SWINE MANURE PHOSPHORUS USE FOR CROP PRODUCTION IN IOWA

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Introduction

Improving manure phosphorus (P) management guidelines should result in a more efficient use of this resource for crop production and in lower risk of P loss to surface water resources. Phosphorus fertilizers are widely used in crop production, there is a great deal of information about their use, and farmers have little doubt about their value to improve crop yield in low-testing soils. However, there is a great deal of uncertainty concerning the value of manure nutrients for crops and about cost-effective methods for its use. Reasons for this uncertainty include large variability of manure nutrient concentrations, scarce research data about plant availability of manure N and P, and difficulties for uniform manure application to fields.

The total P content in manure varies with the animal species, age, and diet and also with the manure storage method. Some manures may have up to 80 to 100 lb P_2O_5 per ton (some poultry manures, for example) whereas others may contain only 5 to 10 lb P_2O_5 per ton. The proportions of organic, inorganic, and water-soluble P in manure also vary greatly. For example, more than 80% of the P of liquid swine manure usually is in inorganic forms while the rest is present as organic P. On the other hand, solid manure from beef and dairy cattle can have less than 50% inorganic P with the rest in organic forms. Estimates of manure P that becomes available to the first crop after application range from 60 to 100% in the North Central Region (Peters et al., 2004). The inorganic and more labile organic P forms in manure become readily available for crops shortly after being applied to the soil and the water-soluble P may be retained to a different degree by the soil.

Therefore, more research is needed regarding the potential of manure to supply crop P needs and to help producers achieve more efficient nutrient management practices. Two different studies were conducted during recent years on Iowa farmers' fields to study utilization of liquid swine manure by crops and manure application impacts on soil-test P (STP). One study focused on manure P utilization by crops and used a conventional research plot methodology. A second study used a strip-trial methodology to evaluate a variable-rate manure application method. This short article summarizes the major results of these studies.

Utilization of Phosphorus in Liquid Swine Manure

Sixteen trials based on a conventional research plot methodology were conducted on farmers' corn and soybean fields. Each trial (nine for corn and seven for soybean) evaluated three liquid swine manure treatments and four P fertilizer rates (0 to 60 lb P_2O_5/acre as triple superphosphate) that were superimposed to each manure treatment. Manure rates for corn were calculated to supply 75 lb/acre or 150 lb N/acre assuming that all manure N was available for the crop. The high N rate used is the highest of a range of fertilizer N rates recommend in Iowa for corn after soybean. Manure rates for soybean were intended to supply approximately one-half (100 lb N/acre) or the total (200 lb N/acre) expected N removal with grain harvest, except at three sites where P rates were the expected P removed with grain harvest and twice this amount. The manure was collected from underground storage pits and was applied in the fall or in spring three to four weeks before planting the crops. The manure was injected or broadcast and incorporated into the soil to a depth of 10-15 cm within 24 hr of the application. Uniform N and K fertilizer rates were applied to all plots before planting (150 lb N/acre and 60 lb K_20/acre). Soil-test P ranged from 11 to 89 ppm across sites (Bray-1 test, 0 to 6-inch depth).

Grain yield response to fertilizer P application was observed at four corn sites and one soybean site. Except for one site, the responsive sites had STP less than 21 ppm, which encompass the Very Low to Optimum soil-test interpretation classes used in Iowa (Sawyer et al., 2002). Only maintenance P application is recommended for the Optimum class. Average results for the four corn responsive sites are shown in Fig. 1. Application of P fertilizer in addition to the high manure rate did not increase grain yield. Yields for plots that received the low or high manure rates yielded more than plots receiving only P fertilizer at rates as high as 60 lb P_2O_5/acre. This "manure effect" was also observed at the non-responsive sites (not shown). A higher yield level with manure and the crop response to manure and not to P fertilizer at one high-testing site cannot be explained with certainty. Perhaps the uniform N and K fertilizer rates applied to all plots were insufficient to offset manure N or K effects on yield. We doubt this is a likely reason or the only reason, however. The uniform N rate applied for corn was the highest of a range of rates recommended for corn after soybean in Iowa. The uniform K rate applied for both crops was in addition to any K applied by the farmers, and the total amount applied could have been lower than rates needed to maximize yield only at two sites. Other possible reasons involve effects on yield of other manure nutrients and manure-induced changes in physical soil properties. These effects have been observed in other studies.

