LIQUID SWINE MANURE NITROGEN UTILIZATION FOR CROP PRODUCTION[1]

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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 fertilizer or higher manure rates are applied to ensure adequate soil fertility levels. 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 would be 88,650,000 lb crop- available N and 95,151,000 lb available P as P_2O_5 produced per year (ISU Pm-1811 – assumed 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 goal of this on-farm demonstration project was to learn more about liquid swine manure N and P as nutrient sources for corn and soybean production in Iowa and to help crop and livestock producers improve manure nutrient management practices. This included demonstration of an integrated approach that encompassed soil testing, manure nutrient analysis, equipment calibration, and agronomic rate application. Specific objectives of the project reported here include: one, work directly with producers and custom applicators to implement

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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, rate calibration, and application equipment; two, document corn and soybean productivity based on manure N; three, measure residual-year response to manure-N; and four, compare responses to N fertilizer. Only the portion of the project related to N is reported here.

Field Demonstration Methods

The strategy for this project was to conduct on-farm replicated demonstrations on multiple corn and soybean fields across Iowa. 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), 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 aspects to the integrated demonstration work: one, calibration of producer and custom applicator manure application equipment; two, determine manure nutrient analysis by pre-application and at-application sampling and laboratory analysis; three, application of replicated manure rate strips across fields by producers or custom manure applicators; and four, placement in sub-strip areas replicated N fertilizer rates within each manure treatment strip to monitor crop use of manure N.

The manure source was from swine finishing facilities with storage in under-building pits or outside concrete tanks (two sites). 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 (97 manure samples for the four years). Manure was agitated during pump-out of the storage structures. Manure samples were analyzed for total-N, ammonium-N, total-P, total-potassium (K), and solids by the Iowa State University Analytical Services Laboratory.

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. Manure was injected except for the 2000 and 2001 Clay County sites where manure was broadcast and incorporated the next day. Manure was either applied in the late fall (November or December) or spring. The individual field-length manure application strip widths matched a multiple of the manure applicator width and combine header width. At each site cooperators did not apply additional manure or N and P fertilizer to the site area. All other field activities were completed as normal by the cooperator, including grain harvest of the application strips using either a yield monitor or weigh wagon to record yield.

Manure Demonstration Rates and Fertilizer Application for Corn

Three manure application rate strips were applied across field lengths and replicated three times: check – with no manure, fertilizer N, or fertilizer P; low – manure to supply approximately half corn N need (75 lb total-N/acre for corn after soybean and 100 lb total-N/acre for corn following corn); and high – manure at rate to supply approximately full corn N need (150 lb total-N/acre for corn after soybean and 200 lb total-N/acre for corn following corn). These rates were intended to supply less-than-adequate N (low) and adequate N (high). At a few sites manure rates were based on intended total-P application or other intended N rates as determined by the cooperator. The assumption was made that all of the liquid swine manure N is first-year crop available, so rates were based on total manure-N.

Fertilizer N (ammonium nitrate) was hand-broadcast applied to small plots immediately after planting within each manure application strip – superimposed four randomized small plot fertilizer N rates: 0, 40, 80, 120 lb N/acre for corn after soybean and 0, 60, 120, 180 lb N/acre for corn following corn. 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.

Manure Demonstration Rates and Fertilizer Application for Soybean

Three manure application strips were applied across field lengths and replicated three times: check – with no manure, fertilizer N, or fertilizer P; low – manure to supply approximately half soybean grain N removal (100 lb total-N/acre); and high – manure at rate to supply approximately full soybean grain N removal (200 lb total-N/acre). At a few sites manure rates were based on intended total-P application or other intended N rates.

Nitrogen Application in Residual-Year Corn

At nine sites in the year following manure application to corn (two sites) or soybean (seven sites), the residual-year impact on corn production was determined from manure-N applied before the preceding crop. At two sites following soybean, field-length strips were left with no fertilizer N or manure applied in the residual corn year. At all residual-year sites, fertilizer N (ammonium nitrate) was hand-broadcast applied to small plots immediately after planting within each prior-year manure application strip – superimposed four randomized small plot fertilizer N rates: 0, 40, 80, 120 lb N/acre for corn after soybean and 0, 60, 120, 180 lb N/acre for corn following corn. 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.

