SWINE MANURE NUTRIENT UTILIZATION PROJECT

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Introduction

Manure is an important resource for meeting the nutrient needs of corn and soybean grown in Iowa. Land application is the most widely accepted and best economic and agronomic use of manure. Concurrently, however, is the environmental concern when manure nitrogen (N) and phosphorus (P) is not adequately accounted for or utilized by crops. Use of manure as a crop nutrient source requires producer confidence in nutrient availability and maintenance of high crop yields. When that confidence is lacking, either because of unknown application rates or uncertain nutrient content and crop availability, then additional nutrient applications are often made to ensure adequate soil fertility levels. Historically these additional applications are increased manure application rates or additions of fertilizer. This leads to over-application of crop nutrients, reduced profits, and potential for off-site movement and water quality degradation.

On a statewide basis, using 11,820,000 market hogs as an example, there is 88,650,000 lb crop-available N and 95,151,000 lb available P as P_2O_5 produced per year (ISU Pm-1811 – 50% of manure nutrients recoverable and 50% crop available the first year of application). This is a conservative estimate and a large amount of N and P that must be managed well for good crop yield, improved profitability, proper soil resource management, and enhanced water quality.

The overall project goal is to learn more about liquid swine manure N and P availability for corn and soybean production in Iowa and to cause change in manure management practices by crop and livestock farmers. This includes adoption of soil testing, manure nutrient analysis, equipment calibration, agronomic rate application, and following land application best-management practices – so that yearly applications of additional commercial fertilizer can be reduced when appropriate. Specific focus is to demonstrate liquid swine manure application calibration and rate selection, document manure N and P availability to crops, compare crop yield with manure compared to commercial fertilizer, monitor soil and plant nutrient responses to manure application, and evaluate environmental soil tests on manured soils.

The project used an integrated producer-demonstration-education approach, with coordinated efforts between producers, agronomic extension and research faculty and staff, field agency and extension specialists, and special project coordinators in a series of field demonstrations across Iowa. Information learned from field observation and data analysis was highlighted at field days and will assist producers with adoption of economic manure and nutrient management practices. This project will also provide information for various manure and nutrient management information sources, educational materials, and education programs.

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Objectives

Objectives include: one, work directly with producers and custom applicators to implement field demonstrations and to calibrate manure application equipment or demonstrate state-of-the-art application equipment – to document current application rates and calibration procedures and share with producers appropriate manure application rates based on their manure analysis, calibration, and tractor speed; two, document crop productivity based on manure N and P nutrients and compare to fertilizer sources; three, transfer information to additional producers, landowners, and custom applicators via on-farm demonstrations and field days (including demonstration awareness through field signage) and education programs; and four, update manure management planning information such as nutrient availability and manure nutrient content.

Field Demonstration Description

The strategy for this project was to conduct on-farm replicated field demonstrations across Iowa with concurrent data collection to document liquid swine manure N and P availability to crops. Crop yield response to manure was compared with crop yield response to commercial fertilizer. In the four years of the project (2000-2003) 46 demonstration sites were established with 16 cooperators in 13 counties. Swine manure was applied before corn (21 sites) and soybean (8 sites) crops, and at 17 sites second-year residual manure N or P response was monitored in the year following manure application to corn or soybean.

There were several critical components included in the field work plan for this integrated demonstration project: 1) CALIBRATION - manure application equipment with expected capability to apply agronomic rates and producer willingness to calibrate the manure applicator, or availability of a calibrated commercial manure applicator with electronic flow control equipment; 2) DOCUMENTATION - compilation of a production, crop rotation, nutrient application, and soil test history of each field; 3) SAMPLING - manure records, pre-application sampling and analysis to set application rates; 4) APPLICATION - working with producers, make manure and nutrient applications to the demonstration sites: (a) replicated manure rate strips, including a control with no manure, and (b) replicated fertilizer N and P rates applied to small areas within each manure application strip; 5) EVALUATION - collect samples for routine soil and environmental N and P tests, plant N and P tests, grain yield, and color aerial images; and 6) FOLLOW-UP - study residual manure effects to the next crop in rotation and provide evaluation results to all cooperating producers. These critical components were required to provide the necessary data and education to move manure management to the desired goal of a recognized and valued nutrient resource – one treated like a fertilizer nutrient source.

Field Activity

Eight field demonstration sites with new manure application were identified in 2000, 15 field demonstration sites were identified in both 2001 (11 new manure application sites, four second-year residual evaluations) and 2002 (eight new manure application sites, seven second-year residual evaluations), and eight field demonstration sites were identified in 2003 (two new manure application sites, six second-year residual evaluations) (Figure 1). All sites utilized

liquid swine manure from finishing facilities. Manure at each site was from under-building pit storage, with the exception of two sites with outdoor concrete tank storage.
Manure application equipment was calibrated at application. At some locations applicators were equipped with an electronic flow monitor and rate controller, which aided application and rate uniformity. Multiple manure samples were collected during application. Samples were analyzed for total-N, ammonium, total-P, total potassium (K), and solids. At each site cooperators were asked to not apply manure or fertilizer to the site area, other than manure strips. All other field activities were completed as normal by the cooperator, including grain harvest of the application strips.

Manure demonstration rates and fertilizer applications for corn

Three manure application strips were applied across field lengths and replicated three times: check – no manure, fertilizer N, or fertilizer P; low – manure at a rate to supply approximately half corn N need (75 lb total-N/acre); and high – manure at a rate to supply approximately full corn N need (150 lb total-N/acre). These rates were for corn following soybean, and were intended to supply less-than-adequate manure N (low) and adequate manure N (high). The assumption was made that all of the liquid swine manure N was first-year crop available, so rates were based on total manure-N. Individual manure strip widths matched a multiple of the manure applicator width and combine header width. At some sites manure rates were based on intended P application or other intended N rates. For example, at a continuous corn site, rates might be at 0, 100 and 200 lb total-N/acre.

Fertilizer N (ammonium nitrate) was hand-broadcast applied to small plots superimposed within each manure application strip; N rates of 0, 40, 80, and 120 lb N/acre. Fertilizer N was applied to the soil surface in the spring immediately after corn planting. A blanket application of P (60 lb P_2O_5/acre) and K (60 lb K_2O/acre) fertilizer was made to the small N plots in order to mask the effect of these nutrients applied in the manure.

Fertilizer P (triple super phosphate, 0-46-0) was hand-broadcast applied to small plots superimposed within each manure application strip (usually only at those sites with optimum to very low soil P tests); P rates of 0, 20, 40, and 60 lb P_2O_5/acre. Fertilizer P was applied to the soil surface in the spring and incorporated with secondary tillage. A blanket application of N (150 lb N/acre) and K (60 lb K_2O/acre) fertilizer was made to the small P plots in order to mask the effect of these nutrients applied in the manure.

Manure demonstration rates and fertilizer applications for soybean

Three manure application strips were applied across field lengths and replicated three times: check – no manure, fertilizer N, or fertilizer P; low – manure at a rate to supply approximately half soybean grain N removal (100 lb total-N/acre); and high – manure at a rate to supply approximately full soybean grain N removal (200 lb total-N/acre). The assumption was made that all of the liquid swine manure N was first-year crop available, so rates were based on total manure-N. Individual manure strip widths matched a multiple of the manure applicator width and combine header width.

Fertilizer P (triple super phosphate, 0-46-0) was hand-broadcast applied to small plots superimposed within each manure application strip (usually only at those sites with optimum to very low soil P tests); P rates of 0, 20, 40, and 60 lb P_2O_5/acre. Fertilizer P was applied to the soil surface in the spring and incorporated with secondary tillage. Fertilizer N (150 lb N/acre) and K (60 lb K_2O/acre) was blanket-applied to the small P plots to mask the effect of these nutrients applied in the manure.