Some of the manure and fertilizer rates used applied approximately similar amounts of P. Regression analyses across sites relating early plant growth and early plant P uptake for these equivalent application rates are shown in Fig. 2. The graphs show slightly higher early growth and P uptake with manure P than with fertilizer P but the difference was small and did not reach statistical significance at *P* # 0.05. Therefore, these results do not support the common concern that swine manure P may not be as effective as fertilizer P for enhancing early crop growth. A similar comparison between manure and fertilizer P was conducted for grain yield and is shown in Fig. 3. The data showed that manure and fertilizer P on average were similar at producing corn and soybean yields. There was significant variation across sites but no P source was consistently better than the other. The results for crop early growth, early P uptake, and grain yield are consistent with the much higher concentration of readily available inorganic P compared with organic P typically found in liquid swine manure.

Producers are uncertain about the residual value of manure P for a following crop and the value of manure at increasing soil P. Study of STP results from samples collected after crop harvest for manure and fertilizer rates that applied approximately similar amounts of P are shown in Fig. 4. The graphs indicate that the Bray-1, Mehlich-3, and Olsen P tests detected approximately similar amounts of plant-available after manure and fertilizer application, although data for the Olsen test were more variable. Study of STP increase from P application compared with the control plots receiving no P (not shown) also indicated inconsistent and not significant differences (*P* # 0.05) between sources. These results are in agreement with results observed for the crop measurements. Total P in liquid swine manure is approximately similar to fertilizer P concerning build-up of soil-test P and the capacity of commonly used soil P methods to measure residual P after P application and crop harvest.

Evaluation of Variable-Rate Technology for Liquid Swine Manure

Soil-test P levels and the P needs of crops can vary greatly within a field. Global positioning systems (GPS), dense soil sampling, and variable-rate technology (VRT) can be used to improve nutrient application to fields. Previous Iowa research evaluated VRT for P and K fertilizer application (Mallarino and Wittry, 1999; Wittry and Mallarino, 2004). This study compared liquid swine manure application using VRT and uniform-rate traditional (URT) methods based on STP for soybean - corn rotations. Manure was applied before planting soybean at rates deemed appropriate to supply the P needs of the two crops for each of two rotation cycles in two fields (using four replications in one field and five in the other). Analysis of data for a third rotation cycle in one of the fields has not been completed. Nitrogen fertilizer (at least 150 lb N/acre) was uniformly applied for corn and K fertilizer (at least 150 lb K_2O/acre) was uniformly applied for each 2-year rotation cycle. Soil samples were collected before applying manure using a dense grid-point sampling method (0.75-acre cells). Initial STP encompassed the Very Low and High or Very High interpretation classes in each field. Manure P increased crop yield (*P* # 0.05) in five site-years but the application methods did not differ. Analysis of responses for field areas with contrasting initial STP levels showed frequent yield response to manure only in areas testing less than 21 ppm (Bray-1 P). In one site-year, yield was higher for VRT than for URT in field areas testing Very Low. These results are not shown.

Observed large crop responses in low-testing field areas, small and infrequent responses in areas testing Optimum, and no response in high-testing areas agree with previous Iowa soil-test P calibration research. The results indicated that use of VRT to apply manure P based on criteria similar to those used in this study seldom would increase crop yield compared with URT. This result coincides with previous evaluations of VRT for fertilizer application in the region (Anderson and Bullock, 1998; Lowenberg-DeBoer and Aghib, 1999; Wittry and Mallarino, 2004). Obviously, URT and VRT methods should not differ when there is no crop response to nutrient additions. However, use of VRT should result in higher yield response in low-testing field areas if higher nutrient rates are applied compared with URT, unless the rates applied with both methods maximize yield. In this study we used recommended P rates according to STP and expected average P removal for the VRT method and only expected average P removal for the URT method. In all instances the VRT method applied more P than URT in the low-testing field areas. On average across the entire experimental areas, the VRT method applied 11% more manure compared with URT. Therefore, other reasons may explain that the application methods seldom differed. Wittry and Mallarino (2004) suggested that very high small-scale STP variability introduces uncertainty when mapping STP, even when a dense soil sampling method is used. Both Anderson and Bullock (1998) and Wittry and Mallarino (2004) suggested that P rates designed to maximize yield and build-up STP in low-testing soil may also explain the results.

