Demonstration of Agronomic and Environmentally Sound Utilization of Nitrogen and Phosphorus in Poultry Manure

Report for the 2004 Crop Year
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DEMONSTRATION DESCRIPTION

Issues Addressed and Objectives

Poultry manure is an important resource for meeting the nutrient needs of crops in Iowa. Land application is an economical and widely used way of utilizing manure. However, many producers do not appropriately account for the nutrients in manure, mainly because of uncertainty about manure nutrient content and crop availability of these nutrients. Because manure handling and application is much more difficult and costly than for fertilizer, this uncertainty leads to producer's reservations about its use and often to unnecessary supplemental fertilization. Scientists also are uncertain about the availability of manure nutrients for crops under many production conditions and have questions about environmental impacts of manure N and P. Therefore, on-farm research and demonstrations to determine the value of nutrients in manure are needed to better utilize this resource.

This project began in the 2004 crop year, and is planned for three years. The overall goal is to expand producers' knowledge about manure N and P management for crop production in Iowa and to improve farm profitability while reducing nutrient loss from fields. This goal can be achieved by cooperating with producers to implement various field demonstrations, providing information to other producers through field days and other educational activities, and also by working with custom manure applicators to make them aware of the importance of careful manure management for optimizing nutrient use, farm profitability, and water quality.

Specific project objectives are to implement manure management field demonstrations to compare crop yield response of poultry manure and commercial fertilizer, estimate manure N and P availability for corn, alleviate producers' uncertainty concerning supplemental fertilization need after manure application, measure soil nutrient responses to manure and fertilizer application, and evaluate potential impacts of poultry manure application on N and P losses from fields through surface runoff immediately after application. The project also will provide educational opportunities for producers, manure brokers, as well as agency and agribusiness personnel through one-on-one contacts, field days, winter meetings, and a variety of educational materials.

General Strategies and Methods

The general strategy for this project is to conduct on-farm field demonstrations across Iowa with concurrent data collection to document poultry manure N and P availability to corn, grain yield, soil-test values, and nutrient loss with surface runoff immediately after manure application. In the first year of the project (2004), six demonstration sites were established with producer cooperators in Bremer, Clay, Hamilton, Palo Alto, and Union (2) counties. In addition, the project directly involved more than 30 other people (other producers, manure applicators, manure brokers, extension specialists) from 15 other counties that helped in many different ways. The demonstration work involved several important aspects, and the following list include some of the most relevant.

1. Contact producers, manure applicators, manure brokers, and producers associations to explain the project, identify producer cooperators, and locate appropriate fields for the demonstrations.
2. Compile production, crop rotation, nutrient application, and soil test history of each field
3. Document manure analysis used to guide application and analyses of manure being applied.
4. Calibrate producer and/or custom applicator manure application equipment.
5. Apply replicated manure rate to strips across fields by producers or custom manure applicators together with assistance from project personnel.
6. Collect initial soil samples to measure nutrient status and characterize the soil.
7. Apply replicated N and P fertilizer rates within each manure treatment strip, with uniform application of a high rate of N, P, or K as appropriate to mask effects of those nutrients applied with the manure.
8. In fields with significant slope, measure N and P loss with surface runoff using a field rainfall simulation technique.
9. Collect soil and plant samples when corn is 6 to 10 inches tall to evaluate soil nitrate, soil P levels by various tests, and early P uptake by corn.
10. Collect in-season measurements of plant tissue N and sensed canopy greenness with a chlorophyll meter.
11. Collect stalk samples for the end-of-season stalk nitrate test and harvest corn grain yield together with the producers.
12. Collect post-harvest soil samples to evaluate residual P and nitrate in the soil.

The strips received no manure (check), a low rate of manure, or a high rate of manure that were replicated three times across the field. The high manure rate was designed to apply manure to supply at least the N needs of corn according to current recommendations and was decided together with the producers. The producers often wanted to apply the rate they normally apply. The high manure rate would typically apply more P than needed by corn because of the N:P ratio in poultry manure. The low rate was approximately one-half the high rate, and would apply less than an adequate amount of N as defined by current recommendations for corn in Iowa and appropriate or less excessive P rates than the high manure rate.

In small areas of the strips, four rates of commercial N fertilizer (ammonium nitrate) and P fertilizer (triple superphosphate) were applied by hand to plots 40 ft long and 15 ft wide. Fertilizer P was applied before the last tillage operation at rates from 0 to 150 lb P_2O_5/acre. Fertilizer N was applied immediately after planting corn at rates from 0 to 150 lb N/acre. A blanket application of P (100 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 with the manure. A blanket application of N (150 lb N/acre) and K (60 lb K_2O/acre) was made across all small P plots to eliminate as much as possible manure N and K effects on corn.