Soil and Plant Sampling

Soil samples (0-6 inch depth) were collected from each site for routine soil test analyses before manure application. One-foot depth soil samples were collected in June for soil nitrate-N analysis. Corn leaf chlorophyll meter readings (measure of leaf greenness and plant N response) were collected from ear leaves with a Minolta® 502 SPAD meter at the R1 growth stage (silking stage). Field-length manure strips were harvested by the cooperators, with yield determined by yield monitor or weigh wagon. The sub-strip small N plots were hand-harvested to determine grain yield. Corn grain yield was corrected to 15.5% moisture, and soybean grain yield was corrected to 13% moisture. End-of-season cornstalk samples were collected from the sub-strip small N plots. Post-harvest profile soil samples were collected from the small plot N areas to a 4-foot depth and analyzed for nitrate-N.

Results and Discussion

Liquid Swine Manure Sampling, Analysis, and Application

Pre-application Manure Analyses Compared with At-application Analyses

Figure 1 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 N based. Figure 1 represents the ability of pre-samples to predict manure nutrient concentrations during application. Overall, pre-samples gave a good prediction of the total-N concentration expected during application. On average, the pre-application sample had 3.7% lower total-N than the at-application samples. Across all sites, the average ammonia-N in the liquid swine manure was 84% of the total-N. For P, the variation between pre- and at-application sampling was slightly larger (4.4% 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 K was 0.4% greater K_2O with the pre-application samples. Because K is contained in the soluble manure solution, the pre-application sample analyses were close to the at-application samples.

Intended Manure Nutrient Rate Compared with Calculated Applied Rate

Figure 2 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 liquid manure-N, then 78% of the applications (29 of 37 applications) were within this range (all but two of the applications outside this range were made 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. These sites were kept in Figure 2, and examples are the two very high application rates. The occurrence of applications well above intended rates happened with vacuum-style applicators, and in conjunction 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, 23% 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. A wider range in P application could be expected as some of the manure pre-application samples were dipped from the manure storage surface for total-N measurement rather than probed through the manure storage profile, which would be expected to not represent P as well.

When based on either total-N or total-P, 16% of applications (8 of 50 applications) were greater than 25% from the intended nutrient rate (Figure 3). The majority of applications (38 of 50) were within 15% of the intended nutrient rate. 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. 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 13 corn following soybean sites (without the expected high very high manure rate application site), 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 92 of 97 samples for 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.

Corn Response to Liquid Swine Manure N Application

Low- and high-rate liquid swine 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 1). 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 an average additional 10 bu/acre increase with the high rate). For the four corn following corn sites, the average yield increase with the low manure rate was 37 bu/acre and an average additional 11 bu/acre increase with the high rate. For the 14 corn following soybean sites, the increase was 25 bu/acre with the low manure rate and an additional 10 bu/acre with the high rate.

At several sites the low rate seemed to supply adequate plant-available N because 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 were considered mainly due to manure-N at most sites, although part of the strip yield increases could be due to response to manure P or K at some sites when soil tests were below optimum (Clay 2001, Story 2001, Hardin (c-c) 2001, and Davis 2002 had average strip P or K soil tests below optimum), or to other factors associated with manure application. When warm, drying conditions during broadcast application (Clay 2001) or excessively wet spring conditions (Washington 2001, Davis 2002, Washington 2002) resulted in apparent N losses, poorly drained soils, or where corn followed corn, then corn yield was increased with higher manure rates (Table 1). If yield was increased 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 (Table 2). 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). 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 4 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 (Figure 5) 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%. With the average ammonium-N in liquid swine manure samples collected at application being 84% 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 instead of book values);

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.

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 3). 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 (a review provided in Sawyer, 2001). 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.

Post-harvest profile soil sampling indicated slight buildup of residual nitrate-N at some sites for either manure rate compared to the no-manure check (Figure 6). 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 recent work in Minnesota that showed buildup of post-harvest profile nitrate-N did not occur until rates were above soybean crop use (see Sawyer, 2001). 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 (Figure 7). 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 (Table 4). Similar responses were measured in ear leaf greenness (Table 5). 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 might 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 (Table 7), and 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 (Table 7). Similar response was measured in ear leaf greenness (Table 8). At the two sites where field-length strip yields were collected, one site (Clay 2001) had yield increase with the prior-year manure application; the other did not (Washington 2002). 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 differential in response to fertilizer N (yield and leaf greenness), 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.

Summary and Conclusions

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, rate monitoring, and rate 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.

The project documented the importance and value of liquid swine manure as a nutrient source for crop production in Iowa. Following a comprehensive approach of pre-application manure sampling and laboratory analyses, manure sampling during application, and calibrated rate applications, it is feasible to agronomically provide corn N nutrient needs from liquid swine manure. Results from these four years also confirm that best management of liquid swine manure should consider practices that enhance achieving desired manure rates for providing N, minimize potential for N loss, and closely estimate rates of needed N.