Soil samples were collected after harvesting the crops from sections of each initial sampling cell that received no manure, manure with VRT, and manure with URT. Average treatment effects on STP for areas of both fields that initially tested within different soil-test interpretation classes are shown in Fig. 5. Soil-test P for the control treatment showed small and inconsistent change across treatments and field areas. The URT method increased STP in all field areas, while VRT increased STP more in low-testing areas and did not increase STP in high-testing areas. Application of swine manure using VRT reduced STP spatial variability and avoided P application where crops did not need it. Although use of this technology may not increase crop yield compared with URT, it provides a more effective and environmentally sound method to apply liquid swine manure P.

Conclusions

Overall, the results of these studies demonstrated that liquid swine manure P is a valuable resource comparable to fertilizer P for crop production. The results demonstrated that P fertilization does not increase yield after applying liquid swine manure at rates that supply the N needs of corn. These two P sources are similarly effective when the manure P concentration is known and the manure is applied properly.

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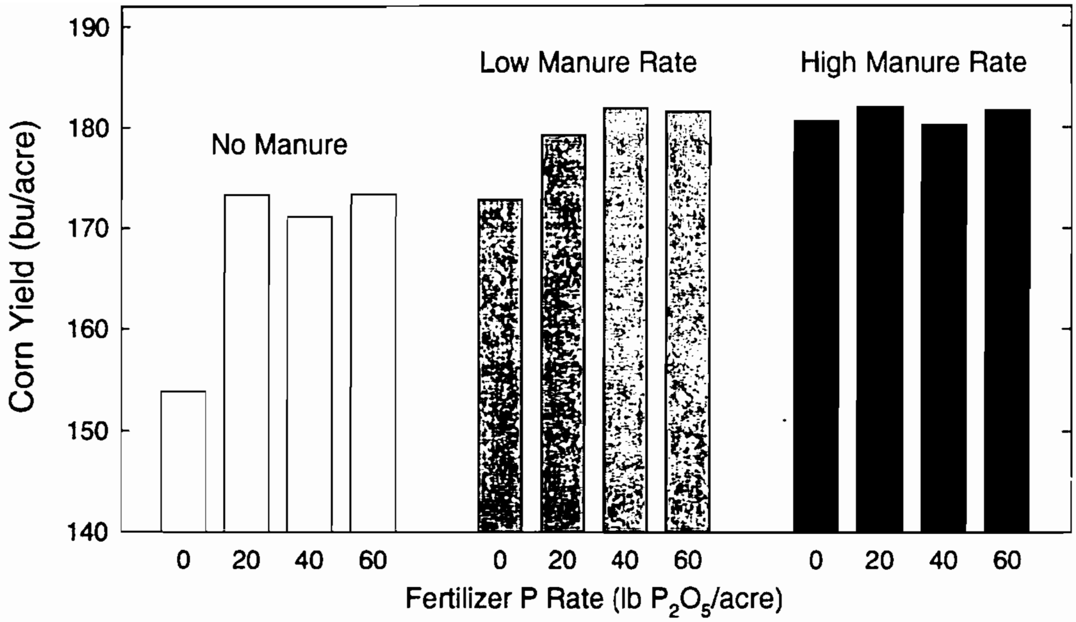

Fig. 1. Average effect of fertilizer P and liquid swine manure P on corn yield across four sites responsive to P fertilization. The P applied with the low and high manure rates averaged 49 and 98 lb P_2O_5/acre. Nitrogen and K fertilizers were uniformly applied across all plots.