Field Demonstration Work Progress

Although grain yield and soil, plant, and surface water runoff samples were collected from the 2004 demonstrations, work continues at this time for chemical analyses of the numerous samples, data management, and outreach activities. Some results cannot be presented or discussed at this time, such as results of fall soil samples, cornstalk test for nitrate, runoff N and P concentrations, and others. All data presented in this report should be considered preliminary until careful analysis is completed in the future.

Initial routine soil test values.

The fields were selected to represent commonly used management practices in Iowa and to have near optimum or lower than optimum soil-test P for corn according to current interpretations. Manure N availability can be evaluated when corn is planted after soybeans in any field that has not received N for the current year. However, P availability of manure is best evaluated in low-testing soils. Data in Table 1 summarizes routine soil tests of 0-6 inch samples collected before applying manure for small plot areas and the strips areas. Results for the three soil P methods indicate that only the Clay County field (Site 2) had soil P above optimum for corn. The data for high-pH soil at Site 1 (Story County) confirm expectations of under-estimation of available P in calcareous soils by the Bray-1 method. The soil-test ranges for the strip areas demonstrate the high soil-test P and K variability usually observed in Iowa fields.

Manure nutrient analysis and application.

The manure was supplied by local poultry producers and consisted of turkey litter at two sites, broiler litter at two sites, and egg layers manure at two sites. The manure was applied either by the producers or custom applicators. Turkey litter was applied to Site 1 in December just before a snowfall, and could not be incorporated until spring. In all other fields, manure was applied in the spring and was incorporated with tillage as soon as possible after the application. Manure was incorporated within one day after application in Sites 2 and 6, and after two days in Site 5. Rain, light snow, or farmer's equipment problems delayed incorporation of manure until seven days after application in Site 4 and four weeks after application in Site 3.

The manure application rates were determined based on preliminary samples taken several days before application. The actual amount of the nutrients is known from six samples that were collected at application at each site from the truck or spreader used to apply the manure. Normally one sample was taken from each strip that received manure. Results of nutrient analyses and the amount of nutrients applied for the six demonstrations are shown in Tables 2 and 3. The data in Table 2 indicates that, as expected, there were nutrient content differences between manure sources but also there was considerable variation among sample analysis collected from loads applied at each field. This variability with dry manure (within stored manure, loads, field collected subsamples, and laboratory analysis subsamples) demonstrates an underlying problem (source and mixing issue) faced by the industry as they try to determine the correct amount of manure to apply.

Data in Table 3 indicates that the low manure rate applied amounts of N within the currently recommended range of N rates when fertilizer is used for corn after soybean (100 to 150 lb N/acre) except at Site 1. The high manure rate applied N within the recommended range at Site 1 and higher rates at all other fields. The low manure rate applied more P then would be recommended for one corn crop, except for Site 1. The high manure rate always applied more P then needed according to current recommendations, and in some fields enough P for one or two additional crops.

Corn grain yields from the manure strips.

Preliminary data show large corn yield increases in most fields when manure was applied. The yield data from the strips areas showed an average response of 17 bu/acre from the low manure rate and 28 bu/acre from the high manure rate. The responses observed across fields and manure rates ranged from 3 to 53 bu /acre (Table 4). The additional response to the high rate of manure over the low rate was small in two fields (less than 7 bu/acre), intermediate in three fields (8 to 14 bu/acre), and large in one field (24 bu/acre). Yields in Site 4 were very low because of a late planting date due to wet soil conditions and poor growing conditions during June in some areas of the strips. In Site 2, the response likely was due to N alone because soil P was High and K was Optimum in most strip areas. In other fields the lowest soil-test P and K values of strip areas ranged from Very Low to Low for P and from Very Low to Optimum for K. Therefore, the yield response in these other fields could have been due to the N, P, and/or K supplied by the manure. The grain yield responses from the small plots that received several fertilizer N and P rates in strips that received no manure and several supplemental fertilizer N and P rates in the two manured strips provide better clues as of the manure nutrient that was responsible for the yield response.

Corn grain yield response to manure and fertilizer nitrogen.

Grain yield response to manure-N application is evident from data from small plots, however the magnitude of response varied with the site and apparent N need. In this first year, one site (Site 1) had no response to manure or fertilizer N (Fig.1 and Table 5). Site 5 was only slightly responsive to fertilizer or manure N application. Addition of fertilizer N resulted in a large increase in yield for Site 2 and 6. The manure source at Sites 2 and 6 was layer manure, with turkey manure at Sites 1 and 3, and broiler manure at Sites 4 and 5. At Site 2, yield increase continued up to 150 lb fertilizer N/acre, thus it is not known specifically how much fertilizer N would have been adequate. It is likely more than 150 lb N/acre would have been needed by looking at the corn yield with manure plus fertilizer N. Corn yield increase due to additional fertilizer N application follows the expected trend for the sites considered responsive. At most sites, corn yield was increased with fertilizer N applied in addition to the manure applications. With increased poultry manure application rate, the response to fertilizer N was generally lower, with sites 1 and 4 being exceptions.