Soil and plant sampling

The overall project soil and plant sampling and analyses included the following: collect initial soil samples for routine analyses before manure application, sample small corn and soybean plants to determine plant weight and P content, collect late spring nitrate test and other soil N test samples, take Minolta® 502 SPAD chlorophyll meter readings from corn ear leaves at the R1 growth stage (silking stage) to monitor N response through leaf greenness, harvest manure strips and small plots for grain yield, collect end-of-season cornstalk samples, fall soil samples, and post-harvest profile soil nitrate samples, and analyze soil samples for routine soil tests, soil N tests, and environmental P tests. Results of preliminary 0-6 inch surface soil samples collected before manure application at 2000-2003 field sites are presented in Table 1. Grain yield was determined for each manure strip by combine harvest and for each small N and P fertilizer small plot by hand harvest of measured areas, with corn yields adjusted to 15.5% grain moisture and soybean yields adjusted to 13% grain moisture.

2000-2003 Results

Field Manure Application (Calibration and Sampling)

An important component of the demonstration project was to increase producer awareness of the importance of manure sampling to estimate total nutrient content. At all demonstration sites (representing 50 manure treatment applications) pre-application manure samples were collected for determination of total-N or total-P_2O_5/1000 gallons manure; once determined, the total-N or P nutrient concentrations were used to calculate agronomic manure application rates for each demonstration site. The results of pre-sampling and sampling during application highlight the consistency of manure total nutrient concentrations within a single manure source, and the ability of pre-sampling to successfully guide application rates. Manure nutrient concentrations varied considerably between sites, indicating the need for a manure analysis history and pre-application sample analysis, and indicating the improvement in setting application rates with actual analyses instead of using tabled (book) values. In conjunction with applicator calibration (through use of weigh pads and application over measured areas), intended rates were achieved with good consistency.

Pre-Application Manure Analyses Compared with At-Application Analyses

Manure samples were collected 2 to 3 weeks before planned application by either dipping manure off the surface or probing the storage profile. Thirty-seven of the 50 applications were based on total-N, with the remaining 13 based on total-P. Multiple samples (up to 11 samples per site) were collected during application to the demonstration sites (97 total manure samples for the 4 years). Manure was agitated during pump-out of the storage structures. Figure 2 shows a comparison between the pre-application sample analyses (total-N, P_2O_5, or K_2O per 1,000 gallons) and the average of the samples per site collected during application. Pre-samples were often analyzed only for total-N if the application was to be based on N. Figure 2 represents the ability of pre-samples to predict the manure nutrient concentration during application. Overall, pre-samples gave a good prediction of the total-N concentration expected during application. On average, the pre-application sample had 4.6 percent lower total-N than the at-application samples. Across all sites, the average ammonia-N in the liquid swine manure was 84 percent of the total-N. For P, the variation between pre- and at-application sampling was larger, (9.1 percent average lower total-P_2O_5 for the pre-application samples), but in some instances the pre-sample was dipped off the manure surface, which is not expected to provide a good representation of P in an agitated pit. The average difference for potassium (K) was 0.4 percent greater total-K_2O for the pre-application samples. Because K is contained in the soluble manure solution, the pre-application samples were close to the at-application samples.

Intended Manure Nutrient Rate Compared with Calculated Applied Rate

Figure 3 shows the comparison of the intended manure total-N or total-P application rate and the calculated applied nutrient rate. The applied rate was calculated from the average analyses of the manure samples collected during application at each site and the application equipment calibration. For total-N, if one accepts ± 30 pounds N/acre as an acceptable ability to apply manure-N, then 22 percent of the applications (8 of 37 applications) were outside this range (all but one of these was with a vacuum style applicator). In some instances, the calibration process indicated that greater than desired rates were going to be applied because of equipment limitations to reduce the flow rate and/or tractor speed limitations. These sites were kept in Figure 3, and examples are the two very high application rates. The occurrence of applications well above intended rates happened with vacuum-style applicators, and especially when the manure nutrient concentration was high. For total-P, if one accepts ± 15 pounds P_2O_5/acre as an acceptable ability to apply manure-P, then 23 percent of the applications (3 of 13 applications) were outside this range, mainly due to the pre-sample P analysis being higher or lower than the at-application samples. However, a wider range in P application could be expected because some of the manure samples were dipped from the manure storage surface for total-N measurement. This sampling method would not be expected to represent P as well as collecting a probe sample through the manure storage profile.

When based on either total-N or total-P, 16 percent of applications were greater than 25 percent from the intended rate (8 of 50 applications). The majority of applications (38 of 50) were within 15 percent of the intended nutrient rate. If you take out the two known high application rates from one site, then 16 percent of applications fall outside the ± 30 lb total-N/acre range. Five of the seven high application rates were made with vacuum-style equipment. Many of the applicators used in the project were equipped with a flow monitor and rate controller. These applicators calibrated well, and variation between intended and calculated rates was generally due to differences in the pre- and at-application manure analyses. Partly due to the pre-application sample analysis being lower than the at-application sample, the tendency was for the calculated applied rate to be larger than the intended rate (Figure 3). Across all sites (with the expected two very high manure rate site applications removed), the average difference in intended versus actual application rate (intended - calculated actual) was 8 lb N/acre (107% of intended) and 5 lb P_2O_5/acre (105% of intended). At the corn following soybean sites (with the expected two very high manure rate site applications removed), the calculated average total-N application for the intended 75 lb total-N/acre rate was 87 lb N/acre and for the intended 150 lb total-N/acre rate was 169 lb N/acre.

Variability in Nutrient Analyses for Samples Collected During Application

Figure 4 shows the comparison of individual manure sample N, P, and K analyses and the site average analyses. Because the project worked with producers from a wide area of Iowa and with different swine production practices, one would expect a wide range in total-N, P, and K content. This is evident in the wide distribution of average site analyses. For total-N, the lowest site had 32 pounds and the highest site 79 pounds total-N/1,000 gallons. For total-P, the lowest site had 17 and the highest 54 pounds P_2O_5/1,000 gallons. For total-K, the lowest site had 23 and the highest 48 pounds K_2O/1,000 gallons. These differences in site averages highlight the importance of sampling and laboratory analysis rather than using book values. Only if a book value happens to coincide with the actual analysis would the book value be helpful for determining application rates.

Figure 4 also shows the variation within the multiple samples collected during each application. For N and K, the ranges are very narrow, with most samples falling within ± 2 pound/1,000 gallons (91 of 97 samples within this range for N and K). For P the variation was wider (72 of 97 samples within ± 2 pounds P_2O_5/1,000 gallons), indicating the tie between P and variation in solids content as a storage structure is emptied.

In summary, the project documented the importance of sampling liquid swine manure for determining nutrient concentrations. In conjunction with application equipment calibration, manure pre-application analyses are helpful for achieving desired nutrient application rates. The entire application process requires effort, but can be successful if careful attention is paid to sampling, calibration, and rate monitoring and control. In addition, over time a manure analysis history from the pre- and at-application samples can be developed that will aid future applications and reduce the reliance on pre-application samples.

Yield and Associated Plant Growth Measurement Response to Swine Manure and N Fertilizer

Corn grain yield level and yield response to liquid swine manure application and additional N fertilizer varied by site in 2000-2003. Low- and high-rate manure applications substantially increased average corn strip yields relative to the no-manure check at 16 of 19 evaluation sites in 2000-2003 where manure was applied before the corn crop (Table 2). Of the total yield increase from manure application (at the 18 sites that had both a low and high manure N rate), the majority typically came with the low manure rate (average 28 bu/acre strip yield increase across sites with the low manure rate and 38 bu/acre increase with the high rate). At the four corn following corn sites, the average yield increase with the low manure rate was 37 bu/acre and 48 bu/acre increase with the high rate. At the corn following soybean sites, the average yield increase with the low manure rate was 25 bu/acre and 35 bu/acre with the high rate.

