National Phosphorus Runoff Project: New York

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Background

The effects of soil test phosphorus (P), field management and runoff P losses from New York soils are being studied as part of the National P Research Project (NPRP). The NPRP represents a consortium of federal and state agencies, as well as land grant universities, with collaboration in over 20 states. New York's contribution to the NPRP has two immediate objectives: (1) identify soil P thresholds for water quality; and, (2) assist in refinement of New York's P Index, which identifies fields that are vulnerable to P loss. These objectives are expected to culminate in the development of cost-effective, integrated nutrient management strategies that target remedial activities on areas specifically at risk of P loss.

Research approach

To address the objective of identifying soil P thresholds for water quality, scientists in New York have collected data to describe the relationship between soil test P and P in runoff P for Berks (loamy-skeletal, mixed, active, mesic Typic Dystrudept), Honeoye (fine-loamy, mixed, active, mesic Glossic Hapludalf) and Lewbeach (coarse-loamy, mixed, semiactive, frigid Typic Fragiudept) soils. To do this, portable rainfall simulators are used to generate runoff from 2 m^2 runoff plots established on soils with a wide range of soil test P concentrations. The project relies on runoff generated by rainfall simulators, rather than by natural rainfall, in order to control potentially confounding variables such as rainfall intensity and uniformity. Extensive research has been conducted to ensure that the simulated rainfall closely matches the intensity, drop size and energy of natural rainfall. Raining on soils in the field, rather than collecting the soils and conducting indoor runoff studies, ensures that results more closely represent actual field conditions.

Because soil P is but one contributor to P in runoff, research is also being conducted to assess the effects of mineral fertilizer and manure management on runoff P losses. This research has been conducted with the field rainfall simulators described above as well as with an indoor rainfall simulator. The indoor rainfall simulator is identical to those used in the field, but, rather than rain on intact soils in field conditions, indoor simulations are conducted on runoff trays. Specifically, thoroughly mixed soil is packed into 1 x 0.2 m runoff trays, which are rained upon to generate runoff. A variety of management alternatives have been evaluated. The results of both the field and indoor rainfall simulation experiments and those of other New York P-index studies currently conducted by Cornell University, contribute to the refinement and calibration of the New York P Index, ensuring that it applies to New York's unique soil and management conditions.

Research findings

Soil P

Soil P can play an important role in determining runoff P losses. Figure 1 illustrates the relationship between soil test P (Mehlich-3 P) and dissolved P concentrations in runoff for Berks, Honeoye and Lewbeach soils. Clearly, the nature of this relationship is soil specific, with the high-lime Honeoye soil releasing significantly less P to runoff than the acidic Berks and Lewbeach soils at comparable soil test P levels. These data indicate the need for soil-specific management in addressing environmental P concerns.

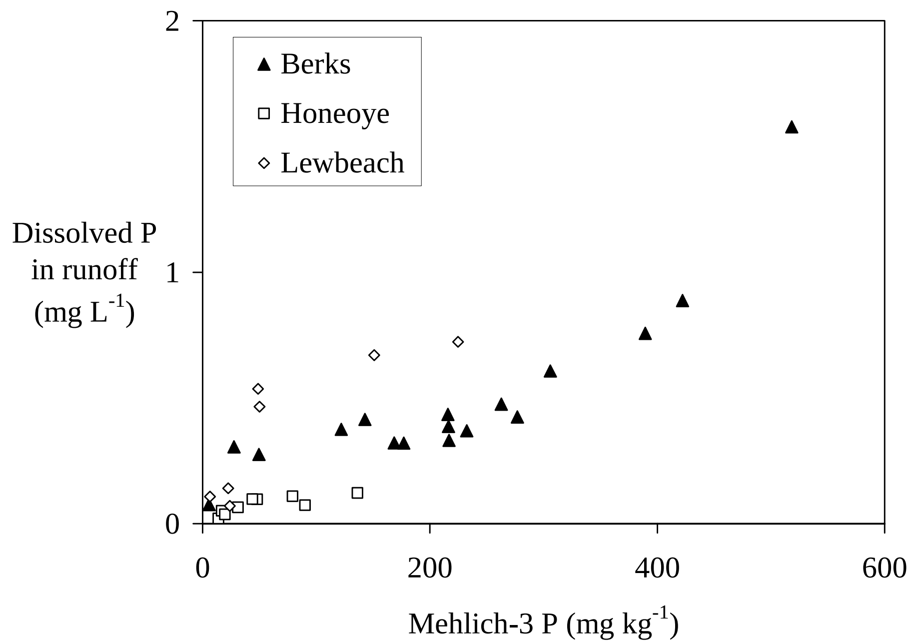

Figure 1. Relationship of soil test P to dissolved P in runoff for three New York soils (adapted from Kleinman and Sharpley, 2001).