Overall, the 2004 corn responses to N suggest that poultry manure N is not fully available in the year of application, which reflects current suggestions for 65% first-year crop N availability. However, more sites and years are necessary to confirm a more precise first-year availability estimate. Specific site responses would also reflect any N losses from volatilization prior to incorporation of the manure or nitrate losses from wet soils.

Soil nitrate and leaf greenness after manure and fertilizer nitrogen application.

The soil nitrate-N values for samples collected in early June show large response to the 100 lb N/acre fertilizer N application (Fig. 2). However, the nitrate-N increase associated with manure application was much lower in comparison. This indicates a low inorganic N supply compared to fertilizer-N. The lack of differences observed in soil nitrate-N between manure rates suggest also that interpretation of additional N need based on soil nitrate should not be the same with poultry manure as fertilizer.

Corn leaf greenness, measured with the Minolta® SPAD meter at the corn silking stage, followed the general corn yield response (Figs. 3 and 4). Looking at the correlation between SPAD values and yield by site (Fig. 3), a lack of association can be observed for Sites 1 and 5, which were sites with no or low responsiveness to N application.

Based on the 2004 results, it appears that leaf greenness measured with the SPAD meter may be more sensitive to site N responsiveness and corn response to poultry manure N than soil nitrate. However, leaf greenness was measured at a later corn growth stage (at silking, R1 growth stage), which would be late for making supplemental N applications.

Corn grain yield response to manure and fertilizer phosphorus.

Fertilizer or manure P increased corn yield in five fields, the exception being Site 2 because initial soil-test P was in the High interpretation category. Supplemental P fertilization did not increase yield in the strips of any field where either the low or high manure rates had been applied. Therefore, the P applied with manure was sufficient to achieve maximum yield, even with the low manure rate. This result is reasonable because the low manure rate applied more P than would be recommended for one corn crop, except for Site 1 where the amount of P applied was approximately crop removal.

Results of P fertilization in strips where manure was not applied showed that maximum yield usually was observed with the lowest rate applied (50 lb P_2O_5). Only at Site 5 did the highest two P fertilizer rates increase yield more than the 50-lb rate (7 bu/acre more), which is reasonable because initial soil-test was in the Low category. However, other sites tested Low and there were no differences between P fertilizer rates.

Data in Fig. 5 summarizes the corn response to selected manure and fertilizer P application rates for the six sites. Yields shown are for plots with no manure of fertilizer P applied, only fertilizer P, and with the low or high rates of manure. The results indicate that fertilizer and manure produced similar corn yield at four sites. At Sites 1 and 4, however, both manure rates produced higher yield than fertilizer P did. At Site 1, the P applied with the two manure rates were within P rates applied with fertilizer. At Site 2, the low manure rate applied P intermediate between the two highest fertilizer P rates and the high manure rate applied much more P. Because the highest P fertilizer rate applied was 150 lb P_2O_5/acre, a much higher rate than currently recommended for corn in low-testing soils, we believe that other factors in the manure were responsible for the additional yield response. Other nutrients in manure or even manure effects on physical properties could explain the additional response. We doubt that manure N or K explain the results because high fertilizer rates of both nutrients were applied across all P plots. At no site did fertilizer P produce higher yield than the low or high manure application rates.

Early corn plant response to manure and fertilizer phosphorus.

Many producers believe that even though manure P may be available for crop use later in the season, not enough P may be available for early growth. This belief is based on the fact that a portion of the manure P is organic and could become available to plants only slowly. To test early crop availability of manure P, we sampled corn plants early in the season (V5 to V6 growth stage), weighed the plants, and analyzed them for total P content. We also took soil samples but the data management for soil tests results was not completed at this time.

Fertilizer or manure P increased corn early growth and P uptake at all sites, even at the high-testing Site 1. Supplemental P fertilization did not increase growth or P uptake in strips at any field where the low or high manure rates had been applied. Therefore, the P applied with manure was sufficient to achieve maximum early plant growth, even when the low manure rate was applied. Results of P fertilization of strips where manure was not applied showed that maximum growth usually was observed with the highest P rates applied (100 and 150 lb P_2O_5).