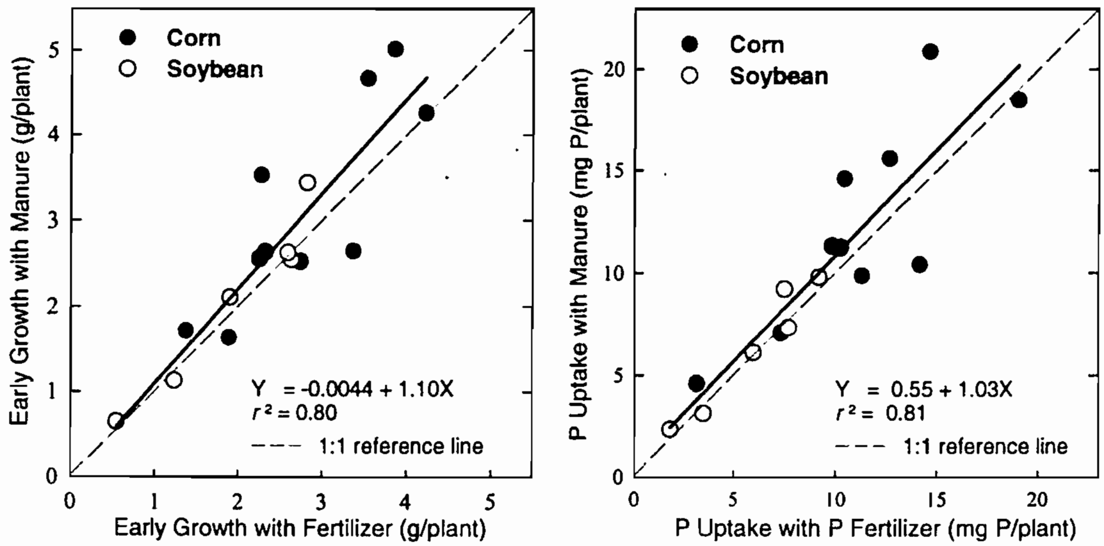

Fig. 2. Effect of fertilizer P and liquid swine manure P applied at approximately similar rates on early corn growth and P uptake across sites.

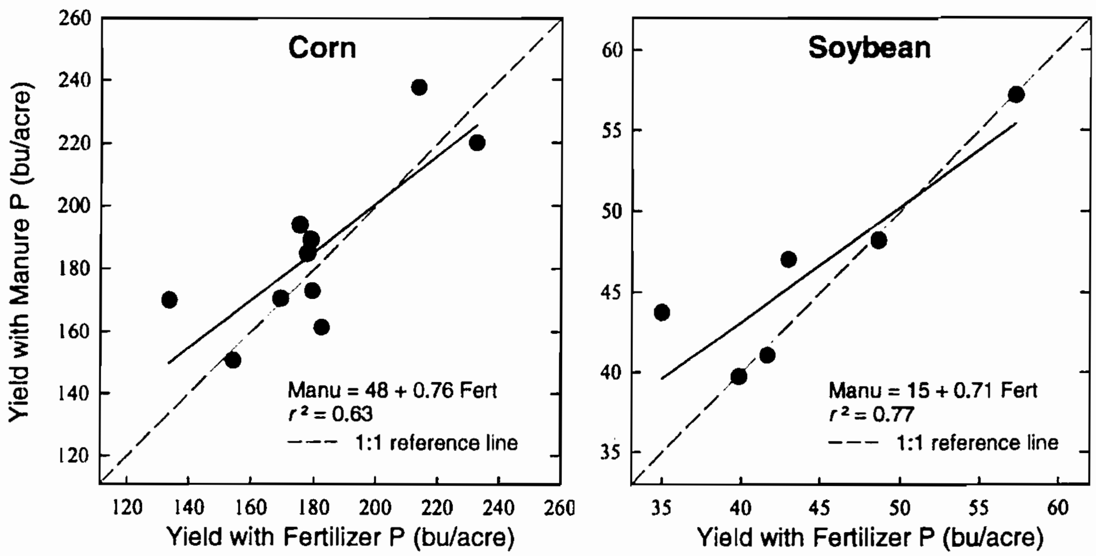

Fig. 3. Effect of fertilizer P and liquid swine manure P applied at approximately similar rates on grain yield across sites.

