EFFECT OF SOIL TEST, TILLAGE, AND MANURE AND FERTILIZER APPLICATION METHOD ON PHOSPHORUS RUNOFF[1]

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Introduction

Loss of phosphorus from agricultural lands into surface waters is of growing environmental concern. Phosphorus transported by surface runoff often ends up in streams and lakes and accelerates eutrophication, which affects the ability to use the water for drinking, fishing, recreation, etc (Foy and Withers, 1995). The major mechanisms by which agriculture contributes phosphorus to surface water is through runoff and erosion (Sharpley et al., 1994). Controlling runoff and erosion from agricultural lands along with controlling the other factors affecting phosphorus transport will greatly decrease the potential for surface water contamination.

Factors that influence the rate of movement of phosphorus from agricultural lands include inherent soil phosphorus level, tillage, ground cover, timing, quantity and method of application of fertilizers or animal manure, time between phosphorus application and receipt of rainfall, intensity of rainfall, and slope of the land (Sharpley et al., 1993). Many of these factors interact to either reduce or enhance phosphorus losses. The inherent soil phosphorus level is positively correlated with the concentration of dissolved phosphorus in runoff (Sharpley, et al., 1981). Tillage or lack thereof influences both the magnitude and the type of phosphorus that leaves the site. Fields that have been tilled will generally have a higher relative concentration of total phosphorus as most of the phosphorus leaving the site is associated with erosion of soil particles. No-till fields and frozen fields that have a sod cover have a higher concentration of dissolved phosphorus in runoff (Wendt and Corey, 1980; Timmons et al., 1970). High rates of phosphorus application either as fertilizer or manure, particularly if it is left on the soil surface, will enhance the potential for movement of dissolved phosphorus from fields (Baker and Laflen, 1982). Incorporation of phosphorus containing fertilizer or organic amendments either through tillage or through injection will generally reduce the potential for phosphorus runoff. The exception would be if the tillage operation enhances the potential for erosion, in which case incorporation of phosphorus materials may actually enhance phosphorus runoff on highly erosive sites. The shórter the time between phosphorus application and receipt of rainfall, the greater the potential for phosphorus runoff. Similarly, the greater the intensity of rainfall, the greater the potential for phosphorus runoff (Edwards et al., 1992). Unless adequate conservation methods are employed, the greater the slope, the greater the potential for erosion and consequently for total phosphorus runoff.

Unfortunately, much of the recent research associated with phosphorus runoff, especially that

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associated with manure application, has been conducted on pasture lands. This does not provide the data necessary to predict phosphorus runoff potential from row crop fields. Even more limited is the research conducted to determine the relative importance of the factors affecting phosphorus transport on Cornbelt soils and the relative vulnerability of these soils to phosphorus loss. The objective of this project is to estimate the influence of agricultural practices common to the Midwest on amounts and rates of phosphorus losses in surface runoff. The practices considered in the project included no-till and chisel plowing with phosphorus added as a commercial fertilizer and with hog manure that was either surface applied or injected. Each of the practices was studied at four soil test phosphorus levels to evaluate the influence of inherent soil conditions on phosphorus losses at different tillage practices.

Materials and Methods

Two blocks of thirty-four plots each were established in the fall of 1999 on a Tama fine-silty clay loam (Typic Argiudoll) with a 2.5 % average slope at the Northwestern Illinois Agricultural Research and Demonstration Center, Monmouth, IL.

The experimental design for the study was a randomized complete block with two replications. Each individual experimental unit was sampled before planting in 1999 and P fertilizer (triple super phosphate) was applied to individual plots based on the soil test result to establish P levels of approximately 15, 37, 75, and150 ppm P. Following the phosphorus application, the entire plot area was tilled and soybean planted in mid May 1999. Soybeans were harvested at the beginning of October. In early November, hog manure with a P concentration of 0.077% was surface applied or injected at rates of 5,000 and 10,000 gal/acre, using an injector with disk-sweeps. Manure P application rates would have been 35 and 70 lb P/acre at the 5,000 and 10,000-gallon application rates, respectively. On a separate set of plots, 48 lb/acre of P as a triple super phosphate was broadcast. The tillage treatments were then chisel plowed 10 in deep, perpendicular to the slope, leaving 35 % residue cover. Manure was injected at a 3 in depth, leaving an average of 65 % of residue cover.