Data in Fig. 6 summarizes the early plant P uptake response to selected manure and fertilizer P application rates for the six sites (similar application rates to data in Fig. 5). The P uptake was higher at Sites 4 and 5 because plants were sampled later than at other sites. Fertilizer and manure produced similar corn P uptake in three sites. In Sites 4, 5, and 6, however, one or both manure application rates increased P uptake further. These responses mainly were due to increase growth, not to increased P concentration. The much higher P applied with the high manure rate might explain these responses. However, at Site 4 the lower manure rate applied an amount of P intermediate between the two highest P fertilizer rates and P uptake was higher. Therefore, other nutrients in manure or manure effects on physical properties that favored growth and root growth could explain the additional response. At no site did fertilizer P produce larger early growth or greater early P uptake than the low or high manure application rates.

Phosphorus removal with grain harvest as affected by manure and fertilizer phosphorus.

Knowledge of the amount of P removed with grain harvest is necessary to estimate maintenance P application needs. Also, increased P supply with high rates of manure could increase total P removal with harvest even if yield was not increased. Previous research has shown a small "luxury uptake" of P, which means that the grain P concentration may be increased by high P application rates when yield is not increased. The results from this demonstration indicate little or no luxury P uptake in grain due to manure or fertilizer P application. The P applications had little effect on grain P concentrations but had a large effect on P removal when yield was increased. Therefore, P removal responses tended to follow closely the grain yield responses. Results are summarized in Fig. 7. Only at Sites 3, 4, and 6 was there evidence of some luxury uptake in response to the high manure application rate, which usually applied much more P than any P fertilizer rate (except in Site 1). At these sites and for this manure rate, increased grain P concentration determined that the P removal response was higher than grain yield response.

Outreach Efforts and Collaboration with Other Projects

Outreach effort.

Although this was the first year of the project, considerable time was dedicated to the outreach component. The project team's early work was dedicated to establishing contacts and enlisting support for the project. This was accomplished by explaining the project and its objectives to many producers, custom manure applicators, and individuals from several organizations. Valuable support was obtained from the poultry producers' associations (Iowa Poultry Association and Iowa Turkey Federation), ISU Extension field staff, the IMMAG program, and many agribusinesses. With the assistance of these groups many interested producers custom manure applicators, and manure brokers were identified. The project team members contacted these producers and identified field sites with appropriate site conditions, producer interest, and available manure and application equipment. In addition to the producers and custom manure applicators involved at six demonstration sites, about 30 persons were directly involved by receiving information about the project, providing input, and helping in a variety of ways.

Another focus of the effort involved explaining the project and discussion of general issues related to manure N and P utilization (no data from the 2004 field demonstrations were available until winter) at various field days and meetings. Major meetings attended by many producers or custom manure applicators during the year included the Agriculture and the Environment Conference, a workshop for solid manure applicator certification, manure management field day demonstration and manure management short course, Clay County Growers Association field day, two ISU research and demonstration farms field days, Southfork Watershed Alliance field day, and four ISU Extension conferences/workshops in various Iowa locations where manure and nutrient management or environmental issues were discussed.

Collaboration with other projects and funding leverage.

This project complements a previous three-year project developed to study and demonstrate nutrient availability of liquid swine manure. General methods used in that very successful project were used to develop methods for this poultry manure project. Funding leverage and collaboration has been successful because the project is developed in coordination with three other major research and demonstration projects. The most direct funding leverage examples relate to additional funding secured by one of us (Dr. Mallarino) from the Iowa Soybean Promotion Board (ISPB) and the Leopold Center for Sustainable Agriculture to develop additional work on the same fields used for this project. Help from the ISPB is used to study residual effects of manure P applied for corn on soybeans grown the following year. This is an ideal complementation of efforts because with the IFLM project we demonstrate manure nutrient utilization for corn and in the same fields and with the same cooperators we demonstrate manure and fertilizer P management for soybeans. The help from the Leopold Center is used to study how soil P tests evaluate early P availability for crops early in the growing season. Therefore, in addition to soil sampling and P analyses before manure application and after corn harvest planned for this IFLM project, the additional funding allows us to collect and analyze additional samples during the growing season. This project also is conducted in close cooperation with another ongoing IFLM project lead by one of us (Dr. Sawyer) to demonstrate in-season fertilizer N management for corn. The complementary nature of these projects is important because in our project we focus on nutrient availability of manure-N and fertilizer-N applied before planting and in the focus of the other project is on studying the needs for in-season N fertilization under a variety of growing conditions. Also, the recently completed IFLM soil N and C management demonstration project developed a chlorophyll meter relationship to corn N fertilization need, which can be applied to this project to see if that tool will work for determining need for supplemental N fertilization following application of poultry manure.

Summary

Work in this first year of the project was very successful at reaching producers, custom manure applicators, and manure brokers to discuss issues relevant to utilization of nutrients in poultry manure. The reactions from cooperators and persons contacted confirmed the great need for this project. In fact, only budget constraints limited the number of demonstrations because many producers were eager to collaborate with us. Only preliminary conclusions can be drawn from partial results available at this time for this first year of the project.