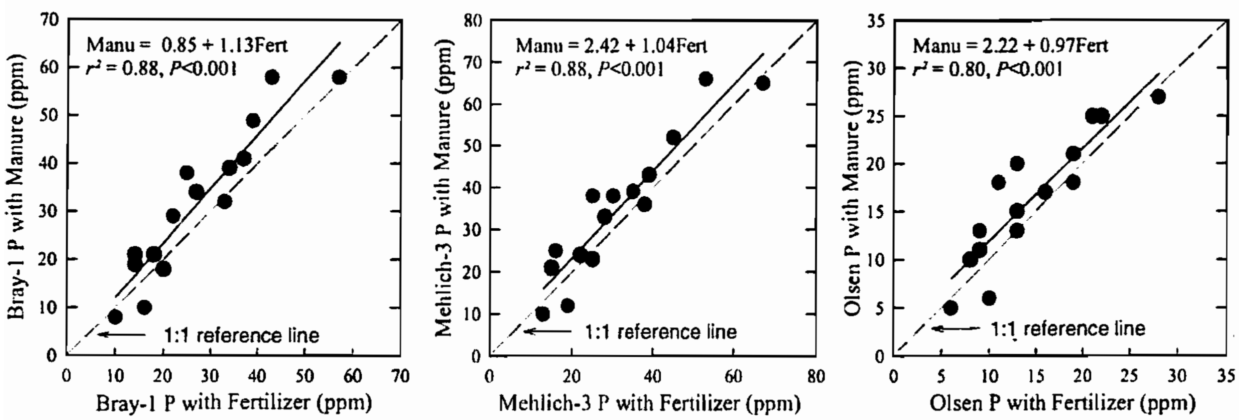

Fig. 4. Effect of fertilizer P and liquid swine manure P applied at approximately similar rates on soil-test P values after crop harvest across sites.

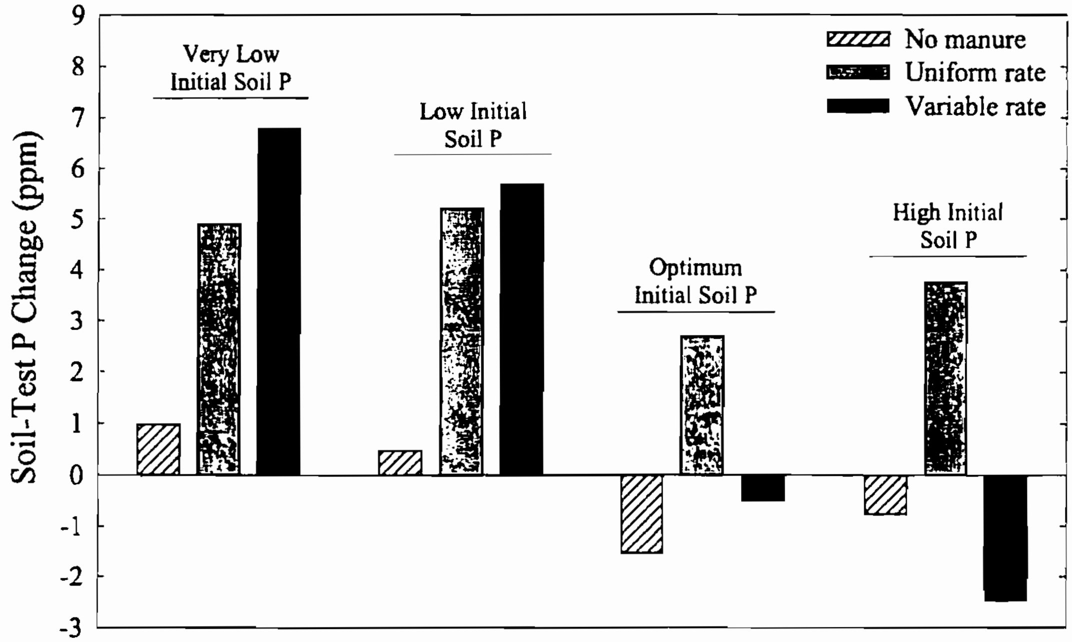

Fig. 5. Effect of uniform and variable-rate application methods for liquid swine manure on soil-test P change after crop harvest for various initial soil-test P interpretation classes (averages of two rotation cycles for two fields).

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