Nutrient sources and application methods

To assess the role of P applied to soils as a source of P in runoff, an initial study was conducted in which three manures (dairy manure, poultry manure, swine slurry) and one mineral fertilizer (diammonium phosphate) were applied by two methods (broadcast and incorporated) to Lewbeach soils with either low initial soil test P (13 mg kg^{-1} Mehlich-3 P) or high initial soil test P (396 to 396 mg kg^{-1} Mehlich-3 P). The manures and fertilizer were applied at a rate of 100 kg total P ha^{-1}.

As illustrated in Figure 2, runoff P losses following incorporation were significantly lower than those following surface application of the manures and mineral fertilizer. This is because soluble P in the broadcast manure and fertilizer was readily available to runoff water. Incorporation resulted in reactions between soil and manure/fertilizer that reduced the availability of soluble P to runoff water.

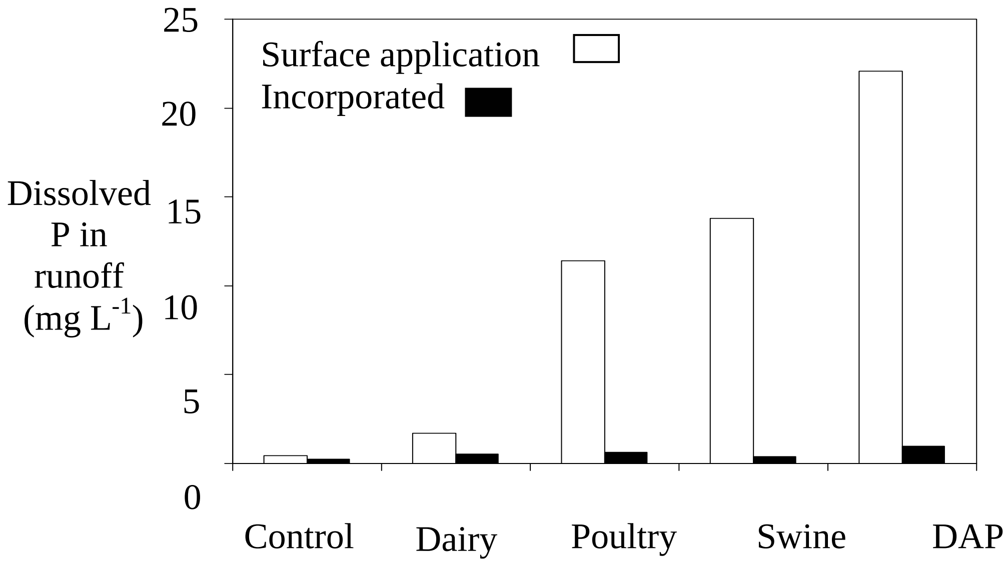

Figure 2. Dissolved P concentrations in runoff from a Lewbeach soil subjected to various P application scenarios. Control treatment represents no P application. Mineral and manure P sources were applied at a total P rate of 100 kg ha^{-1} (adapted from Kleinman et al., 2002b)

Further insight into the causes of elevated runoff P concentrations from surface applied treatments is provided by Figure 3. While erosion (suspended sediment) is clearly related to total P concentration in runoff from soils following incorporation, it is not related to total P concentrations in runoff from surface applied soils as soluble P in the manures and fertilizer serves as the primary source of P in runoff from these soils.