Poultry manure application increased corn yield in most fields. The average response across fields was 17 bu/acre for the low rate and 28 bu/acre for high rate, but ranged from 3 to 53 bu /acre. The corn response to N suggested that poultry manure N is not fully available in the year of application, which reflects current suggestions for 65% first-year N availability. Supplemental P fertilization did not increase yield in any field where either the low or high manure rates had been applied. At no field did fertilizer P produce higher yield than the low or high manure application rates. On the contrary, in two fields both manure rates produced slightly higher yield than fertilizer P, probably because effects of other factors in the manure. Results of evaluations of early corn growth and early P uptake also show that no supplemental P fertilizer was needed when either the low or high manure rates were applied, and that in some fields corn growth was higher with the manure even though uniform high rates of N and K were applied across the small plots.

More sites and years are needed to obtain better first-year nutrient availability estimates. Specific site responses in different years and sites would also reflect any N losses from volatilization prior to incorporation of manure or nitrate losses from wet soils. Work in other years will also provide better information about P availability in manure and residual availability for following crops. Complete information for this first year will be provided during the second year of the project.

TABLES AND FIGURES

Table 1. Initial routine soil-test values before applying poultry manure at six demonstration sites in 2004. Values are averages for the areas of small N and P plots and ranges across zones of the strip areas.

		Small Plot Area Initial Soil Test Levels						Zone Soil P and K Ranges			
		P Tests						M3† P		M3† K	
Field	County	Bray	M3†	Olsen	M3† K	pH	OM	Low	High	Low	High
		--------------ppm--------------					%	-----------ppm------------			
1	Story	6	12	9	92	7.5	8.6	13	29	83	148
2	Clay	26	28	14	141	6.2	6.0	27	39	127	141
3	Bremer	12	14	9	155	7.3	3.3	10	16	126	181
4	Union	9	10	5	110	6.8	4.2	13	24	121	177
5	Union	10	11	7	220	6.5	4.7	5	10	157	163
6	Palo Alto	17	17	10	102	6.4	5.0	10	31	80	115

† M3 = Mehlich-3 soil extractant for P and K.

Table 2. Types of poultry manure applied and nutrient composition at six demonstration sites.

		Moisture†		Total N†		Total P_2O_5†		Total K_2O†	
Site	Manure Type	Avg	Range	Avg	Range	Avg	Range	Avg	Range
		-------- % --------		--------------------------- lbs/ton ----------------------------					
1	Turkey	52	47-56	51	44-61	51	47-54	30	25-34
2	Layer	51	46-59	54	40-75	43	40-49	22	19-25
3	Turkey	48	45-52	58	54-62	59	53-65	36	32-40
4	Broiler	49	38-60	56	41-69	68	50-83	50	32-64
5	Broiler	48	41-57	63	52-73	62	45-74	50	36-63
6	Layer	53	51-55	45	40-53	42	40-43	20	18-22

†All values are reported for manure as-is.

Table 3. Amounts of manure and manure nutrients applied at six demonstration sites.

	Manure Applied		Total N		Total P_2O_5		Total K_2O	
Field	Low	High	Low	High	Low	High	Low	High
	ton/acre		lbs N/acre		lbs P_2O_5/acre		lbs K_2O/acre	
1	1.1	2.0	56	102	56	101	33	121
2	1.9	3.7	101	198	81	158	41	136
3	1.9	3.8	110	220	112	224	68	60
4	1.9	3.7	107	208	129	252	95	185
5	1.9	3.7	120	233	119	231	95	185
6	2.2	4.1	96	180	90	168	43	80

Table 4. Corn grain yield for manure strips at six demonstration sites.

	Site and Grain Yield					
Manure Rate	1	2	3	4	5	6
	---------------------------------- bu/acre ----------------------------------					
None	180	146	185	77	135	128
Low	183	175	197	98	134	166
High	187	199	203	106	142	180

Table 5. Corn yield response to fertilizer N applied in addition to poultry manure.

Site	Poultry Manure Application			Response Interaction
	None	Low	High	
	bu/acre response to additional N †			
1	10	24	24	
2	101	82	46	*
3	43	39	7	
4	74	61	92	
5	14	31	5	
6	79	34	12	*

* Indicates a different response to fertilizer N for the manure rates.
† Yield difference between no fertilizer N and the highest rate applied within each manure rate.

Figure 1. Grain yield response to manure application and additional N fertilizer.