At several sites the low rate supplied adequate plant-available N, as there was no additional yield response with the high rate. Two sites in 2000 (Hardin and Plymouth) and one site in 2003 (Boone) were non-responsive due to high manure application history (high soil N supply) or drought conditions. Strip yield increases are considered mainly due to manure-N at most sites, although part of the strip yield increases could be a response to manure P or K at some sites where soil tests were below optimum (Clay 2001, Story 2001, Hardin (c-c) 2001, and Davis 2002 had average strip P and K soil tests below optimum), or to other factors associated with manure application. When warm, drying conditions occurred during broadcast application (Clay 2001) or excessively wet spring conditions (Washington 2001, Davis 2002, Washington 2002) resulted in apparent N losses, on poorly drained soils, or where corn followed corn, then corn yield was increased with higher manure rates or with additional fertilizer N application. If yield was improved with the higher manure rate, it was due to a combination of specific manure N rates applied and site conditions (corn N requirement and potential N loss). These results with liquid swine manure, and potential effects from loss conditions, are similar to those encountered with N fertilizer.

Corn yield response to additional N fertilizer was most consistent in the strips that received no manure or the low manure rate. At only the most N-responsive sites did corn yield increase with additional fertilizer N applied in addition to the half-rate manure application. As an example, in 2000 and 2001 at five sites with similar manure total-N rates and corn following soybean, the average response was only up to 40 lb fertilizer N/acre (Figure 5). Figure 5 represents average corn grain yield, relative corn ear leaf greenness, and end-of-season cornstalk nitrate response to swine manure N and superimposed small plot fertilizer N. At those corn following soybean field sites receiving excess rainfall after manure application (denitrification or leaching losses) or warm temperatures at manure application (N volatilization losses of surface applied manure) corn yield increased with additional fertilizer-N applied in addition to the high manure rate—no sites in 2000, one site in 2001, and three sites in 2002. These four years of yield data suggest that supplementing swine manure with additional fertilizer N is only necessary when the manure-N rate is inadequate to meet specific corn needs or losses reduce N supply.

Grain yield and relative leaf greenness indicated similar corn responsiveness to manure and fertilizer N (example for five similar corn following soybean sites shown in Figure 5). Leaf greenness (Minolta SPAD chlorophyll meter readings) will not indicate excess N (readings do not increase once maximum greenness is reached, even with more N) but will show deficiency (at approximately <95% relative SPAD – relative to adequately N fertilized corn greenness). Corn yield responded to higher manure or fertilizer N rates when relative SPAD values were below 95%. Relative SPAD values above 95% generally indicated yield did not increase with more N. When manure N or manure plus fertilizer N application was greater than corn need (especially when the rate was excessive), stalk nitrate indicated high levels (well above 2,000 ppm). The average manure total-N rate of approximately 150 lb N/acre seemed to supply adequate plant-available N at these five sites. At an average 80 lb total manure N, approximately 40 lb additional N/acre was needed from fertilizer.

Corn was responsive to liquid swine manure application, with large yield increases at responsive sites (largest increase was 80 bu/acre). Most yield increase was with the low manure rates, with further yield increase from high manure rates at the more N-responsive sites. It was possible to meet corn N requirements solely with liquid swine manure. Although it is not possible to exactly discern first-year crop availability, yield and plant N measurements suggest that N in liquid swine manure is highly available to corn in the year of application and appears to support the current recommendation that first-year swine manure N availability is near 100 percent. With the average ammonium-N in liquid swine manure samples collected at application being 84 percent of the total-N, this would indicate that crop availability should be high. Results from these four years also indicate that liquid swine manure should be applied following steps of known manure total-N content (manure pre-application and at-application laboratory analysis); applied with equipment calibrated at rates to supply corn N fertilization recommendations; applied in a manner to minimize volatile loss (injection instead of broadcast); and applied at times to minimize conversion of manure ammonium to nitrate well before crop use.

Yield and Associated Plant Growth Response to Swine Manure and P Fertilizer

Effects of supplemental P fertilizer on corn yield were tested at 16 locations from 2000 to 2003 where preliminary soil sampling of small-plot areas indicated "optimum" or lower Bray-1 soil P test levels. Results support ISU fertilizer and manure P recommendations--additional P applied in the form of manure and supplemental P fertilizer may increase early-season corn growth and plant P uptake, but seldom increase grain yield when soil test levels are optimum and higher.

Table 3 shows corn response to four supplemental P fertilizer rates after applying manure. Because the actual P amount varied across sites and treatments, the results across locations are summarized for several ranges of N-based manure rates. The lower manure-N application range (70 to 100 lb N/acre) applied on average an amount of P equivalent to the P removed by a corn yield of about 150 bu/acre. The higher manure rates applied amounts of P that were up to four times the P usually removed by an average corn crop. The yield data showed no significant yield response to supplemental P fertilization, although there was a small responsive trend for the lower manure application range. The initial soil-test P values were highly variable within a site, but at most sites the average initial soil-test P before applying manure tested in the optimum (16 to 20 ppm, Bray-1 test) or higher interpretation classes for corn. These results demonstrate that manure application based on N needs of corn (usually 100 to 150 lb N/acre) supply excessive P for corn and sometimes enough P for two crops.

In these fields, manure and fertilizer P often increased early-season corn growth and plant P uptake (not shown) but these responses did not translate into higher grain yield. The P uptake response was mainly due to increased early growth compared with P tissue concentration. Previous research based on P fertilization also showed early growth responses at soil-test P levels higher than levels needed to maximize grain yield; however, factors other than P from the manure could explain early growth responses seen at some field sites.

The high manure rate did not increase plant growth or P uptake compared with the low manure rate. The P uptake response was mainly due to increased early growth compared with P tissue concentration. These responses were not clearly associated with soil test P levels. Previous research based on P fertilization also showed early growth responses at soil test P levels higher than levels needed to maximize grain yield; however, factors other than P from the manure could explain the responses seen at our field sites. At 2000-2003 sites, application of additional P fertilizer in addition to P supplied by liquid swine manure did not increase corn yield (Table 3).

Soybean Response to Liquid Swine Manure Application

Effect of liquid swine manure application on soybean yield was tested at eight locations in 2000-2002 (Table 4). Because most fields tested optimum or higher in soil-test P and K, a lack of soybean yield response at most fields is reasonable (Clay 2001, Floyd 2002, and Hamilton 2002 had average strip soil test P or K below optimum). There was a statistically significant response to manure application at only one site (Washington 2002), which was a very high-testing field. The average soybean yield increase measured would not be large enough to offset the cost of the manure-N that could be utilized for corn production. These results are similar to results from other studies in Iowa and other states that show inconsistent, unpredictable, and usually small soybean yield increases from liquid swine manure application when soil-test P and K is high. Soybean yield response in high P testing soils due to manure-P is not indicated in this project as there was no observed yield increase when fertilizer P was applied to each manure rate. The response to liquid swine manure is most likely due to complex, poorly understood nutritional and physical factors influenced by manure application.

Table 5 shows the soybean response to four supplemental P fertilizer rates after manure application. Because the actual manure P applied varied across sites and treatments, the results across locations are summarized for several ranges of manure P application rates. The lower manure application range (40 to 60 lb P_2O_5/acre) applied an amount of P equivalent to the P removed by a soybean yield of about 60 bu/acre. The higher manure rates applied as much P as 3.5 times the P usually removed by an average soybean crop. The yield data showed no significant yield response to supplemental P fertilization. These results also demonstrate that manure application ahead of soybeans can be used to supply the nutrient needs of this crop and also to build-up P if needed, but that will also apply unneeded high N rates. Evaluation of the effects of manure application at rates greater than P removal in grain of one crop on the yield of second-year crops (not shown here) indicate that the manure-P is available in the second year and that producers should account for it when planning for the next crop.