Within each treated plot, a smaller area (2-m downhill by 1.5 m across) was isolated by plastic boards with a trianglular outlet attached at the downhill slope ending over a plastic container set completely into the soil. Rain simulations were conducted at each of the plots in mid November 1999 and again before planting, mid May 2000. Rain simulators equipped with one TeeJetTM 1/2HH-SS50WSQ nozzle placed at 10 ft above the soil surface were used to simulate 3-in/hr intensity rainfall. The square aluminum tubing frame supporting the nozzle was fitted with tarp sheets to provide a windscreen. The watering period varied from plot to plot, with enough water applied to provide for a 30-minutes of runoff. Runoff samples were collected from each plot at 2.5, 7.5, 17.5 and 27.5 minutes after runoff began. Runoff volumes were recorded at each of the times and at 30 min. Within 12 hours after the sample collection, portions of the runoff samples for soluble reactive P analysis were filtered through a Whatman No. 1 filter paper and then vacuum filtered through a 0.45μm Millipore filter paper. After filtering, the samples were kept in a freezer and were analyzed the next day for soluble reactive P using the ascorbic acid method (APHA, 1995). Unfiltered portions of the samples were kept frozen after the fall experiment and at 4°C after the spring experiment until analyzed for bioavailable P. Bioavailable P was measured on unfiltered runoff samples with the iron oxide strip method (Sharpley, 1993). Unfiltered samples were used to analyze total P with a kjeldahl digestion method (Patton and Truitt, 1992). Once digested, the samples were pre-filtered through a Whatman No.54 filter paper to remove silt and then through a 0.45μm Millipore filter paper. Samples analyzed for both bioavailable and total P were neutralized before using the ascorbic acid method (APHA, 1995). Sediments were measured by drying 10 mL of unfiltered sample at 110°C until constant weight was achieved. Residue cover was measured by the line-transect method (Shelton, Dickey and Jasa, 1992). During the winter, runoff was collected for total P analysis and the volume was measured.

Results and Discussion

Application of P fertilizer in the spring of 1999 resulted in the establishment of soil test values that ranged from 32 to 180 ppm in the fall of 1999 on samples collected to a 1 inch depth, and from 16 to 190 ppm on samples collected to a 7 inch depth. Since this fertilizer had been applied less than 5 months earlier, it is possible that it may have been more readily available for movement off of the soil surface than would have been the case for similar soil test values that had been equilibrated for a longer time period.

Effect of soil test P level and tillage

Soluble P concentrations contained in the runoff waters were significantly correlated to the soil test P concentrations at the one inch level in both the fall and spring runoff samples (Fig. 1a and 1c). The relationship between soil test level and soluble P and magnitude of soluble P in the runoff were very similar between the fall and spring runoff periods. Concentrations of soluble P were much higher in runoff from no-till plots than from tilled plots in both fall and spring rainfall simulations (Fig.1). At soil test levels less than 80 ppm for no-till or less than 135 ppm for tilled plots, soluble P concentrations were less than 0.05 ppm. At higher soil test levels, the soluble P concentrations increased rapidly as soil test levels increased, for both tilled and no-till. Sharpley et al. (1981), Daniel et al. (1994), and Pote et al. (1996) observed a linear correlation between runoff P losses and soil test P levels. Our results differed in that the relationship between soil test level and soluble P was linear at test levels less than about 100 ppm and then curvilinear at higher soil test levels.

The content of soluble P lost during the 30 minute runoff period were higher from the no-till than the chisel plowed plots for both fall and spring rainfall simulation (Fig. 1b and 1d). The differences between total soluble P losses from no-till and chisel plowed plots were higher in fall than in spring (Fig. 1b and 1d). The rainfall simulation in fall was conducted soon after the tillage operation, so the surface of the chisel plowed plots was extremely rough, which significantly delayed the start of runoff and reduced the runoff volumes. Following the weathering over winter, the surface roughness of the chisel plowed plots was greatly reduced, resulting in spring runoff volumes from chisel plowed plots that were comparable to those from the no-till plots. This may not occur on longer term no-till (these plots were no-till following only one crop) as there is evidence that long term no-till will result in more macropores that tend to increase infiltration.