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Table 1. Effect of liquid swine manure application on field-length strip corn grain yield, 2000-2003.

Site-Year[†]	Swine Manure Application			Manure Total Nutrient Application					
	None	Low	High	Low	High	Low	High	Low	High
	- - - - - - bu/acre - - - - - -			lb N/acre		lb P_2O_5/acre		lb K_2O/acre	
2000									
Webster (sp)	119a*	135b	138b	70	139	48	96	43	86
Clay (sp)	130a	159b	182c	77	154	46	91	38	77
Hardin (sp)	145a	144a	145a	83	195	100	236	81	191
Washington (lf)	136a	--	165b	--	216	--	188	--	180
Plymouth (sp)	99a	110a	99a	308	526	199	340	164	280
2001									
Cerro Gordo (sp)	121a	155b	161b	92	154	58	97	66	111
Clay (sp)	106a	131b	145c	71	142	35	70	38	77
Washington (lf)	89a	153b	169b	105	189	74	140	62	112
Wright (sp)	119a	145b	157c	91	181	65	130	61	122
Hardin (c-c)[‡] (sp)	122a	141b	146b	115	192	91	152	75	124
Story (lf)	146a	165b	165b	85	171	73	146	48	96
Hardin (c-c)[‡] (sp)	131a	144b	147b	69	189	55	150	45	122
2002									
Davis (sp)	41a	72b	99c	70	159	48	109	48	109
Hamilton (lf)	134a	156b	174c	94	188	38	76	64	128
Washington (lf)	130a	182b	202c	119	238	82	165	74	147
Hardin (lf)	190a	205b	216b	111	160	59	85	104	150
Hardin (c-c)[‡] (lf)	124a	167b	188b	67	158	35	84	62	148
2003									
Boone (lf)	195a	199a	197a	61	122	37	74	48	96
Scott (c-c)[‡] (lf)	113a	187b	203c	101	180	66	117	67	120

* 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.

[‡] Sites where corn followed corn. Hardin site in 2002 was second year with manure application (same site as 2001). At other sites corn followed soybean.

Table 2. Corn grain yield response to fertilizer N applied in addition to liquid swine manure total-N rate, 2000-2003.

Site-Year	Swine Manure Application			N Response	Manure Total-N	
	None	Low	High	Interaction	Low	High
	bu/acre response to additional N†				lb N/acre	
2000						
Webster	28	26	-1	*	70	139
Clay	47	18	-1	*	77	154
Hardin	28	0	7	NS	83	195
Washington	6	--	-13	NS	---	216
Plymouth	--	--	--	--	308	526
2001						
Cerro Gordo	29	8	-14	NS	92	154
Clay	43	32	31	NS	71	142
Washington	67	21	-4	*	105	189
Wright	66	25	-2	*	91	181
Hardin (c-c)‡	23	26	7	*	69	189
Cerro Gordo (c-c)‡	22	3	7	NS	94	211
2002						
Davis	48	49	29	NS	70	159
Hamilton	5	22	24	NS	94	188
Washington	93	32	23	*	119	238
Hardin (c-c)‡	95	63	35	*	67	158
2003						
Boone	8	8	-6	NS	61	122
Scott (c-c)‡	76	36	10	*	101	180

* Manure x Fertilizer N $Rate_L$, M x N_Q, or M x N_R contrast significant ($P \leq 0.05$).

† Yield difference between no fertilizer N applied and the highest fertilizer rate within each swine manure rate.

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

Table 3. Effect of liquid swine manure appliation on field-length strip soybean grain yield, 2000-2002.

Site-Year[†]	Swine Manure Application None	Low	High	Manure Total Nutrient Application 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 4. Corn grain yield response to fertilizer N rate where liquid swine manure had been applied before the previous-year soybean or corn crop, 2001-2003.

Site-Year	Prior-Year Swine Manure Application None	Low	High	N Response Interaction	Manure Total-N[†] Low	High
	bu/acre response to fertilizer N[‡]				lb N/acre	
Following Soybean						
Clay 2001	35	48	47	*	114	228
Webster 2001	46	51	49	NS	91	182
Clay 2002	24	10	22	NS	100	201
Washington 2002	78	98	90	NS	114	201
Floyd 2003	29	30	26	NS	147	271
Hamilton 2003	48	33	55	NS	107	214
Washington 2003	96	72	63	NS	124	249
Following Corn						
Hamilton 2003	37	49	43	NS	94	188
Davis 2003	18	40	23	*	70	159

* Manure x Fertilizer N $Rate_L$, M x N_Q, or M x N_R contrast significant ($P \leq 0.05$).

† Manure total-N applied before the prior-year soybean or corn crop.