Post-harvest profile soil sampling indicated no increase at some sites and slight buildup of residual nitrate-N at some sites for either manure rate compared to the no-manure check (average four-foot profile nitrate was 60, 72, and 76 lb NO_3-N/acre for the none, low, and high manure rates, respectively). There was considerable variability in profile nitrate between sites when no manure was applied, and increases in profile nitrate were not consistent between sites or manure-N rate. These results indicate that the soybean crop readily utilized applied manure N, and are consistent with those of work in Minnesota that showed buildup of post-harvest profile nitrate-N did not occur until rates were above soybean crop use. It is not possible to equivocally state that nitrate did not leach from the soil profile, but since largest nitrate-N concentrations remaining after harvest tended to be in the top foot, one would expect that leaching was not predominant in removal of applied manure-N.

Residual-Year Corn Response to Liquid Swine Manure N Application

Average corn yield response to fertilizer N in the residual manure year (for manure applied either before soybean or corn, and then corn grown the following year) was similar for all prior year manure rates for corn after soybean (Figure 6). Only two sites showed a differential increase in corn yield to fertilizer N, and in those instances the yield increase was larger when manure had been applied in the previous year. Similar responses were measured in ear leaf greenness (Figure 7). This indicates little second year crop-available manure N supply, and that no second-year available-N credit should be taken in the second year following liquid swine manure application – whether swine manure is applied before a previous corn or soybean crop. With the high ammonium-N, low organic-N, and low solids content of the liquid swine finishing manure (96% samples had solids content less than 10%), this result is not surprising. Soil nitrate-N concentrations in the top foot of soil collected in June were the same for all prior-year manure rates (Table 6). However, if manure-N is over-applied, then residual carryover nitrate would be expected as more mineral N is supplied than the crop can utilize.

Corn yields were enhanced at some sites from prior-year manure applications (on average 6 to 15 bu/acre across all residual sites) (Figure 8). Four sites had higher yield where the low or high manure rate had been applied in the prior year. Similar response was measured in ear leaf greenness at some sites, but on average the ear leaf greenness response was much smaller than the grain yield response (Figure 9). Two of three sites where field-length strip yields were collected (Clay 2001 and Floyd 2003) had yield increase with the prior-year manure application; the other (Washington 2002) did not (data not shown). This matched the small plot results for those sites. These results indicate some effect from the prior-year manure application, but since there was no difference in response to fertilizer N, and similar yield increase to fertilizer N within each prior-year manure rate, then the higher yield may be due to other factors resulting from manure application to the prior crop. Since broadcast P and K was applied across all fertilizer N plots, it is assumed that yield enhancement was not due to residual manure P or K. For the residual strip yields at the Clay 2001 site, yield increase could be due to P or K.

Swine Manure Effect on Soil P as Measured by Agronomic and Environmental Tests

A component of the demonstration is to evaluate the performance of new environmental soil P tests. Preliminary results from 2000-2001 summarized in Figure 10 suggest that the three agronomic soil P tests (Bray-1, Olsen, and Mehlich-3 methods) and the two environmental soil P tests (based on P extraction with iron-oxide impregnated paper or water) provided similar estimates of manure application effects on post-harvest soil-test P levels. As expected, low manure rates generally produced little change in post-harvest soil-test P levels (as measured by all tests), and the tests extracted widely different amounts of P. Full manure rates increased post-harvest soil-test P levels of all tests. Increases in soil test P provide an indication of the high crop availability of P in liquid swine manure.

As expected, the amount of P extracted by the five soil P tests used varied markedly. However, the relative increase in soil test P after applying the high rate of manure was similar for all P tests. Agronomic and environmental tests seemed similar in estimating P availability in fertilized or manured plots. However, the water environmental P test was less sensitive to changes in soil P caused by manure P application compared with the other tests mainly because very little P was extracted from the soils. Previous research showed that the agronomic soil P tests are better correlated to yield response from soil nutrient additions. Producers are advised to use the currently used routine soil tests (Bray-1, Olsen, and Mehlich-3) for agronomic assessment of the impact of manure on soil P.

Education Benefits

An important component of this project was to document the process of applying agronomic-based liquid swine manure application rates – especially a method that can successfully result in the application of desired nutrient rates. For most corn production fields, and for current requirements of the Department of Natural Resources manure management plans, the rate is based on corn N needs. Once the rate of N to be applied is determined for a particular field, the manure rate is calculated from that N need. This project documented that it is possible to accurately set those rates, and accurately achieve application of those rates in the field. It takes effort and proper equipment, but it is possible. Following is the process utilized in the project. First, a pre-sample of the liquid manure is collected ahead of manure application. This sample is collected by dipping manure off the top of the manure in storage (only if total-N is determined), or probing the depth of the storage volume. The sample is collected far enough in advance of planned application for chemical analysis by a laboratory. The results for total-N are compared to historical analyses from the structure to confirm nutrient content. Having a history of analyses is important to confirm current sample results. The pre-sample total-N content is used to set the manure applications for the planned rates. Once the rate is determined, the applicator is calibrated before application, or a calibrated flow controller is utilized. Once calibrated, the manure rates are applied. As the manure is applied, multiple manure samples are collected and sent to the lab for chemical analysis. The results of these samples are compared to the pre-sample and for determination of actual applied nutrient rates, and to develop a manure analysis history. When this process is followed carefully, the intended nutrient rate is accurately achieved.

A concern identified during this project is the inability of some application equipment (either applicator rate constraints or tractor size) to apply rates low enough for the intended project rates or to meet N rates required in a manure management plan. This issue could be addressed through assistance to producers for purchase of improved application technology such as driven pumps and especially liquid flow controllers and rate adjusting valves. Through the calibration component of this project, this type of application technology has been shown to accurately apply liquid manure at desired rates. Through this project, and educational activities throughout the state, we are convincing producers of the value of liquid swine manure as a nutrient resource and improving the understanding of manure nutrient availability. However, the next step is to improve the capability of producers to apply liquid swine manure at planned agronomic rates.

A success demonstrated in this project has been the transfer of manure from area swine producers to cooperating crop producer sites (farmers that are not swine producers). This has occurred at multiple demonstration sites in the project and is an important aspect of improved interaction between livestock and crop producers, demonstration and acceptance of manure as a nutrient resource by crop producers, and recognition of the high crop nutrient availability and nutrient value of swine manure. This recognition has important implications for best manure utilization as application to land controlled by crop producers helps with manure management plans, provides improved manure distribution within a geographic area, relieves the pressure on swine producers to apply manure to land that doesn’t need additional P, and gets the manure applied to land where crops can best utilize the nutrients.

Project Partners:

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Iowa Department of Natural Resources
Iowa Department of Agriculture and Land Stewardship, Division of Soil Conservation
Leopold Center for Sustainable Agriculture
Iowa Central Community College

Table 1. Routine soil test averages for 0-6 inch surface soil samples collected from field-length strips before manure application at corn and soybean sites, 2000-2003.

