Forms of P in Different Manures and Their Impact on P Runoff and Leaching Losses from Manure Amended Soils: Summary and Implications

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Summary

Continuous application of manure P at rates that exceed the rate of P removal by crops results in a buildup of soil phosphorus (P). High concentrations of soil P increase the risk of P runoff loss from agricultural land and lead to problems with surface water quality, such as excess algae growth. However, there is little or no information about the effect of applying different sources or types of manure P on the risk of P loss after manure interacts with soil, especially for Prairie soils. Therefore, the objectives of this study were to quantify and compare P losses from soil treated with four sources of liquid swine manure and four sources of solid cattle manure and to relate P runoff and leaching losses to manure P forms and soil test P measurements.

Prior to being applied to the soil, the manure P was analyzed by a series of sequentially stronger chemical solutions to determine the proportion of P in each manure that ranged from easy to more difficult to extract. The total amount of P extracted from the manures was higher in liquid swine manure than in solid cattle manure, when expressed on a dry basis. However, on a fresh weight basis (as applied) solid cattle manure and liquid swine manure had similar total P contents. Therefore, to apply the same rate of total P, similar rates of fresh manure were applied as either liquid swine or solid cattle manure. The proportion of P that was easily extracted from the liquid swine manures (i.e., the "labile P" extracted with water and sodium bicarbonate) was greater than from the solid cattle manures. Therefore, when both types of manure were applied at the same rate of total P, as in our experiment, more "labile P" or readily available P was applied with liquid swine manure than with solid cattle manure.

In the simulated runoff experiment, 4 sources of solid cattle manure, 4 sources of liquid swine manure, 1 source of monoammonium phosphate synthetic fertilizer (MAP, 11-52-0) were applied at the rate of 200 lb of P_2O_5 per acre to either Lone Sand or Newdale Clay Loam soil. A "check" treatment was also included, in which no manure or synthetic fertilizer was applied. All nutrient sources were mixed into the soil; the mixture was then moistened to 90% of field capacity and incubated at 20ºC for 6 weeks. After incubation, treated soils were analyzed for Olsen-P and Modified Kelowna-P (soil P tests commonly used in Manitoba) as well as Mehlich 3-P and water extractable P. Treated soils were then packed into runoff trays and placed at a 5% slope underneath a rainfall simulator that provided artificial rainfall at a rate of 3 inches per hour. Samples of water that ran off the soil surface and water that percolated through the soil were collected over a total of 60 minutes and analyzed for soluble reactive P (the type of P in water that is most easily used by algae), as well as total dissolved P and total P (which includes P attached to soil particles, in addition to dissolved P).

Overall, the runoff losses of P were greatest from MAP fertilizer, followed by liquid swine manure, solid cattle manure and the untreated check. The concentration of soluble reactive P in runoff was significantly greater from soils treated with liquid swine manure or MAP fertilizer

than from solid cattle manure, which was not significantly different from the untreated soil. Similarly, the total quantity of soluble reactive P collected during the runoff period was greatest from soil treated with MAP fertilizer, followed by soil treated with liquid swine manure, solid cattle manure and the untreated check. A very small proportion of dissolved P was in soluble non-reactive P forms (probably in organic forms), so the pattern of losses for total dissolved P followed the same pattern as for dissolved reactive P. When all the forms of runoff P were considered together, the total P concentrations in runoff samples were substantially higher than for dissolved P because of large losses of P attached to soil particles. However, even though the losses of total P were large, our main focus was on P loss in dissolved P forms, since dissolved P forms are the dominant forms of P loss from agricultural fields under natural conditions on the Prairies.

When dissolved P losses in runoff were compared with the forms of P extracted from the raw manures, the pattern for runoff losses was the same as for the proportion of easily dissolved or "labile" P in the manure. The "labile" P extracted by a combination of water and sodium bicarbonate was strongly related to the amount of dissolved P in runoff from the incubated mixtures of manure and soil. Equations for relating runoff losses of dissolved P to "labile P" in manures were similar for both soils. Water, on its own, was not an effective extractant for predicting dissolved P runoff losses from different manures after incubating mixtures of soil and manure for 6 weeks. For testing manured soil after incubation, Mehlich 3, Modified Kelowna and Olsen extractable P were better than water extractable P for predicting dissolved reactive P loss in runoff, with Olsen P being the most accurate of the soil tests for this purpose.