In contrast to soluble P, total P loss in runoff was greater for tilled than no-tilled plots but the relationship to soil test was less evident in the fall for total P than it was for soluble P. There was a linear relationship between soil test and total P concentration in runoff (Fig. 2).

Effect of manure and phosphorus applications

When rainfall simulation was conducted within 1 month of surface application of manure, the concentration of both soluble and total P (data not shown) in the runoff, irrespective of manure rate was not related to soil test P. Concentration of P in runoff from manured plots was much higher than where no manure had been applied (Fig. 4). Rainfall simulation conducted on these same plots after the manure had overwintered on the soil surface for 6 months resulted in a marked reduction in the concentration of soluble and total P (Fig 4) and it tended to follow a pattern (Fig. 3) similar to that observed with no manure (Fig.1). Differences between fall and spring results may have been due in part to some of the P being lost in runoff over winter. However, this differential between fall and spring was more likely due to absorption of some the soluble P onto the soil particles or movement of the soluble P into the soil as shown by Eghball et al., (1996).

At phosphorus soil test levels less than 40 ppm, soluble and total P in the runoff were increased by the surface application of fertilizer and manure (Fig. 5). The increases were greatest with the two rates of manuré application as compared to the fertilizer application, even though the rate of P application with fertilizer was intermediate between the 2 manure rates. This trend occurred in runoff collected within 1 month of application (fall) and 6 months after application (spring). When fertilizer and manure was added, variability in soluble P concentrations was relatively high, resulting in lower correlation between soil test P level and soluble P concentrations than was observed with no P additions (Fig. 5).

Effect of manure and fertilizer incorporation

Manure application method had a significant effect on the soluble P concentrations and content in runoff samples taken in both fall and spring. Soluble P concentrations were substantially higher in runoff from plots with surface applied manure than from plots with injected manure (Fig. 3). The soluble P concentrations in runoff associated with the surface applied manure were higher than the range of P concentrations critical for eutrophication development in surface waters as accepted by National Research Council (1993). Both in fall and spring, the content of soluble P associated with surface applied manure exceeded those from plots with injected manure. Soluble P concentration in runoff from plots with surface applied manure was much higher with fall compared to spring rainfall simulation (Fig. 3).

Manure application rates affected soluble P concentrations and content in runoff from plots with surface applied manure, however their influence was more pronounced in spring than fall runoff. No differences in P losses between low and high manure application rates were observed for plots with injected manure in either fall or spring experiment. Since injected manure was applied under the soil surface, it did not come in direct contact with the runoff water, hence, the P losses from the plots with injected manure were more related to the soil test P level than to the manure application rate.

Summary

Analysis of soluble P in surface runoff revealed that soil test P levels affected both runoff P concentrations and contents with both being higher with higher soil test levels. Soluble P losses were much greater from no-till plots that from chisel plowed plots, but total P losses were greater from tilled than no-till plots. Both higher soluble P runoff concentrations and higher runoff volumes of no-till plots resulted in significant differences in the total P loss between no-till and chisel plowed plots. Surface fertilizer application substantially increased the soluble phosphorus losses compared to chisel plow-incorporated fertilizer. The method of manure application affected the P losses to a much a greater extent than the manure application rates. Plots with surface applied manure had the highest soluble P concentrations and content. However, P losses from plots with injected manure were similar to those from the control plots where neither manure nor fertilizer was added. Our results so far demonstrate that fertilizer incorporation and manure injection have advantages compared with surface applications from both economical and environmental points of view.