Site-Year	Soil Test P (Bray-1)	Soil Test K (Ammon. acetate)	pH	Organic Matter
	- - - - - - ppm	- - - - - -		%
<u>2000 corn sites</u>				
Webster	17	133	6.6	5.7
Clay	44	220	5.8	6.8
Hardin	104	269	6.4	5.8
Washington	"Very High"	"High"	- -	- -
Plymouth	45	228	6.0	3.7
<u>2000 soybean sites</u>				
Clay	30	198	6.1	6.0
Webster	29	168	6.5	5.6
Hardin	113	232	5.7	4.9
<u>2001 corn sites</u>				
Cerro Gordo	19	222	5.8	4.3
Clay	7	171	5.8	5.9
Washington	48	216	7.0	6.1
Wright	34	212	6.5	4.9
Hardin	27	147	6.6	4.8
Story	16	114	6.3	3.9
Hardin (c-c)†	27	117	7.3	5.6
Cerro Gordo (c-c)†	25	186	6.7	6.4
Floyd (alf-c)‡	15	114	6.7	5.6
<u>2001 soybean sites</u>				
Clay	10	170	6.2	5.9
Washington	17	194	6.5	4.7
<u>2002 corn sites</u>				
Davis	13	85	7.1	3.4
Hamilton	19	186	7.0	6.5
Washington	122	219	6.7	5.1
Hardin	38	161	6.5	5.2
<u>2002 soybean sites</u>				
Floyd	19	98	6.7	3.8
Hamilton	21	98	6.0	3.6
Washington	42	238	6.6	6.1
<u>2003 corn sites</u>				
Boone	208	606	6.3	5.0
Scott (c-c)†	75	167	6.8	4.0

† Sites where corn followed corn. Hardin site in 2002 was second year with manure treatment application (same site as 2001).

‡ Site where corn followed alfalfa.

Table 2. Average corn grain yield increase from liquid swine manure application, 2000-2003 (yield with low or high manure rate minus yield with no manure).

	Swine Manure Application		Manure Total Nutrient Application					
Sites	Low	High	Low	High	Low	High	Low	High
	bu/acre increase		lb N/acre		lb P_2O_5/acre		lb K_2O/acre	
Corn after soybean	25	35	87†	169†	59†	117†	60†	116†
Corn after corn	37	48	88	180	62	126	62	129
All sites	28	38	87	171	59	119	60	119

† Not including manure rates at Plymouth 2000 and Washington 2000 sites.

Table 3. Corn grain yield response to fertilizer P applied in addition to various liquid swine manure-N based rates, 2000-2003.

Manure Nutrient Application			Supplemental P Fertilizer Rates, lb P_2O_5/acre			
N range†	Average N rate	Average P rate	0	20	40	60
- - - - lb N/acre - - - -		lb P_2O_5/acre	- - - - - - - corn yield, bu/acre - - - - - - -			
70-100	79	47	177	184	186	183
101-140	115	75	198	198	196	204
141-180	161	99	193	198	193	196
181-207	194	120	206	199	211	202

† Manure-N ranges across eight sites and two manure application rates at each site.

Table 4. Effect of liquid swine manure application on field-length strip soybean grain yield, 2000-2002.

	Swine Manure Application			Manure Total Nutrient Application					
Site-Year†	None	Low	High	Low	High	Low	High	Low	High
	- - - - - bu/acre - - - - -			lb N/acre		lb P_2O_5/acre		lb K_2O/acre	
2000									
Clay (sp)	48a*	49a	50a	114	228	73	146	54	109
Webster (sp)	42a	43a	45a	91	182	58	115	59	118
Hardin (sp)	56a	57a	56a	83	192	100	232	81	188
2001									
Clay (sp)	47a	51a	51a	100	201	53	105	54	109
Washington (sp)	49a	51a	53a	114	201	68	125	61	114
2002									
Floyd (lf)	60a	60a	61a	147	271	103	189	112	207
Hamilton (lf)	55a	56a	56a	107	214	53	107	79	158
Washington (lf)	58a	65b	65b	124	249	95	189	68	137

* Yields within each site not significantly different when followed by the same letter ($P \leq 0.05$).

† Relative application timing shown in parentheses: sp = spring before planting and lf = late fall.

Table 5. Soybean grain yield response to fertilizer P applied in addition to various liquid swine manure-N based rates, 2000-2003.

Manure Nutrient Application		Supplemental P Fertilizer Rates, lb P_2O_5/acre			
P range[†]	Average P rate	0	20	40	60
- - - - lb P_2O_5/acre - - - -		- - - - - - - soybean yield, bu/acre - - - - - - -			
41-60	51	44.8	45.3	45.5	46.3
61-100	80	48.7	49.7	48.0	47.7
101-140	111	46.2	45.0	46.4	47.8
141-189	168	58.5	57.0	56.5	59.5

† Manure-P ranges across seven sites and two manure application rates at each site.

Table 6. Late spring soil nitrate concentration where liquid swine manure had been applied before the previous-year soybean or corn crop and no fertilizer N applied, 2001-2003.

	Prior-Year Swine Manure Application		
Site-Year	None	Low	High
	- - - - - nitrate-N, ppm - - - - -		
Following Soybean			
Clay 2001	8	7	8
Webster 2001	9	9	9
Clay 2002	12	13	13
Washington 2002	3	3	3
Floyd 2003	6	7	7
Hamilton 2003	9	8	9
Washington 2003	4	5	4
Following Corn			
Hamilton 2003	9	6	12
Davis 2003	18	10	19

Figure 1. Swine manure nutrient utilization project demonstration sites, 2000-2003. Stars represent locations of 2000 field demonstration sites, circles represent 2001 field sites, splashes represent 2002 field sites, and large crosses represent 2003 field sites.

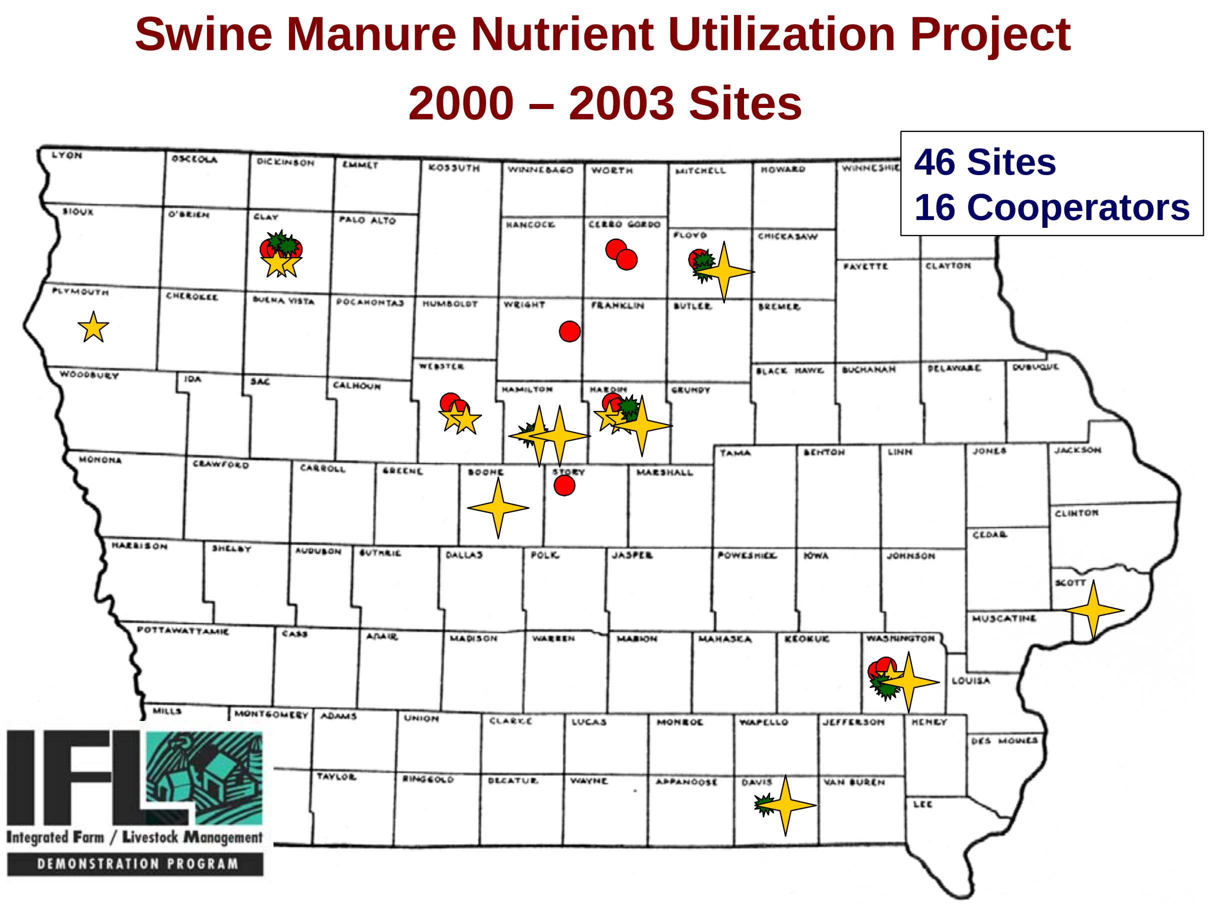

Figure 2. Comparison of pre- and at-application liquid swine manure nutrient analyses, 2000-2003.