‡ Yield difference between no fertilizer N applied and the highest fertilizer N rate within each previous-year swine manure rate.

Table 5. 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.

	Prior-Year Swine Manure Application			N Response
Site-Year	None	Low	High	Interaction
	- - - SPAD value response† - - -			
Following Soybean				
Clay 2001	10.1	7.6	6.5	*
Webster 2001	4.1	1.3	3.0	NS
Clay 2002	5.3	3.8	4.8	NS
Washington 2002	11.1	15.2	14.6	NS
Floyd 2003	11.3	9.7	10.3	NS
Hamilton 2003	6.4	4.2	5.4	NS
Washington 2003	13.3	10.5	7.2	*
Following Corn				
Hamilton 2003	10.7	13.2	6.3	NS
Davis 2003	0.5	5.8	2.0	*

* Manure x Fertilizer N Rate$_L$, M x N$_Q$, or M x N$_R$ contrast significant ($P \leq 0.05$).

† SPAD value difference between no fertilizer N applied and the highest fertilizer N rate within each previous-year swine manure rate.

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

Table 7. Corn grain yield 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
	- - - - - - - bu/acre - - - - - - -		
Following Soybean			
Clay 2001	99	104	125*
Webster 2001	172	177	175
Clay 2002	140	160*	156*
Washington 2002	142	125	135
Floyd 2003	142	152*	156*
Hamilton 2003	173	187	195
Washington 2003	123	149	176*
Following Corn			
Hamilton 2003	90	104	101
Davis 2003	141	115*	140

* Check versus low- or high-rate contrast significant ($P \leq 0.05$).

Table 8. Corn ear leaf chlorophyll meter reading 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
	- - - - - - - SPAD value - - - - - - -		
Following Soybean			
Clay 2001	41.2	46.7*	49.8*
Webster 2001	57.0	59.6	58.2
Clay 2002	52.1	54.4	54.5*
Washington 2002	44.6	40.7	41.5
Floyd 2003	48.8	51.9	51.7
Hamilton 2003	52.4	54.1	54.1
Washington 2003	48.1	50.3	53.8*
Following Corn			
Hamilton 2003	46.9	44.0	51.2
Davis 2003	59.0	55.6	59.7

* Check versus low- or high-rate contrast significant ($P \leq 0.05$).

Figure 1. Comparison of pre- and at-application liquid swine manure nutrient analyses, 2000-2003.

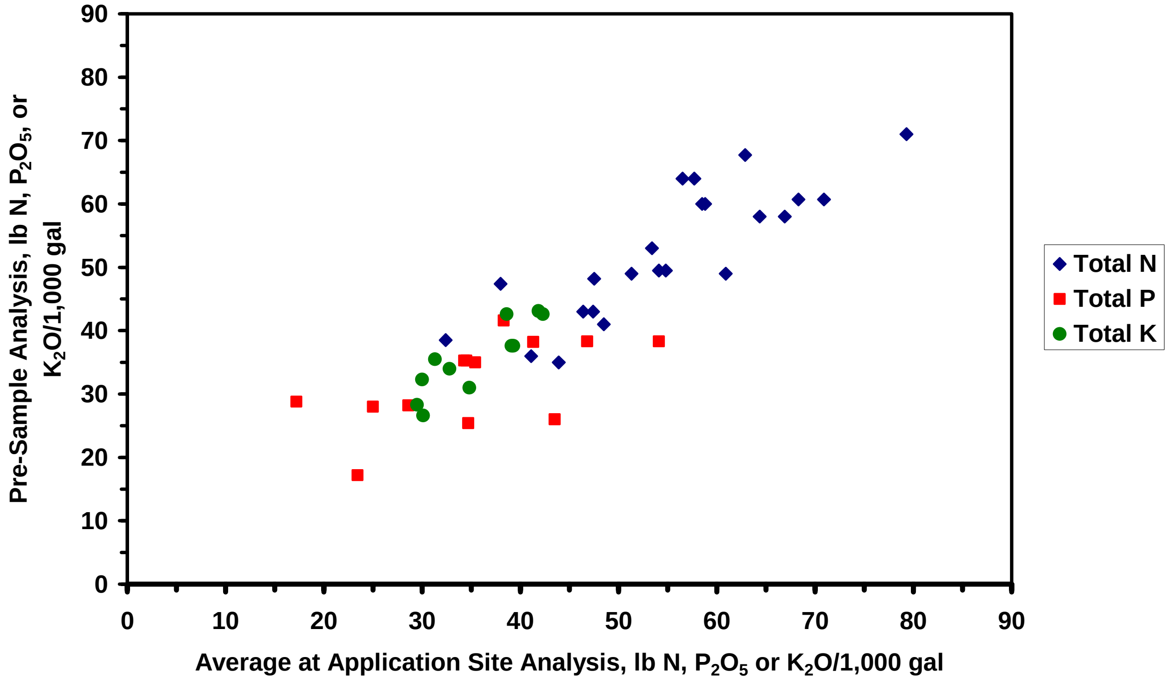

Figure 2. Comparison of intended and calculated as-applied manure nutrient application rates, 2000-2003.