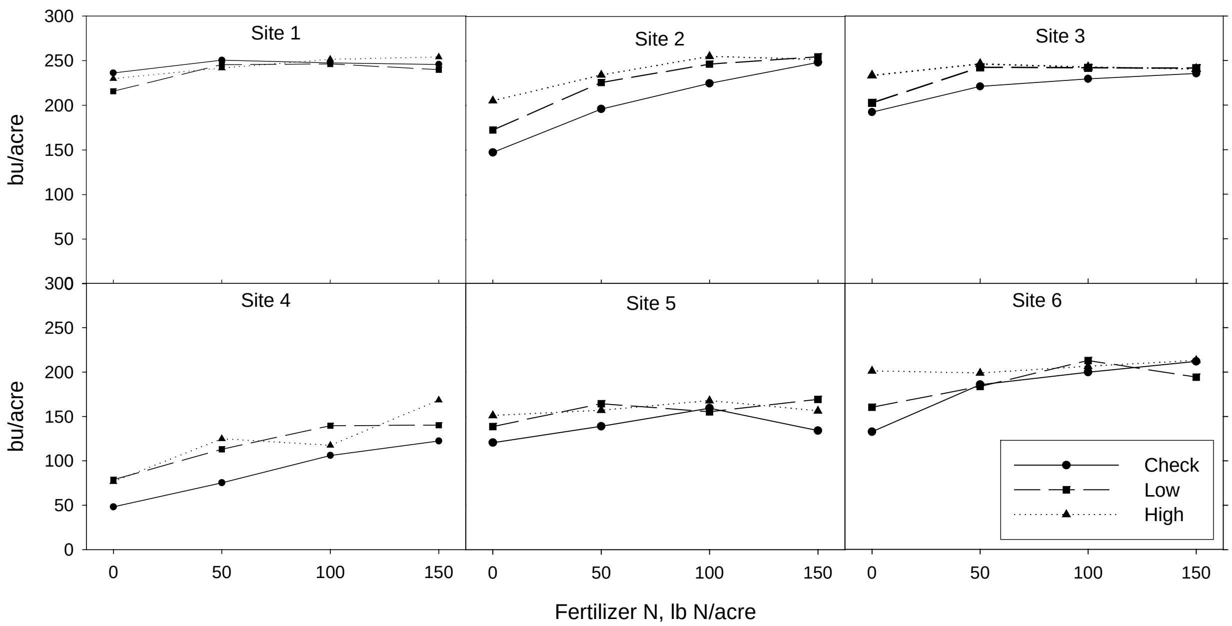

Figure 2. Late-spring soil nitrate concentrations with manure application and two levels of fertilizer N.

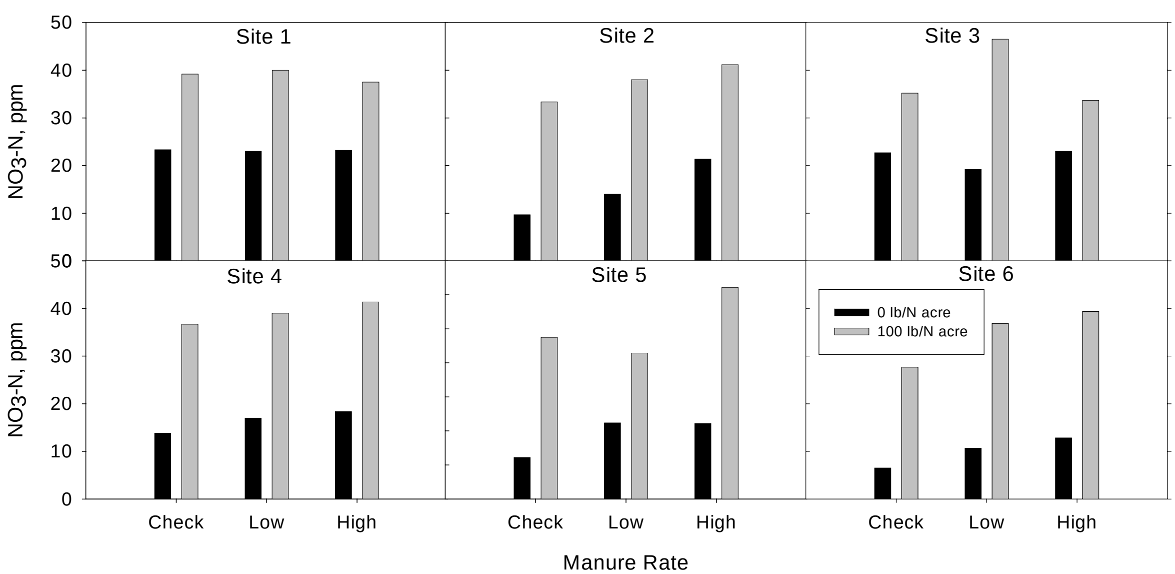

Figure 3. Corn leaf greenness (SPAD values) response to manure application and fertilizer N.