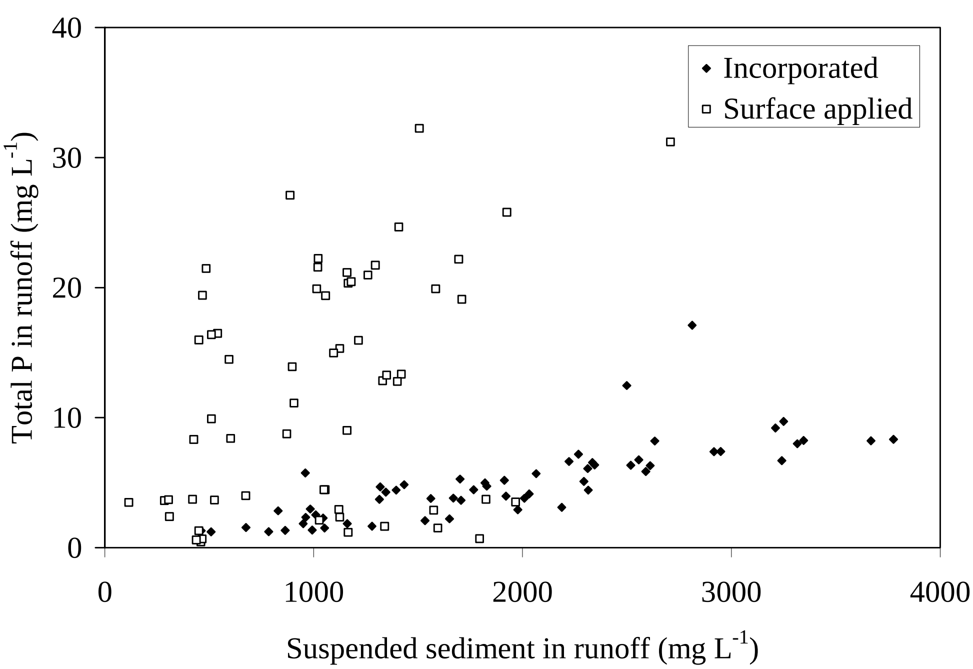

Figure 3. Relationship of suspended sediment to total P in runoff following surface application or incorporation of manure (adapted from Kleinman et al., 2002b).

For surface applied manures, a simple test of manure P solubility, in which distilled water is used to extract P from manure, effectively predicted P concentration in runoff. This test predicted 86% of the variability in the dissolved P fraction in runoff, and 78% of the variability in the total concentration of P in runoff. Given the importance of soluble P in manure to runoff P losses, initial soil test P concentration did not relate to runoff P concentrations from manure and mineral fertilizer amended soils. Based upon these results, manure testing laboratories have now developed an environmental manure P test that will soon be offered to farmers across the Northeast.

<u>Manure source, application rate and timing</u>

A follow-up study was conducted to provide greater insight into the effects of specific manure application factors on runoff P losses. In this study, three manures (dairy, layer poultry and swine slurry) were broadcast onto a Lewbeach soil at rates of total P addition equivalent to 0, 10, 25, 50, 77, 100 and 150 kg ha^{-1}. Rainfall simulation experiments were conducted 3-, 10- and 24-d after manure application.

Results from this study revealed an increase in runoff P concentrations related to application rate. Figure 4 illustrates this relationship for the first rainfall simulation, conducted 3-days after manure application. Note that differences in runoff P concentrations between manures are only significant at higher rates of application. As explained above, these differences can be explained by the water soluble P concentration of the manure.

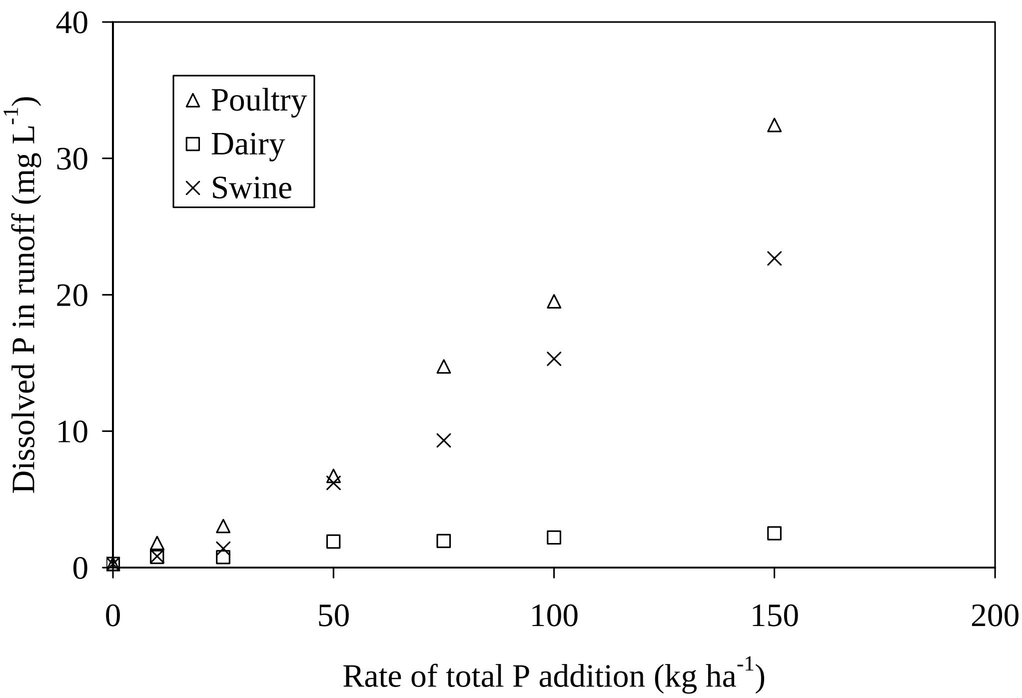

Figure 4. Relationship of total P application rate to dissolved P concentrations in runoff (Adapted from Kleinman and Sharpley, 2002).