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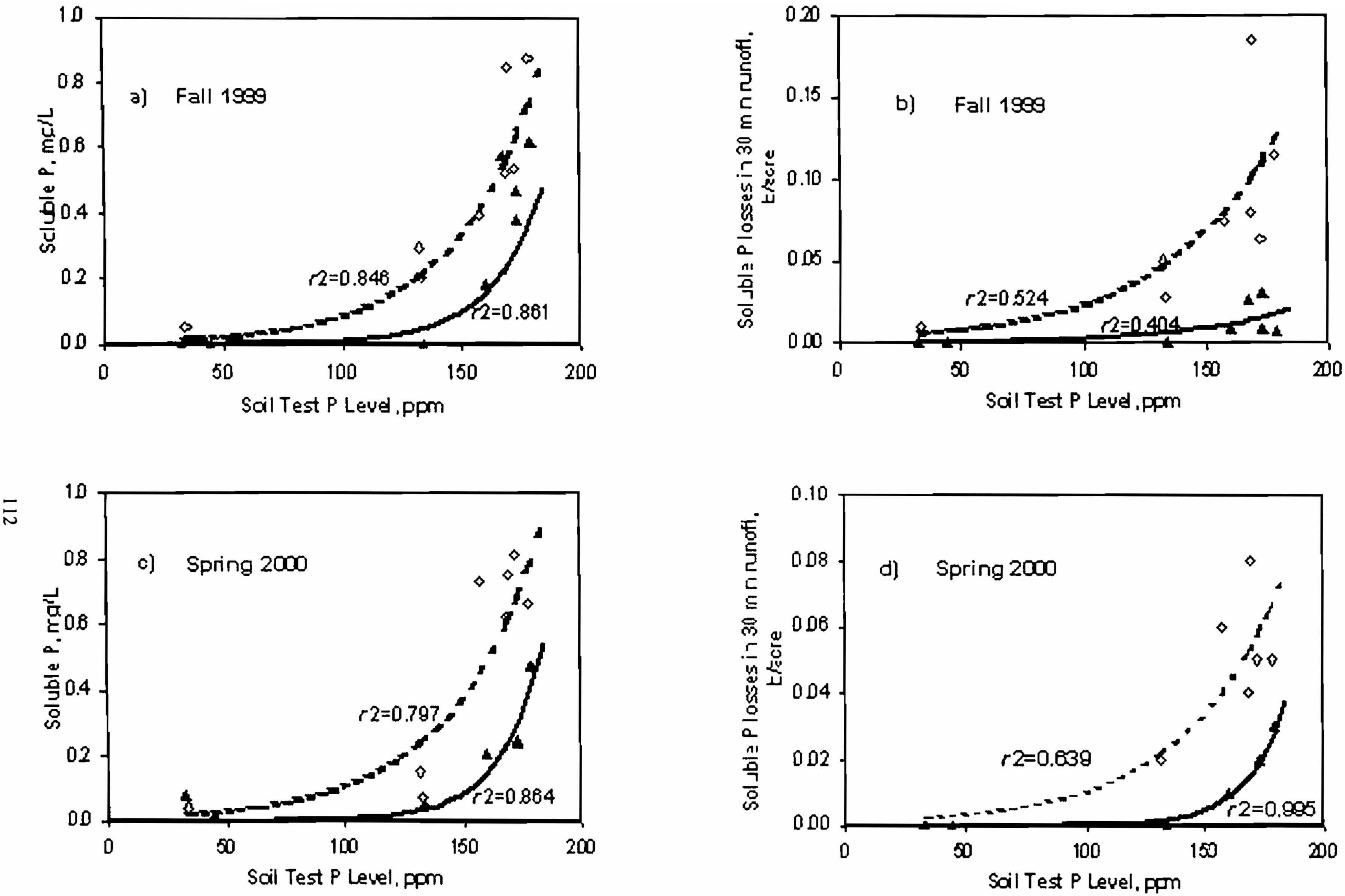

Fig. 1 Effect of soil test P concentration, tillage, and time of sampling on the concentration and content of soluble P in runoff samples from plots with no fertilizer or manure added.