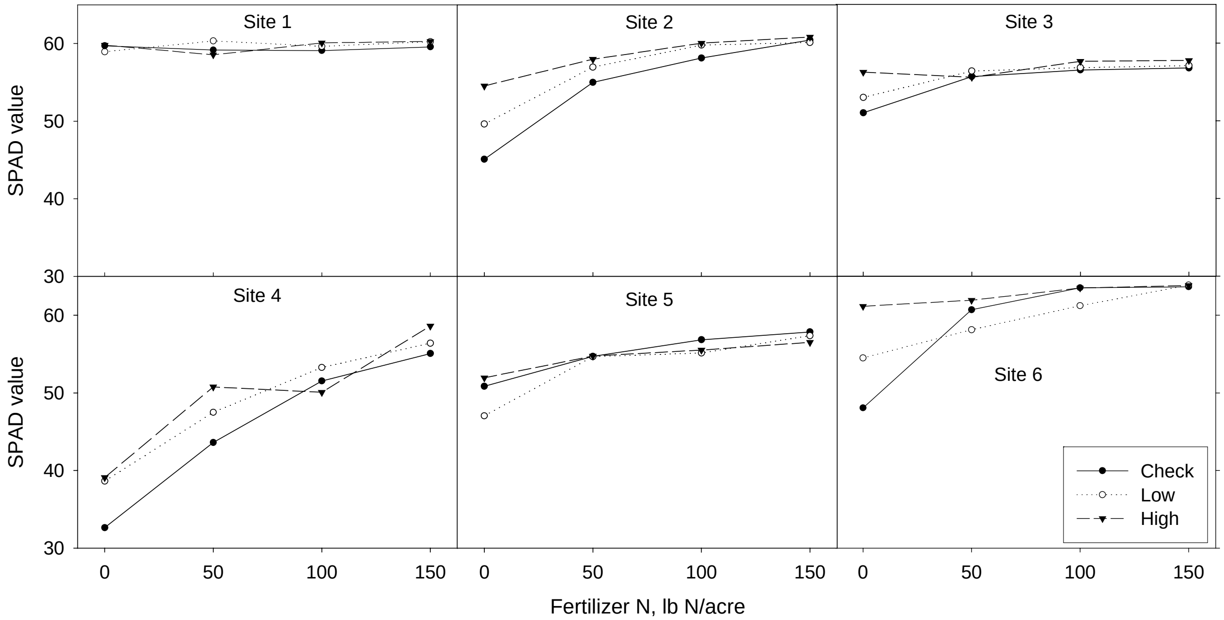

Figure 4. Corn leaf greenness (SPAD values) and corn yield correlation.

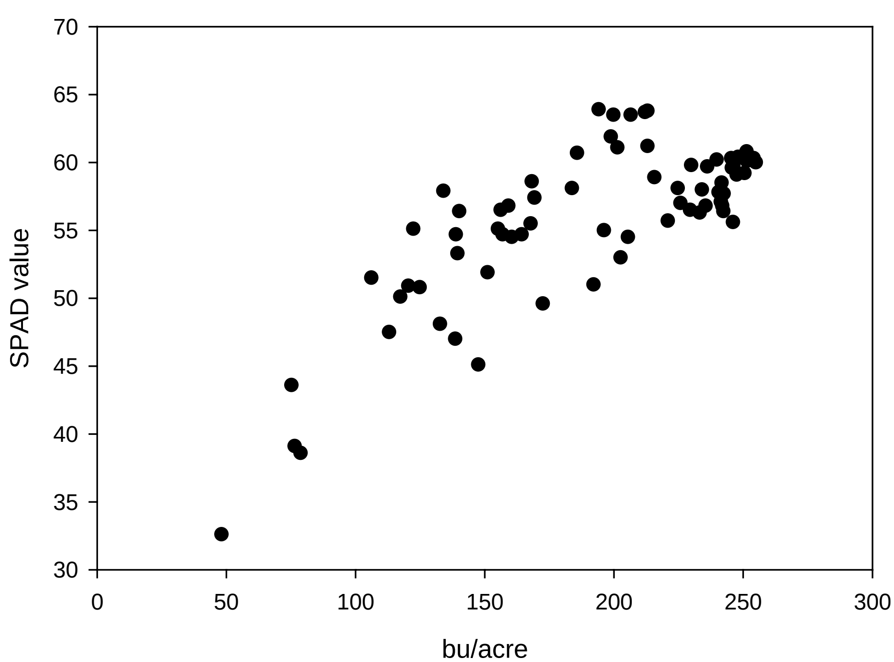

Figure 5. Effect of selected manure and fertilizer P application rates on corn yield at six demonstration sites. Data for fertilizer P are averages of the rates that resulted in the highest yield (the two highest rates for Site 5 and all rates for other sites).