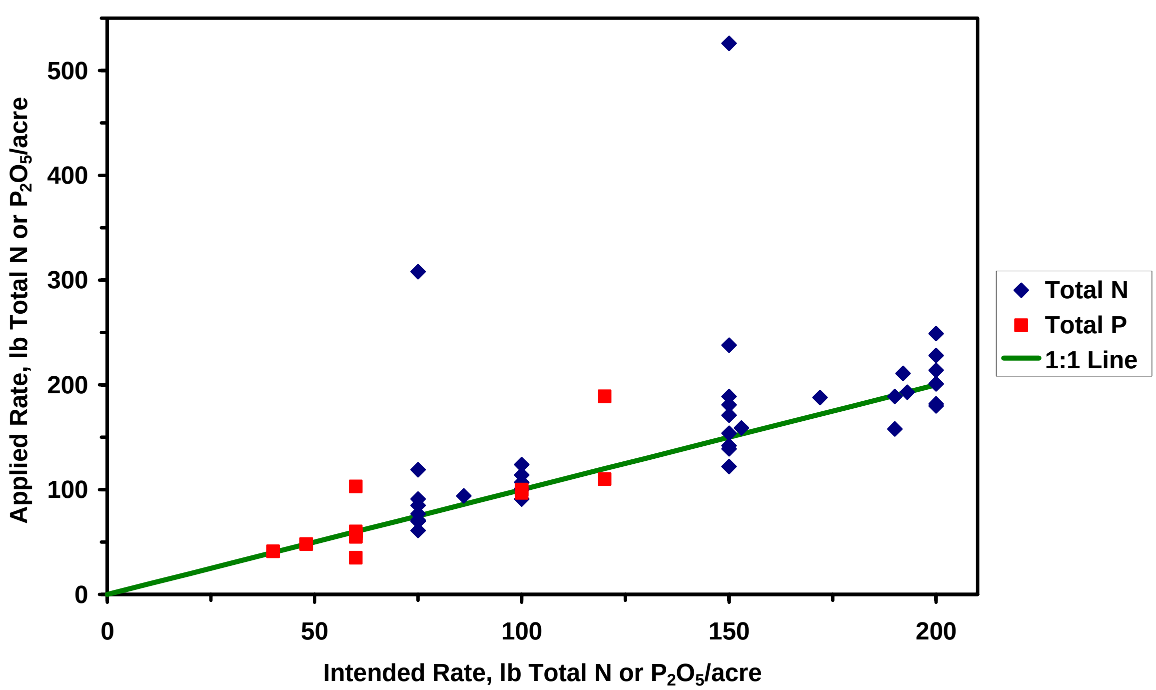

Figure 3. Frequency distribution showing percent of intended liquid swine manure rate, 2000-2003.