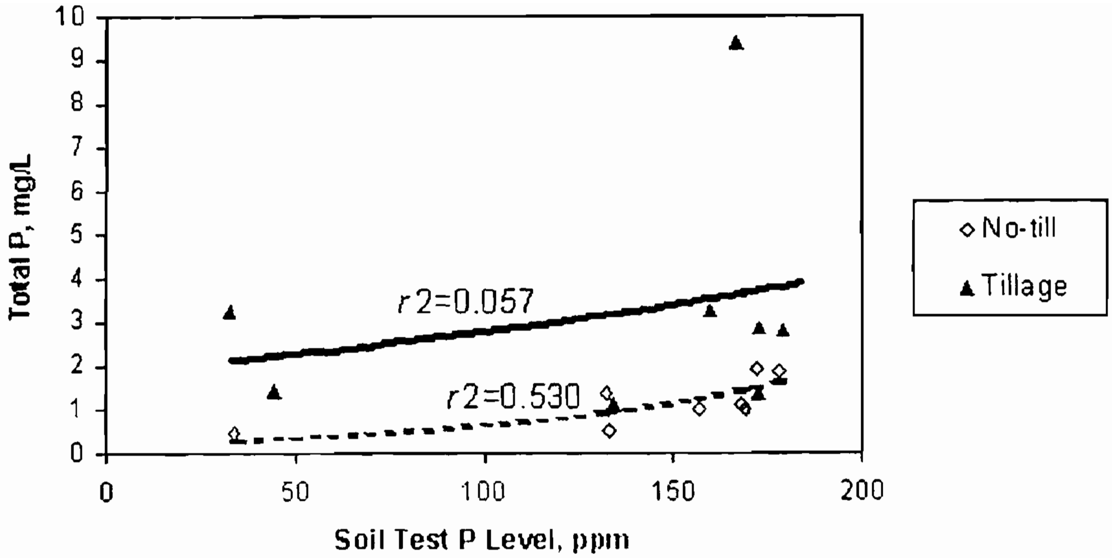

Fig. 2 Effect of soil test P concentration and tillage on the concentration of total P in runoff in spring from plots with no fertilizer or manure added.