For the column leaching study, incubated soils were packed into PVC (sewer pipe) columns and water was supplied through a rain-drip system at a very low intensity of 0.5 inches per hour. Leachate samples were collected at intervals of approximately 90 minutes over a 24 period and were analyzed for soluble reactive phosphorus. As expected, overall losses of P by leaching were greater from the Lone Sand than from the Newdale Clay Loam, due to the clay loam's greater capacity to retain P. Peak concentrations and total losses of soluble reactive P in leachate from the Lone Sand soil were greatest for liquid swine manure and MAP fertilizer treatments, followed by the cattle manure and check treatments, respectively. However, this effect was not observed in the Newdale Clay Loam, where only the MAP fertilizer treatment resulted in losses of soluble reactive P that were greater than those from untreated soil. In contrast to the runoff study, water extractable P in soil proved to be the most accurate soil test method to predict SRP loss during low intensity leaching, probably because the leaching study allowed water to interact with soil more thoroughly than in the runoff study.

These studies showed that when nutrients are broadcast and incorporated into soil, then incubated for a period of 6 weeks, the environmental availability of P from liquid swine manure was generally greater than that from solid cattle manure, but less than from MAP fertilizer. Contrary to runoff studies conducted with freshly applied manures, water extractable manure P on its own, was not a good analysis for predicting losses soluble reactive P in runoff from manured soils that were incubated. Conversely, the P extracted from manure by water followed by sodium bicarbonate was a useful predictor of runoff losses of soluble reactive P. Water extractable P in manure, however, was a useful analysis for predicting low intensity leaching losses. Of the four soil test P methods, the Olsen method was best for predicting runoff P loss while water extractable P was best for predicting leaching losses.

Key Findings, Implications and Precautions

1. Average amounts of P, in total, were greater in liquid swine manure than in solid cattle manure, when expressed on a dry weight basis. However on a fresh weight basis (as applied) solid cattle manure and liquid swine manure had similar total P contents. Therefore, to apply the same rate of total P, similar rates of manure need to be applied with both liquid swine and solid cattle manure.

2. The proportion of easily extractable or "labile" P was greater in liquid swine manure than in solid cattle manure. Thus, when manures are applied at the same rate of total P per acre, a higher rate of labile P is applied with liquid swine manure than with solid cattle manure.

3. When nutrients were broadcast and incorporated, runoff concentrations and total losses of soluble reactive P were greatest from MAP fertilizer, followed by liquid swine manure and solid cattle manure (i.e., following the same pattern as for the rate of labile P applied). However, it is important to keep in mind that although this type of laboratory study is useful for comparing the relative availability of P to runoff from various nutrient sources, it represents a "worst case" scenario, with sloped, unplanted, bare soil subjected to unnaturally high rates of runoff for lengthy periods, as well as P application rates that are much greater than those that are typically applied on Manitoba farms. Fortunately, typical agronomic practices and weather conditions minimize the risk of loss of P from the most labile nutrient sources in real field situations. For example, average rates of MAP fertilizer on Manitoba cropland is approximately one tenth of that used in the study; furthermore, MAP is usually banded below the soil surface, in the seedrow, in spring, after our main runoff event (snowmelt) has passed. Much of our liquid swine manure is injected or incorporated, a beneficial management practice that is easily used with liquid forms of manure and that is well-suited to address the risk of runoff P loss from this manure source. Lastly, although solid cattle manure is practically impossible to inject and not easy to fully bury by incorporation, this type of manure has very low P availability to runoff.

4. Leaching losses of soluble reactive P in sandy soils followed a pattern that was similar to that for runoff losses: greater for soils treated with MAP fertilizer and liquid swine manure than for cattle manure treated soils. Therefore, to reduce the long term risk of P leaching into groundwater on these soils, long term rates of P application should not exceed rates of P removal by crops, especially for MAP fertilizer or liquid swine manure.

5. The sodium bicarbonate extractable P in manure as well as Olsen P content in soils amended by manure or fertilizer are good predictors of the runoff loss of P where runoff is not likely to occur immediately after applying manure. Therefore, these tests appear to be well-suited to situations where manure is applied in spring, summer or early fall, well ahead of snowmelt, the major runoff event in the Prairies. Also, Manitoba's current soil P test for regulatory enforcement, the Olsen test, appears to be a reliable tool for assessing the risk of runoff P losses, regardless of whether P is applied in the form of MAP fertilizer, liquid swine manure or solid cattle manure.

6. Given its greater chemical and environmental availability, P from liquid swine manure may be more agronomically available than P from solid cattle manure. However, the agronomic availability of P to crops was not evaluated in this study.