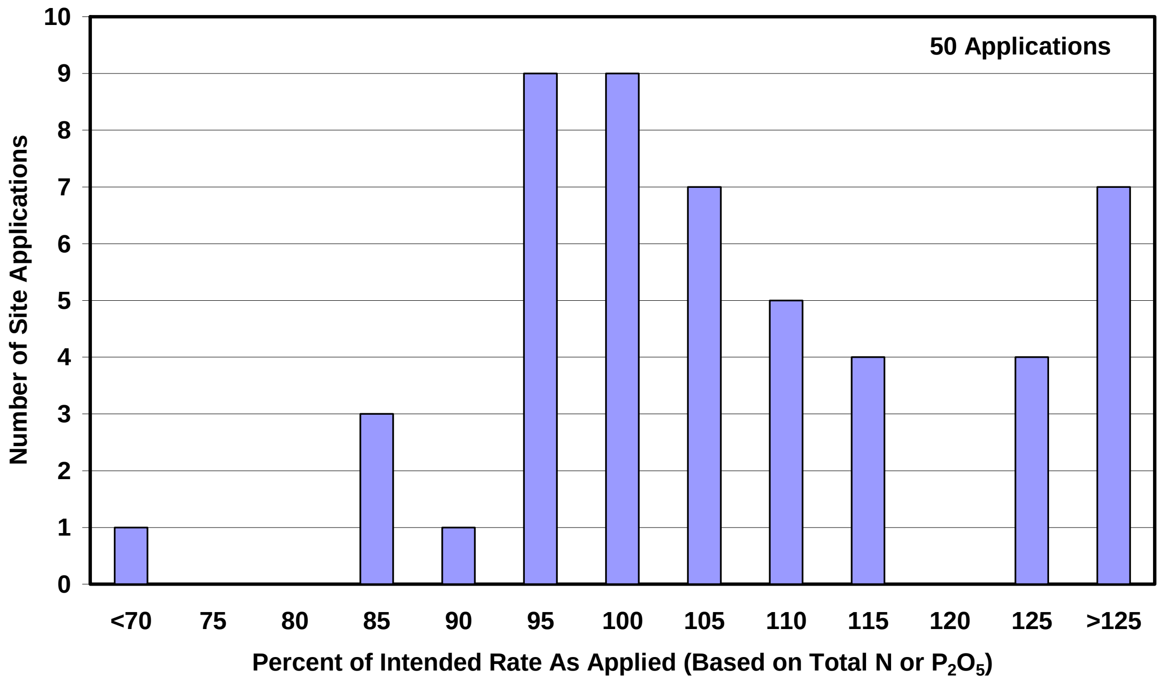

Figure 4. Variability in average manure nutrient analyses between demonstration sites and within sites for multiple samples collected during application, 2000-2003.

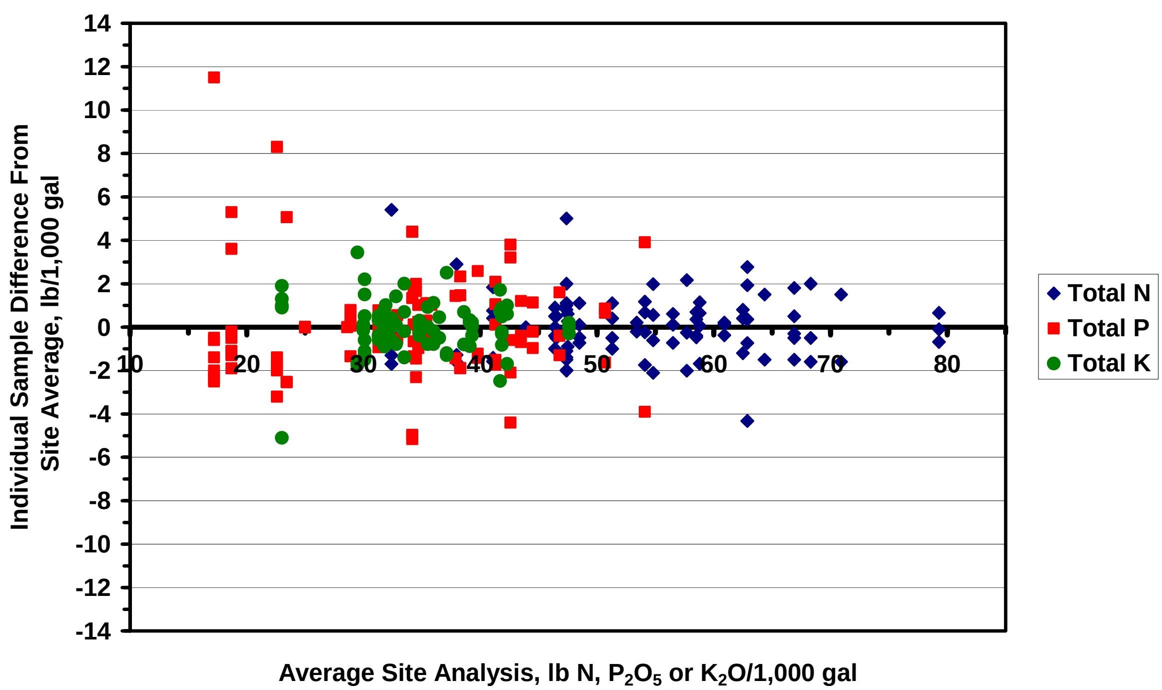

Figure 5. Effect of liquid swine manure average total-N rate and additional fertilizer N, five sites following corn in 2000-2001.