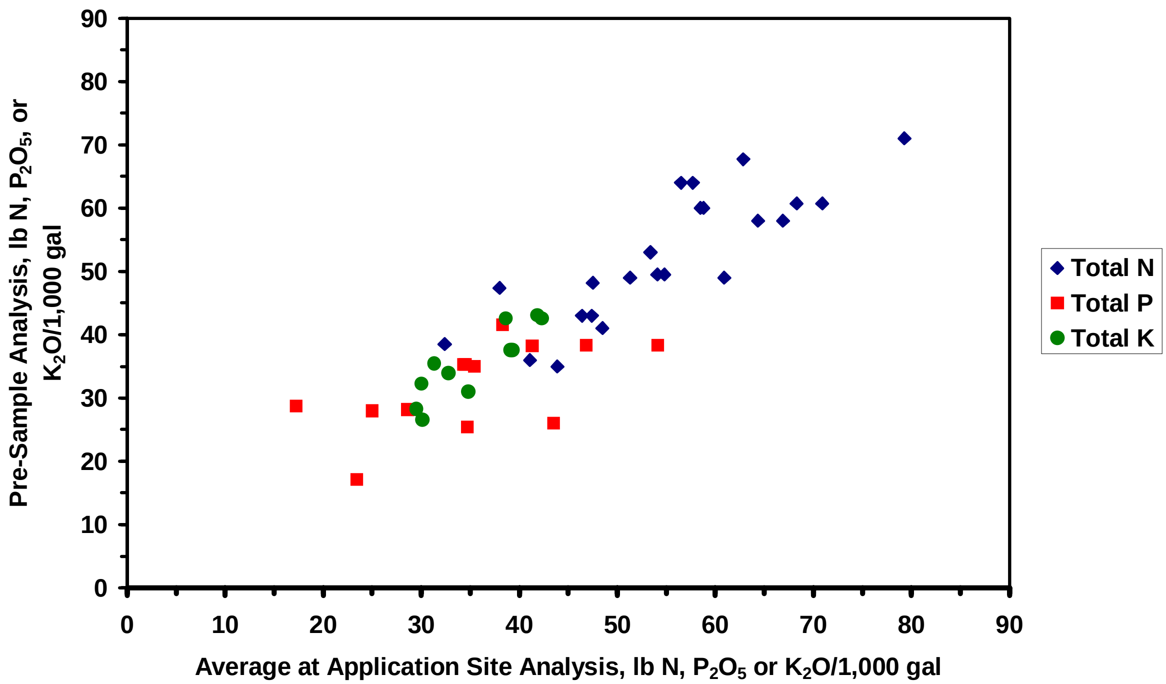

Figure 3. Comparison of intended and calculated as-applied liquid swine manure nutrient application rates, 2000-2003.

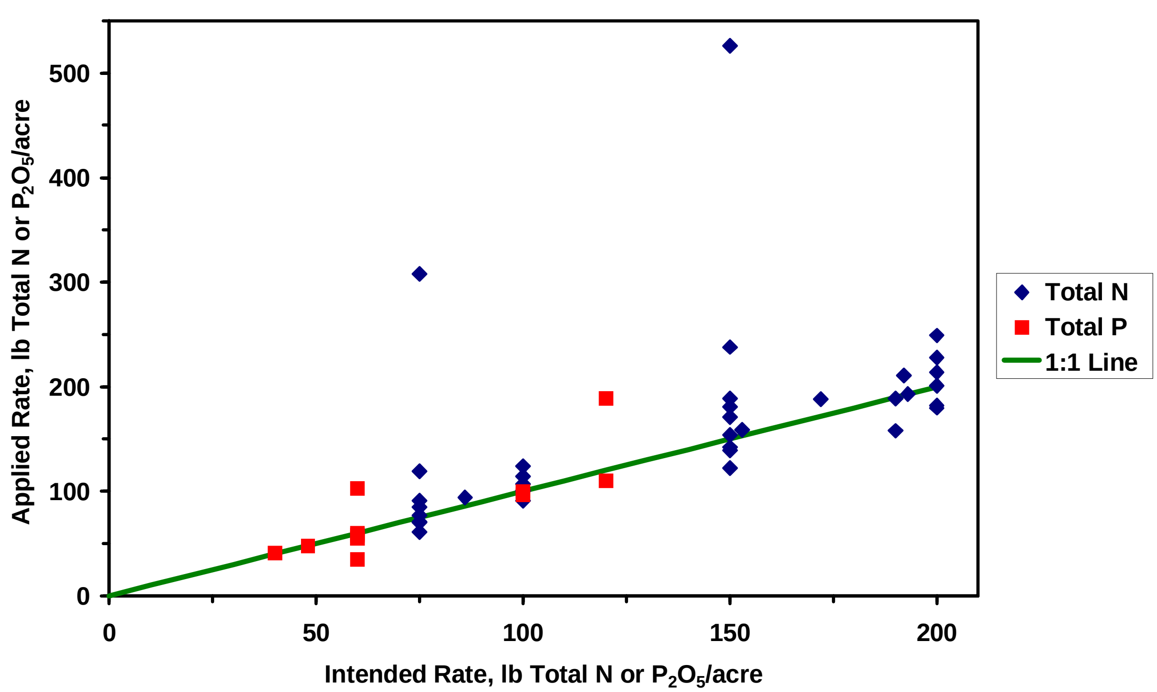

Figure 4. Variability in average liquid swine manure nutrient analyses between demonstration sites and within sites for multiple samples collected during application, 2000-2003.