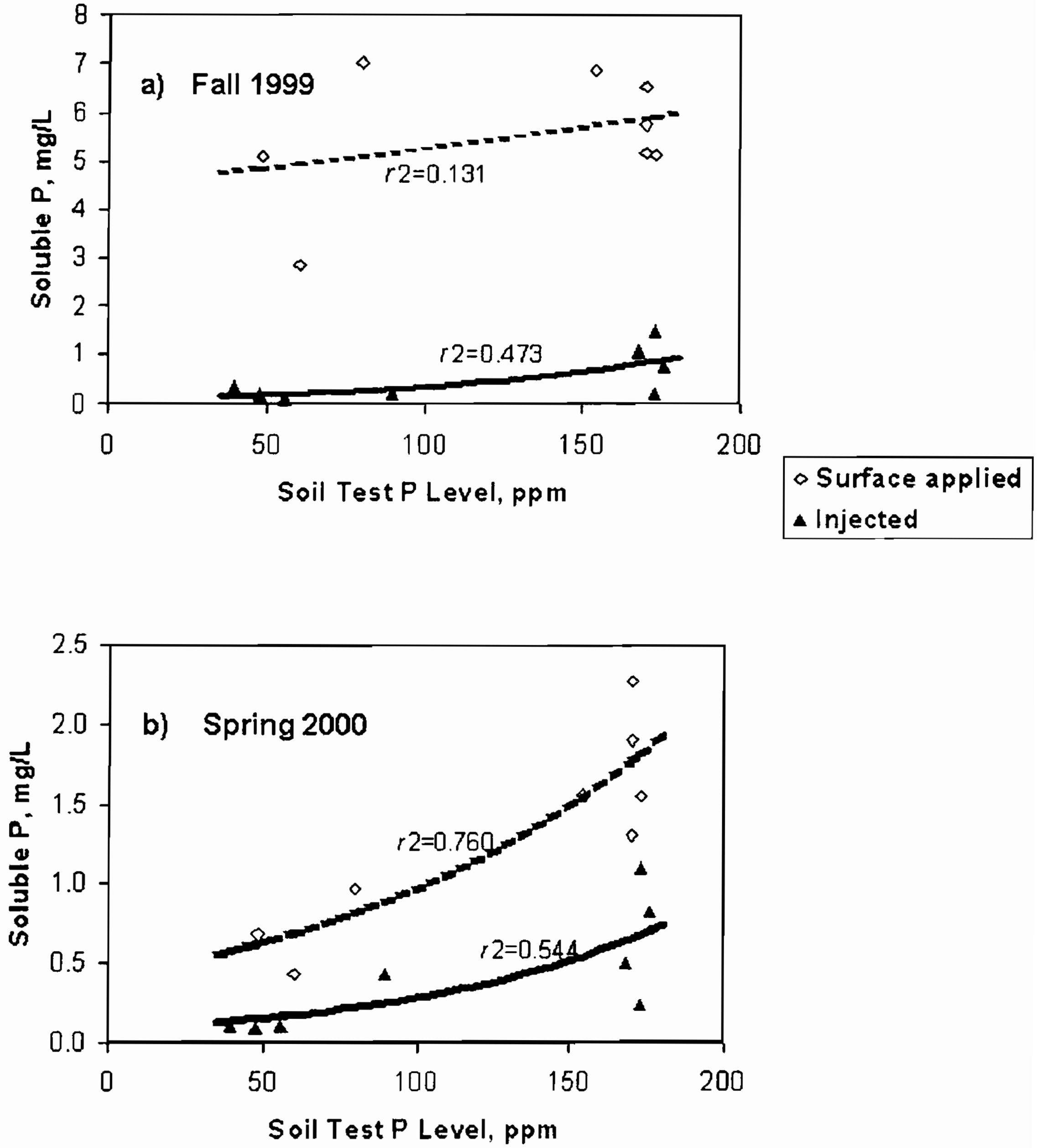

Fig. 3 Effect of soil test P level and method of manure application on the concentration of soluble P in runoff collected a) one (Fall) and b) six (Spring) months after manure application from plots with 10,000 Gal/acre manure applied.

