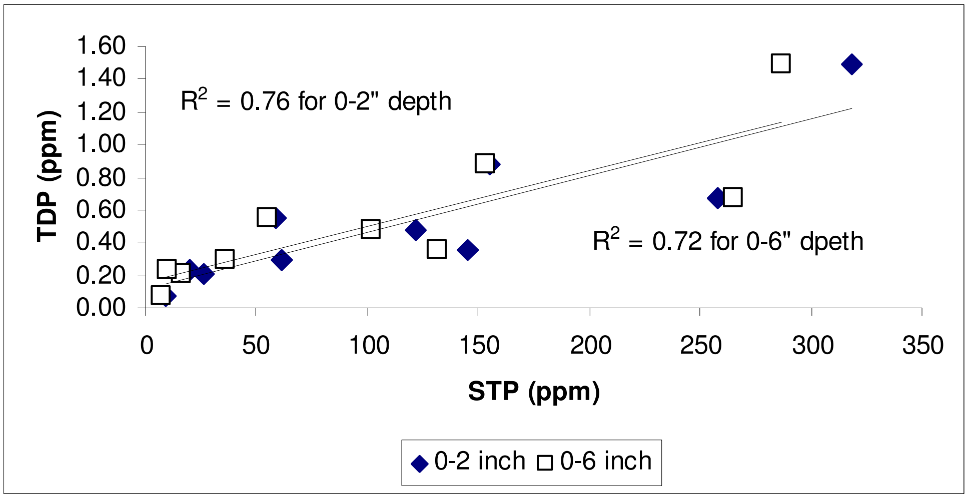


Figure 1. The relationship between total dissolved P (TDP) in field runoff and STP (Olsen-P) of the Poinsett soil at the 0-2 and 0-6 inch depths.

Table 1. Stepwise regression analysis of select South Dakota Soils using the predictor variables Olsen-P, Clay Content, and Olen-P x Clay content to estimate total dissolved P concentrations in field surface runoff.

Soil Type	Variables	R^2	P>F
Vienna	a. Olsen b. Olsen, Clay c. Olsen, Clay, Olsclay	0.93 0.93 0.93	<.0001 <.0001 0.0007
Kranzburg	a. Olsen b. Olsen, Clay c. Olsen, Clay, Olsclay	0.80 0.80 0.85	0.0012 0.0078 0.0169
Poinsett	a. Olsen b. Olsen, Clay c. Olsen, Clay, Olsclay	0.75 0.79 0.91	0.001 0.0048 0.017
Moody	a. Olsen b. Olsen, Clay c. Olsen, Clay, Olsclay	0.93 0.93 0.93	<.0001 <.0001 0.006

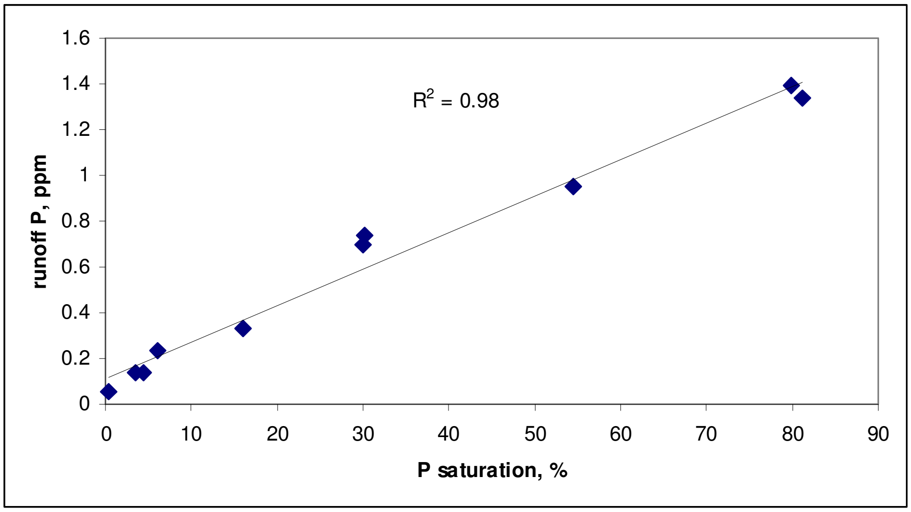


Figure 2. The relationship between total dissolved P (TDP) in indoor runoff and P sorption saturation percentage of the Poinsett soil.