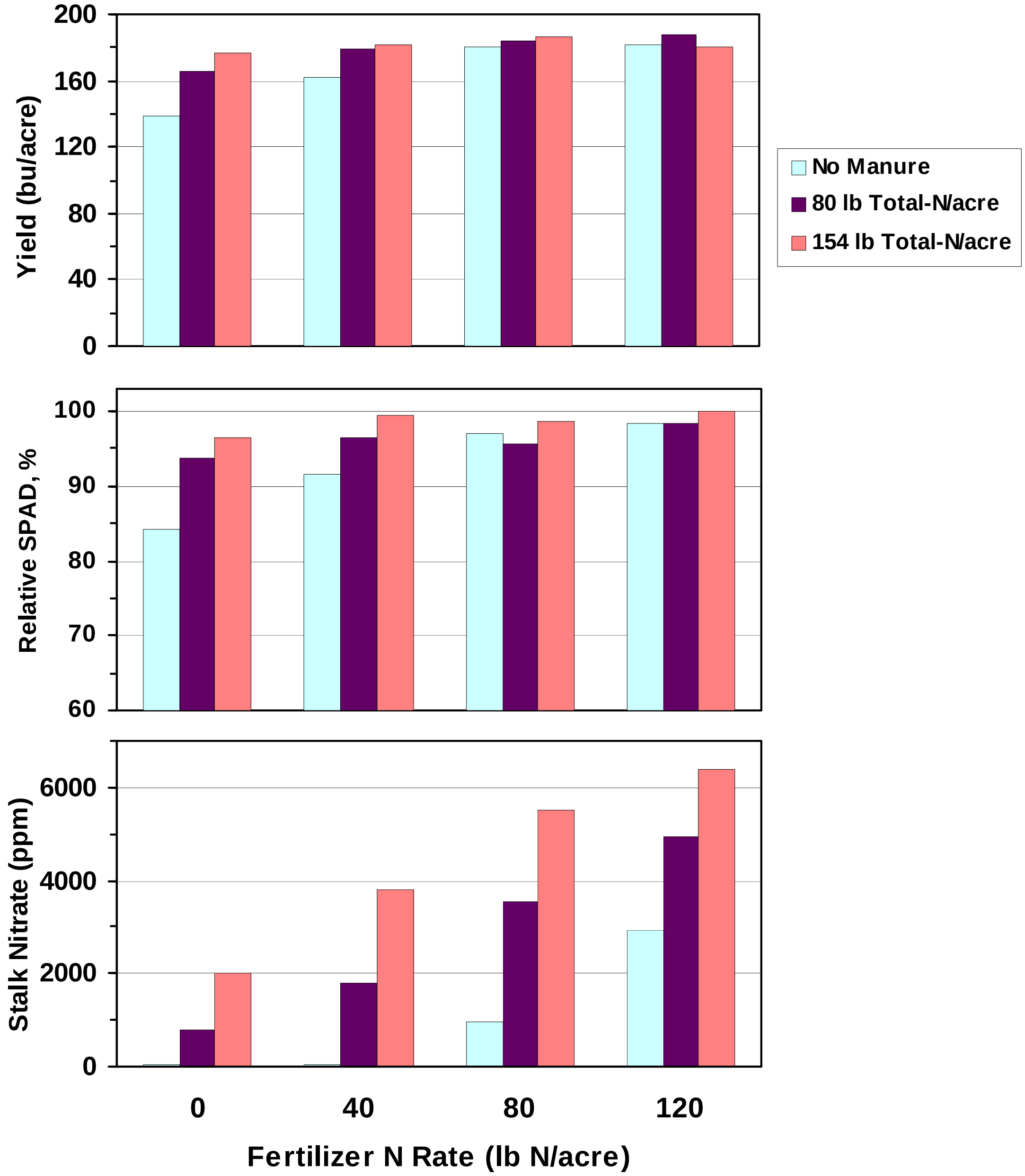

Figure 6. Site average post-harvest profile nitrate-N following soybean, 2000-2002.