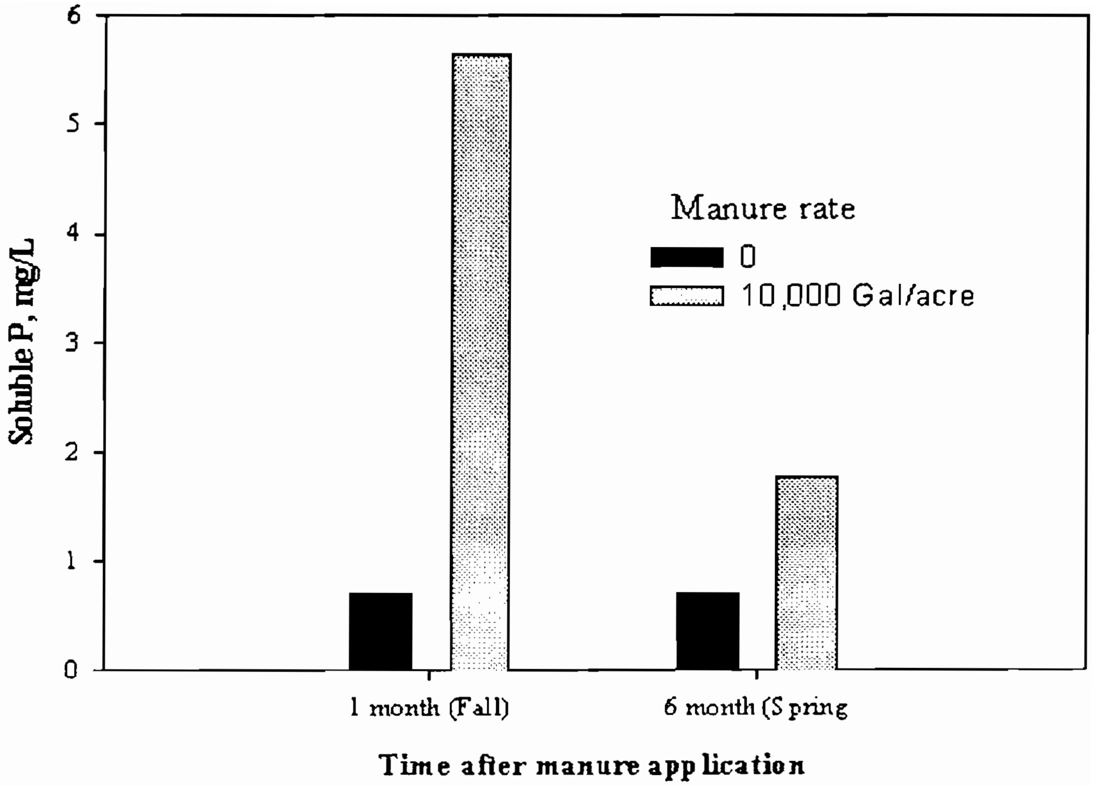

Fig. 4 Soluble P concentration in runoff as affected by manure rate and time after application.

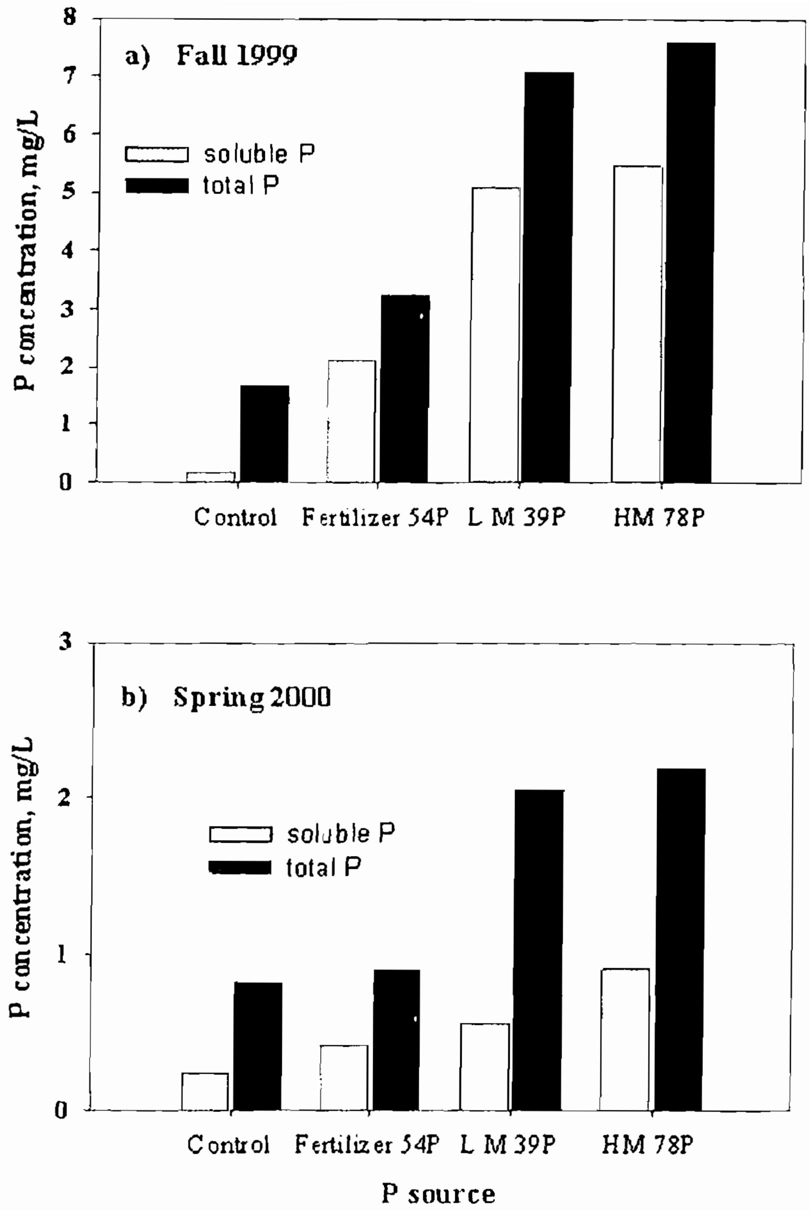

Fig. 5 Effect of surface application of fertilizer and manure on soluble and total P concentrations in runoff collected a) one (Fall) and six (Spring) months after application at soil test levels less than 37 ppm.

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