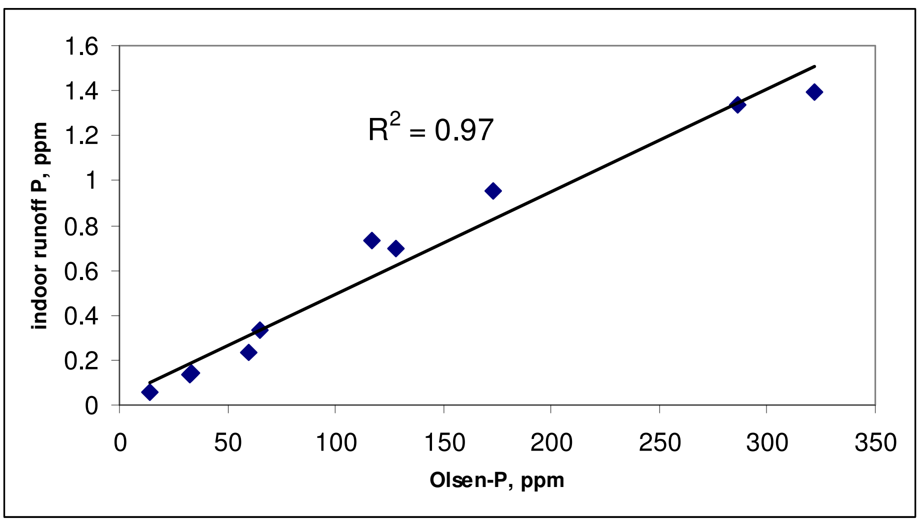


Figure 3. The relationship between total dissolved P (TDP) in indoor runoff and Olsen-P of the Poinsett soil.

PART II:

Information Transfer Program: Mr. Jim Gerwing, South Dakota Soil Extension Specialist, presented the P runoff information generated from this project at his annual manure training and meetings/workshops. Meetings conducted included soil testing workshops for ag consultants and fertilizer dealers, manure application training workshops for people applying for state CAFO permits, and Certified Crop Advisor CEU workshops.

A field day demonstration of rainfall simulation, in cooperation with the SDSU Plant Science Department, College of Agriculture & Biological Sciences, and SDSU Agricultural Experiment Station & Cooperative Extension Service, was also conducted at the Northeast Research Farm Summer Tour at Watertown, SD on July 1, 2004. Two demonstrations were given that day to a total of 30 area producers, extension personnel, and various other stakeholders.


NE Farm Tour 2004


Dakota Fest 2004

Rainfall simulation demonstrations were conducted at the Dakota Fest on August 17-19, 2004. Brochures and various P runoff handouts were made available to the public. An example of the handout can be seen in Appendix 1 of this report.

Approximately one hundred P runoff brochures were created with updated information and distributed to area producers via the cooperative extension service. Copies of the brochures were given to the directors of the South Dakota Corn Utilization and the South Dakota Pork Producers Councils to distribute at their discretion. Approximately 100 P runoff handouts were created and distributed to producers, agronomists, and extension personnel during our field demonstration at the Northeast Research Farm Summer Tour at Watertown, SD on July 1, 2004.

P-runoff brochures are also made available to area producers and agronomists at the SDSU Soil and Plant Testing and the SDSU Water Resources Institute laboratories.

Student Support: This project helps support one graduate student enrolled in the Doctor of Philosophy program in the Atmospheric, Environmental, and Water Resources field of study. This program is in cooperation with South Dakota State University and South Dakota School of Mines. This project will be a significant part of the graduate student's dissertation.

Appendix 1.

Phosphorus Runoff Research in South Dakota

Dakota Fest (August 17-19, 2004)

Research Need:

- ✓ Declining water quality has been linked to poor manure management
- ✓ When meeting N needs of the crop with manure, P is often over-applied for crop needs
- ✓ Average soil test P (STP) levels of manured soils in South Dakota have increased
- ✓ Soil and Runoff P relationships need to be developed for South Dakota soils to ensure the development of sound P management strategies

Objectives:

- ✓ Develop correlation between runoff P and soil test P on select soils of South Dakota using rainfall simulation
- ✓ Evaluate P sorption saturation relationships to runoff P
- ✓ Relate field runoff to indoor runoff

Methods:

- ✓ Identify Field Sites (Vienna, Poinsett, Kranzburg, Barnes, and Moody)
- ✓ Sites range from low to very high STP
- ✓ Use National P protocol (SERA-17)
- ✓ Use Rainfall Simulation

Results:

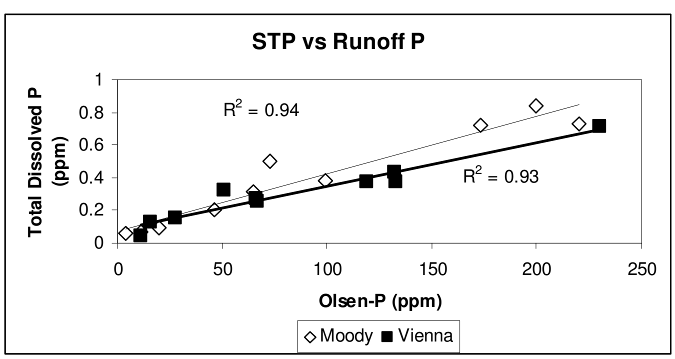


Figure 1. Relationship between Olsen Soil Test P (STP) and total dissolved P in runoff for the Vienna and Moody soil series at 0-2 inch soil depth.

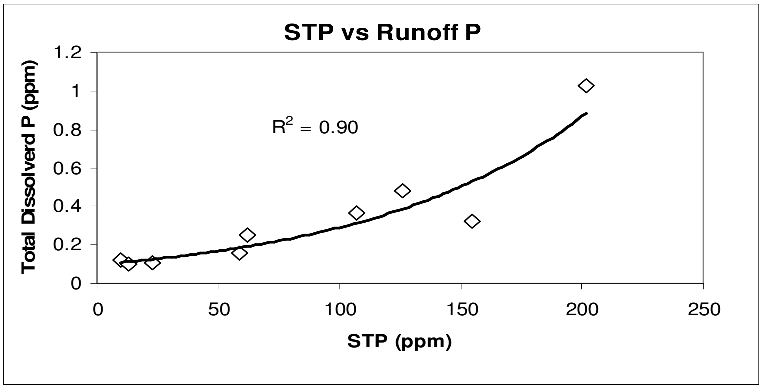
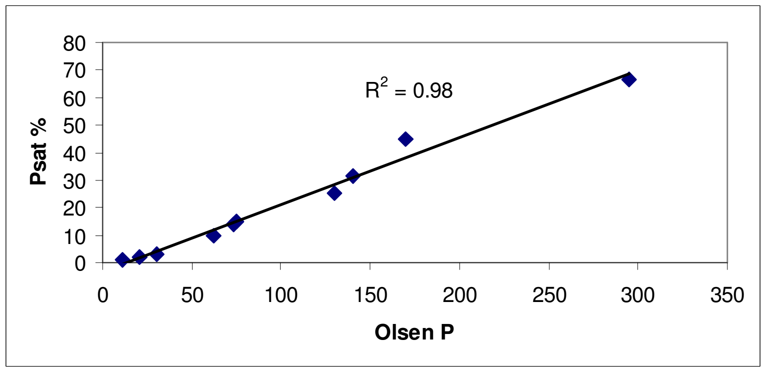


Figure 2. Relationship between Olsen Soil Test P (STP) and total dissolved P in runoff for the Kranzburg soil series at 0-2 inch soil depth.

Figure 3. Relationship between P sorption saturation and Olsen-P for the Vienna soil series.



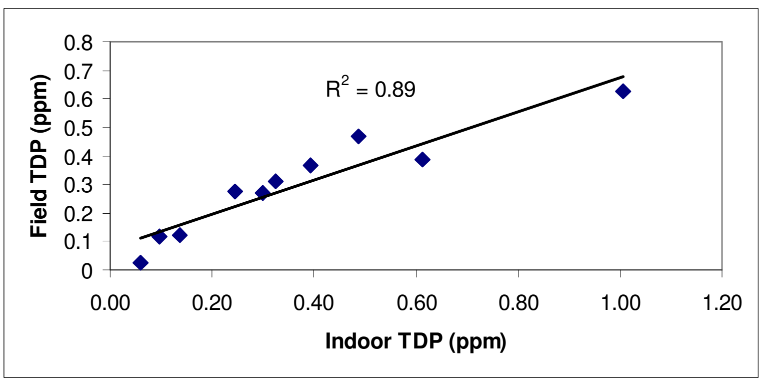


Figure 4. Relationship between TDP in field runoff and TDP in indoor runoff for the Vienna soil series.

Financial Support Provided by:

- South Dakota Department of Environment and Natural Resources
- SD Corn Utilization Council
- SD Pork Producers Council
- National Institutes for Water Resources-US Geological Survey
- South Dakota Agricultural Experiment Station

South Dakota State University
Department of Chemistry and Biochemistry
South Dakota Cooperative Extension Service
Water Resources Institute
Department of Plant Science