With subsequent rainfall simulations, the slope of the regression describing this relationship declined, indicating that manure applied P becomes less available to runoff over time. Figure 5 shows the decline in dissolved P concentration in runoff with time for a single application rate (100 kg total P ha^{-1}). These declines appear to be related to depletion of soluble P at the soil surface, primarily through infiltration and reaction of applied P with soil. These results confirm the view that the greatest risk of P loss in runoff occurs immediately after manure is broadcast.

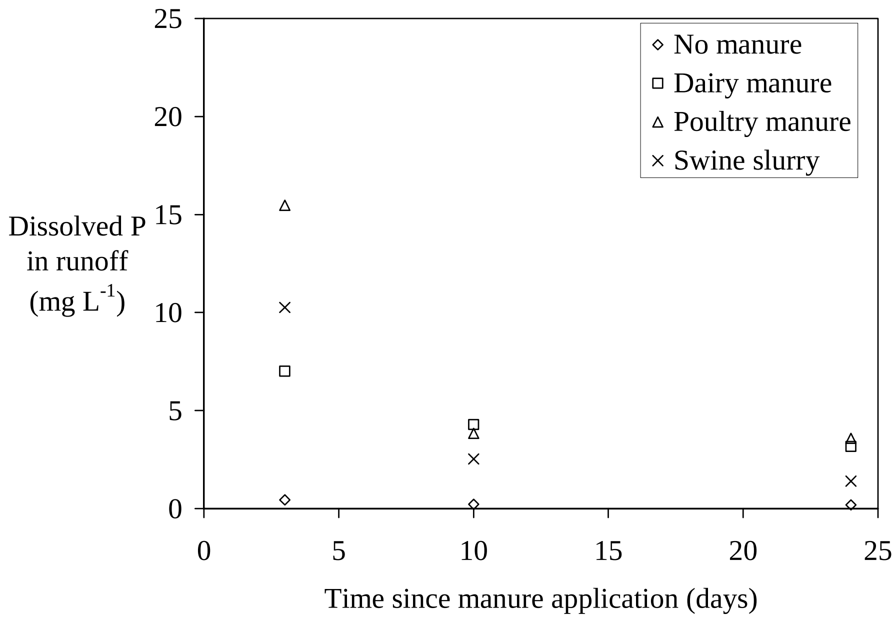

Figure 5. Relationship of time since manure addition to dissolved P concentration in runoff. Note that even in the third runoff event, 24 days after the manure application, P concentrations in runoff from manure amended soils remain elevated above those from the unamended, control soil (adapted from Kleinman and Sharpley, 2002).

<u>Evaluating the benefits of cover crops</u>

The beneficial effects of cover crops on erosion control, tilth and soil N reserves have been well documented. However, in the northeastern U.S., cover crops are not widely grown in comparison with other farming regions of the US. Scientists at USDA-NRCS Plant Materials Center (Big Flats, NY) have developed a cover cropping system whereby cover crops (alfalfa, perennial rye grass, red and white clover) are seeded at time of corn planting. Post-emergence, low-volume imidazolinone herbicides are used to reduce competition between the cover crops and the corn so that satisfactory corn yields can be achieved.

As part of ongoing trials in Delaware County, three cover crops (white clover, red clover, perennial rye grass) and one control (corn only) were established in a randomized complete block design on a Lewbeach soil. Rainfall-runoff experiments were conducted to quantify the benefits of cover crops relative to conventionally cropped corn. Figure 6 illustrates differences in total and dissolved P concentration in runoff from the various treatments. Notably, cover crops significantly reduced total P concentrations in runoff. Dissolved P concentrations, however, were not significantly different from the control, as they reflected subtle differences in soil test P concentration between the various plots (Mehlich-3 P ranged from 64-94 mg/kg).