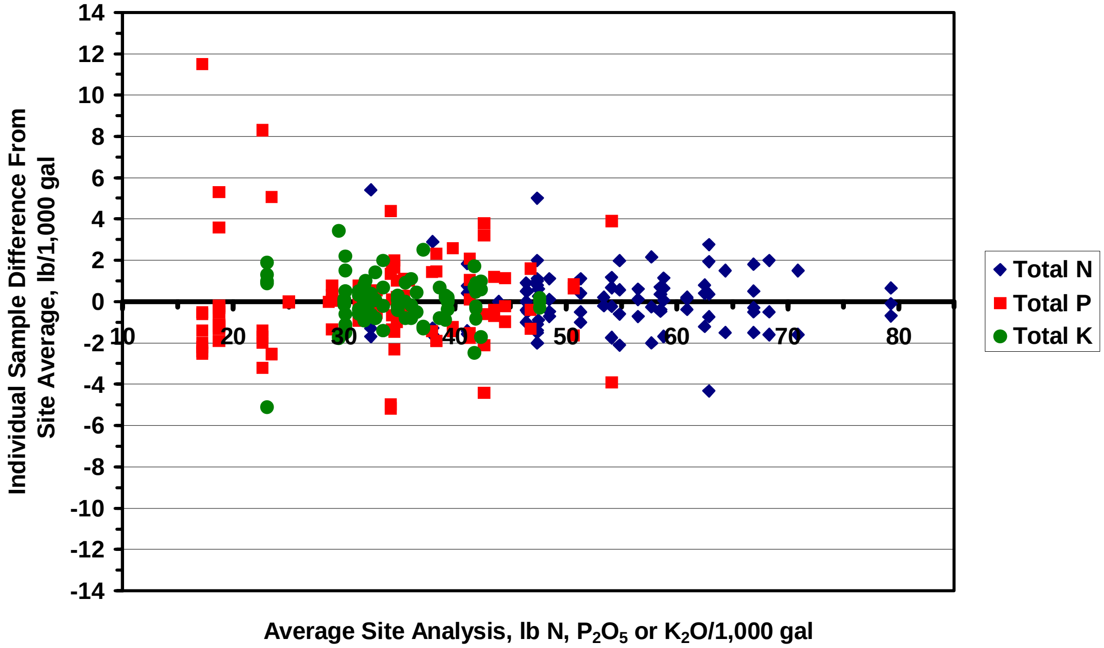

Figure 5. Effect of liquid swine manure average total-N rate (none, low-, and high-rate applications averaging 0, 80, and 154 lb N/acre, respectively) and additional fertilizer-N on corn grain yield, relative corn ear leaf SPAD chlorophyll meter reading, and end-of-season stalk nitrate level at five corn-soybean sites in 2000-2001.

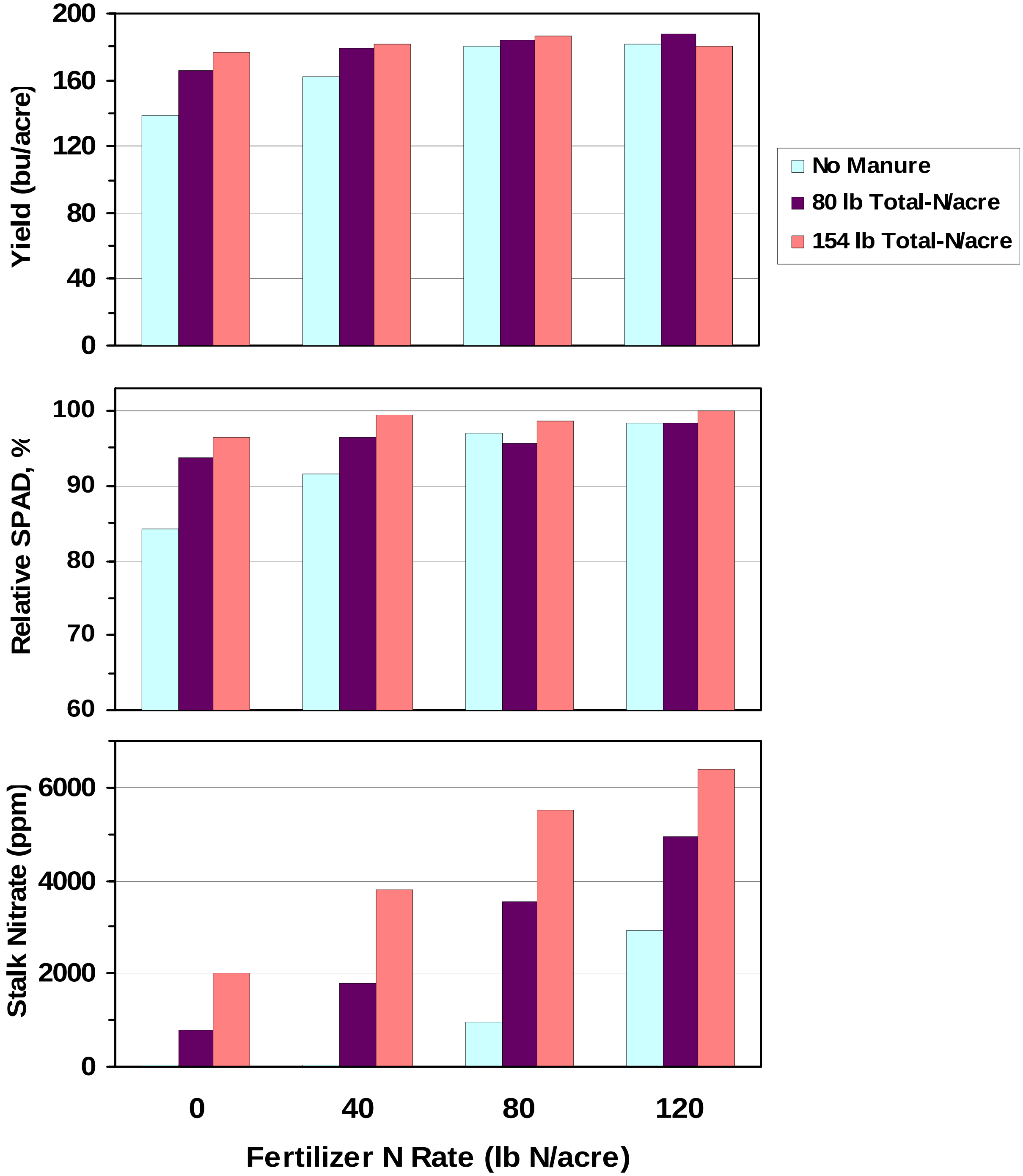

Figure 6. Average corn yield increase to fertilizer N rate where liquid swine manure had been applied before the previous year soybean crop, 2001-2003.

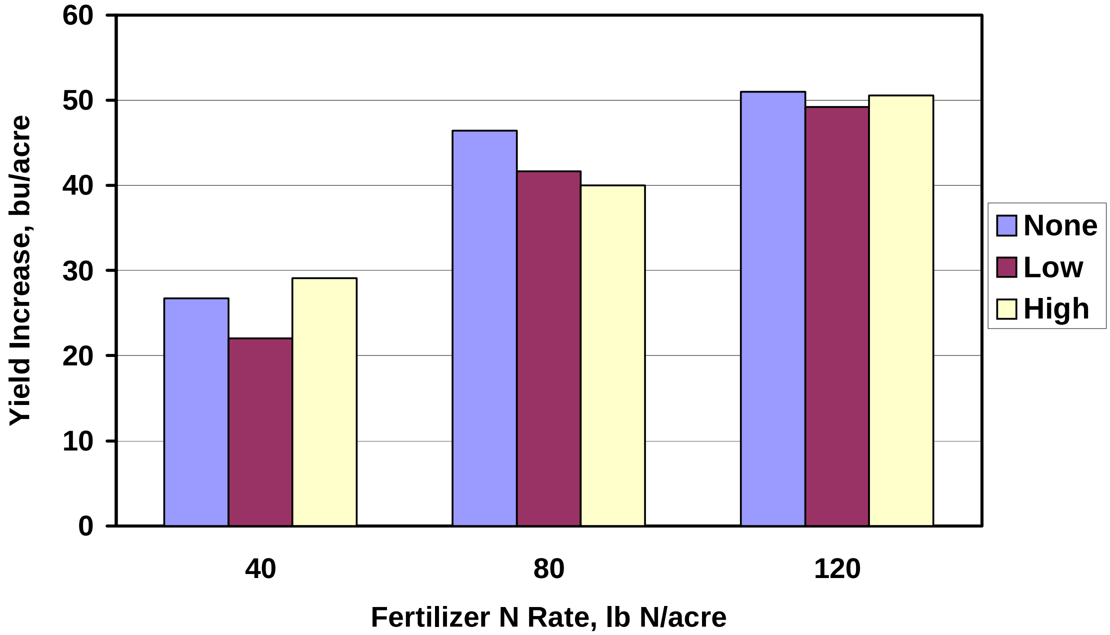

Figure 7. Average corn ear leaf chlorophyll meter reading response to fertilizer N applied to corn where liquid swine manure had been applied before the previous year soybean or corn crop, 2001-2003.