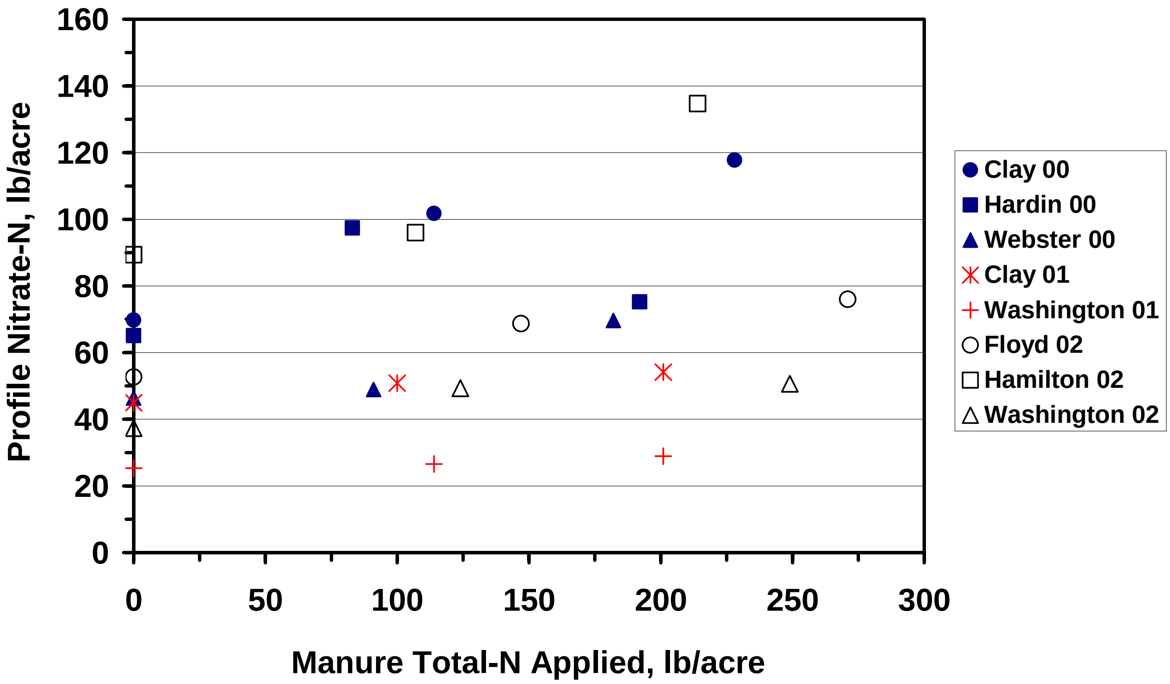

Figure 7. Average corn yield increase to fertilizer N rate where liquid swine manure had been applied before the previous year soybean crop, 2001-2003.

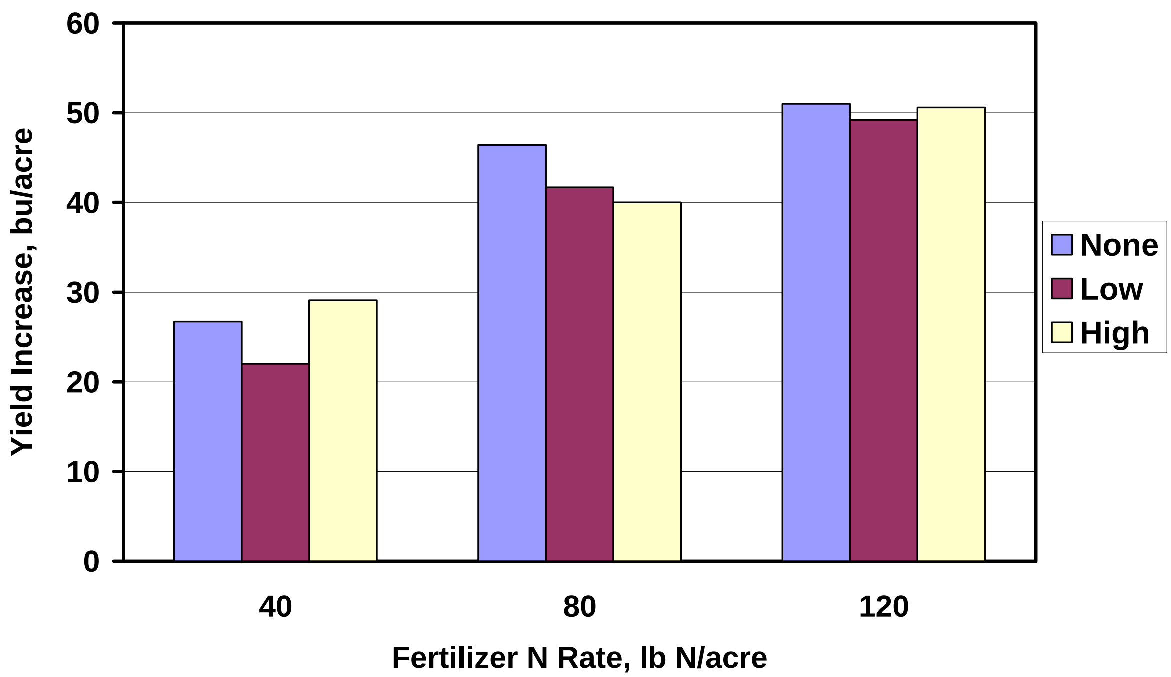

Figure 8. Average corn grain yield where liquid swine manure had been applied before the previous year soybean crop and response to fertilizer N, 2001-2003.