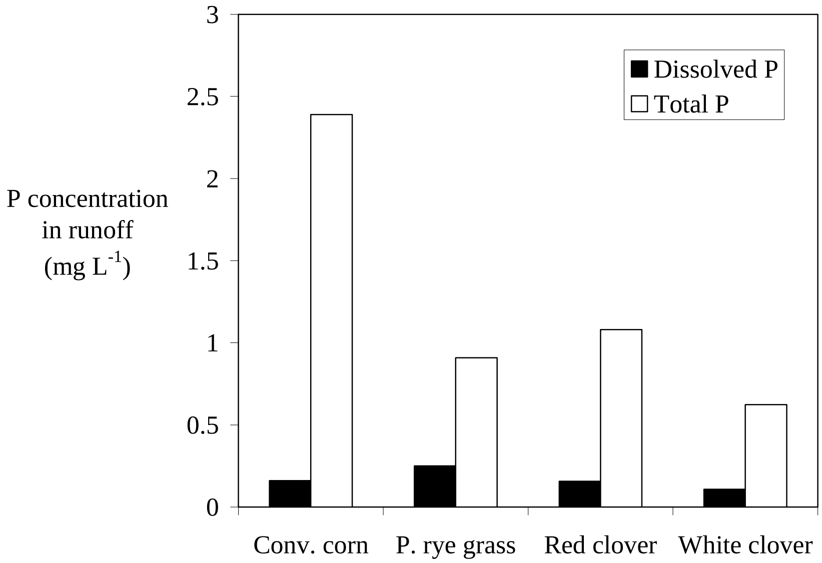

Figure 6. Runoff P concentrations from conventional corn, and various corn/cover crop combinations established on a Lewbeach soil (adapted from Kleinman et al., 2001).

As summarized in Figure 7, total P concentrations were related to erosion, which was effectively controlled by the cover crops. Thus, benefits of this system extend to control of TP losses, not necessarily dissolved P losses.

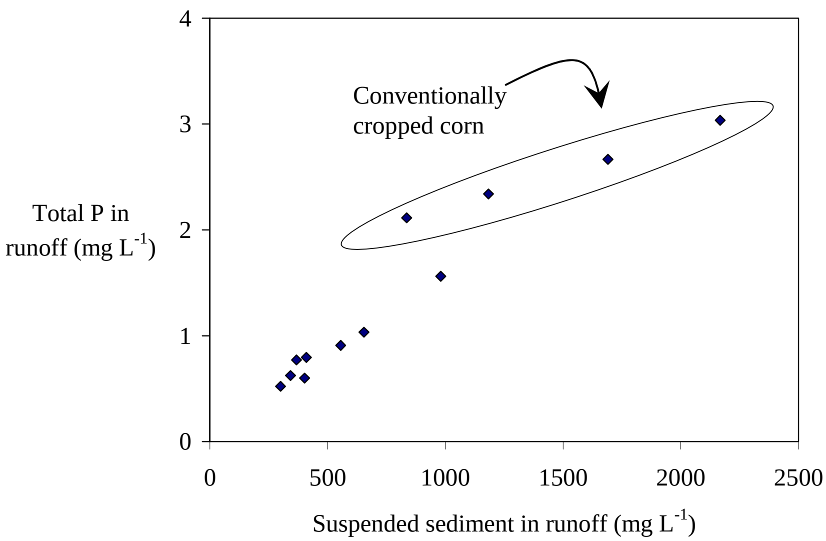

Figure 7. Relationship of suspended sediment to total P concentration in runoff, demonstrating importance of erosion control by cover crops to reduction in total P losses (adapted from Kleinman et al., 2001).

Ongoing research

Research under the NPRP continues in New York, with an emphasis on providing data necessary to calibrate the New York P Index and quantifying the benefits of alternative nutrient management practices.

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References

Kleinman, P.J.A**.** and A.N. Sharpley. 2001. Applying the National Phosphorus Research Project to P Index development in northeastern states. ASA-CSSA-SSSA 2001 Abstracts.

Kleinman, P.J.A., P. Salon and A.N. Sharpley. 2001. Evaluating alternative cover crops for the control of runoff phosphorus losses. ASA-CSSA-SSSA 2001 Abstracts.

Kleinman, P.J.A., A.N. Sharpley, A.M. Wolf, D.B. Beegle and P.A. Moore, Jr. 2002a. Measuring water extractable phosphorus in manure as an indicator of phosphorus in runoff. Soil Sci. Soc. Am. J. In press.

Kleinman, P.J.A., A.N. Sharpley, B.G. Moyer and G.F. Elwinger. 2002b. Effect of mineral and manure phosphorus sources on runoff phosphorus. J. Environ. Qual. In press.