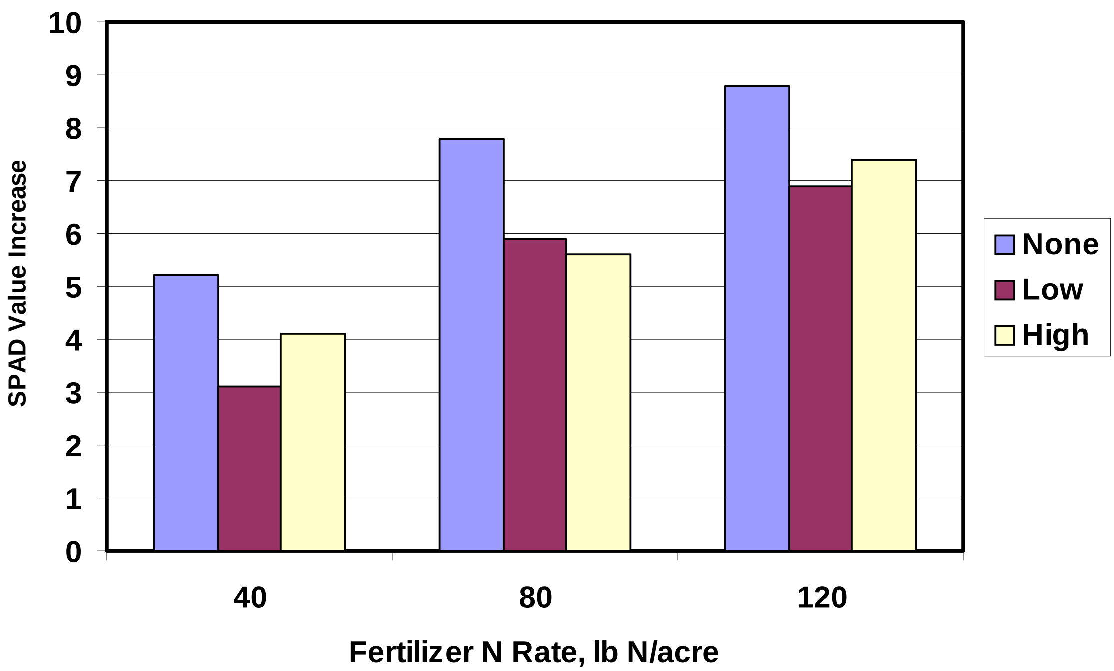

Figure 8. Average corn grain yield where liquid swine manure had been applied before the previous year soybean crop and response to fertilizer N, 2001-2003.

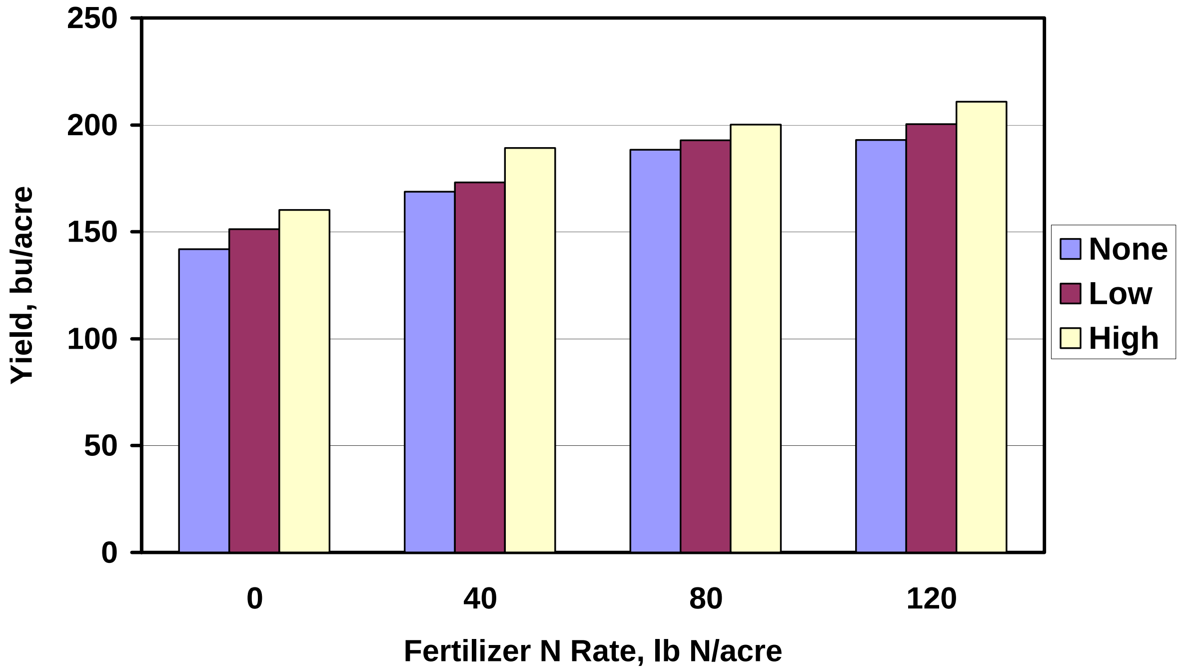

Figure 9. Average corn ear leaf chlorophyll meter reading where liquid swine manure had been applied before the previous year soybean crop and response to fertilizer N, 2001-2003.

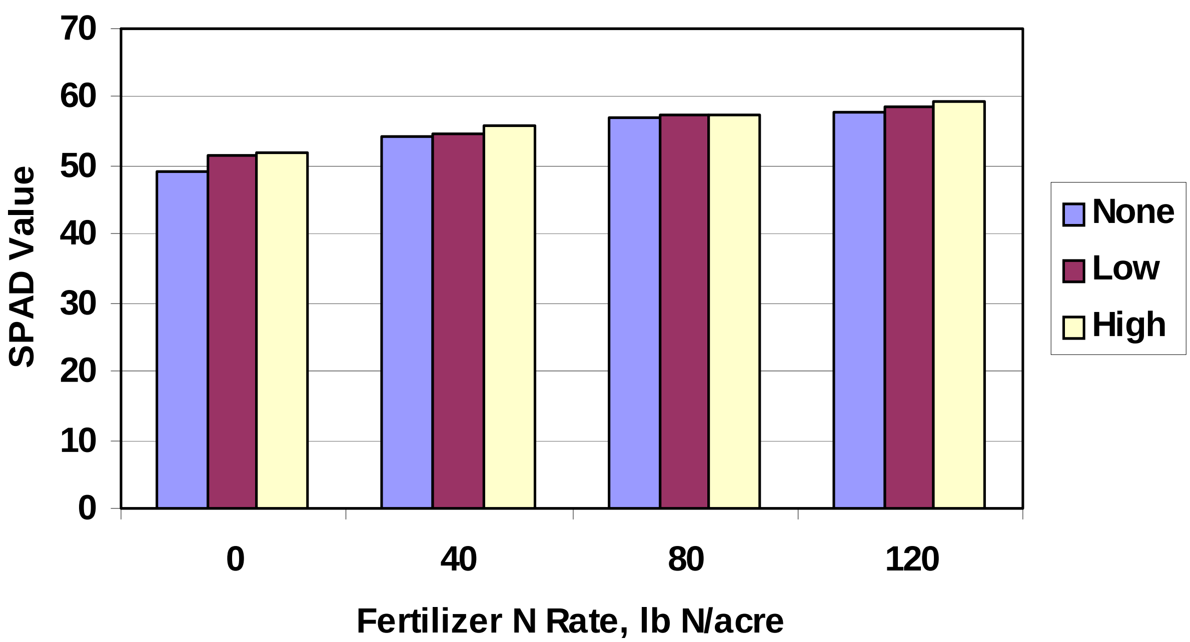

Figure 10. Effect of liquid swine manure application rate on post-harvest residual soil P as measured by five soil tests (2000 and 2001 data).