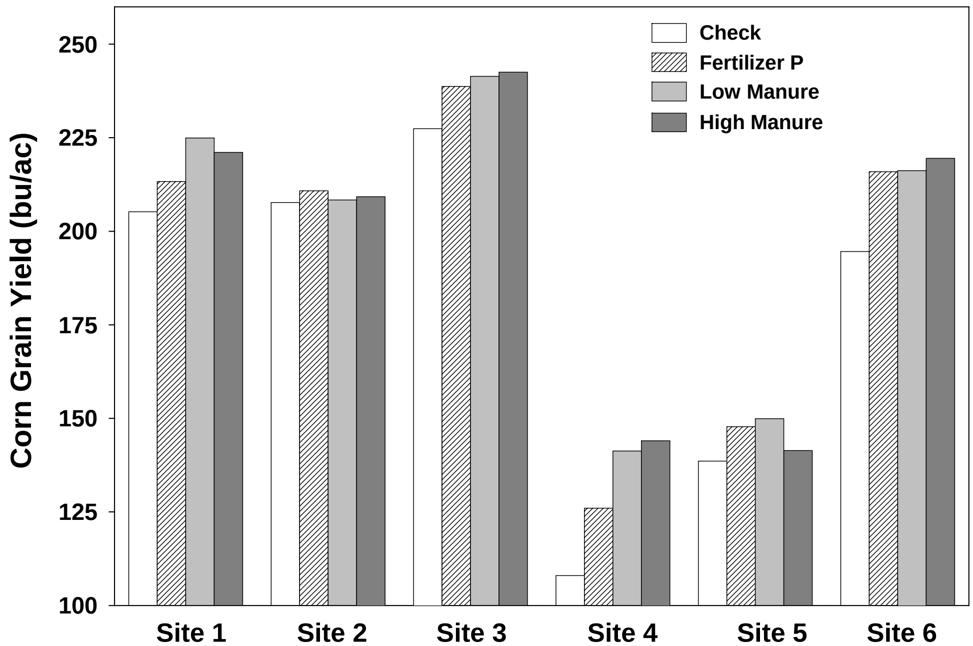

Figure 6. Effect of selected manure and fertilizer P application rates on early plant P uptake (at V5 to V7 growth stages) at six demonstration sites. Data for fertilizer P are averages of rates that resulted in the highest P uptake.

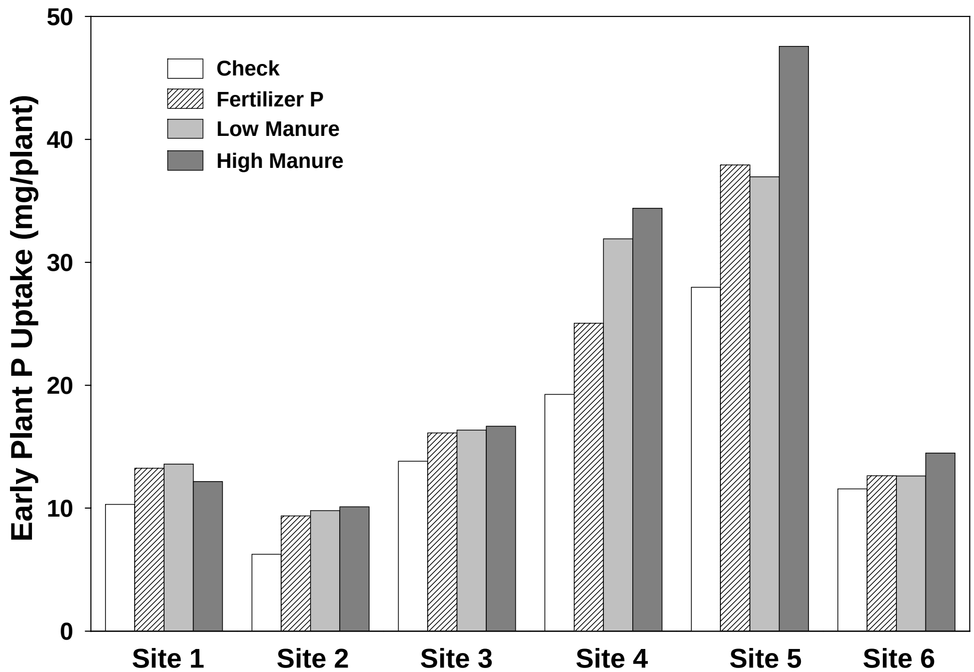

Figure 7. Effect of selected manure and fertilizer P application rates on P removal with grain harvest at six demonstration sites. Data for fertilizer P are averages of rates that resulted in highest removal.