LINKING FARMS: RECONNECTING DAIRY AND CASH-GRAIN FARMS THROUGH SHARED MANURE MANAGEMENT

I. Production results and nutrient budgets from 2003 and 2004

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INTRODUCTION

Current trends in the Wisconsin dairy sector show that average herd size is increasing, with a growing proportion of the milk stream produced on farms of 500 animal units (AU) or more (one animal unit = 1000 lbs animal live weight, WASS, 2004). In addition, these larger farms have higher stocking rates (PATS, 1997), or animals per acre. This results in having more manure to manage, and relatively less land to manage it on. These industry trends, however, are colliding with stricter regulations on nutrient management, as first nitrogen, and now phosphorus standards are being applied (NRCS, 2004). These new standards currently effect permitted farms (farms with >1000 AUs, or Concentrated Animal Feeding Operations—CAFOs), and are due to go into effect for all Wisconsin farms in 2008 (Porter, 2004). As a result, many Wisconsin dairy farmers must look for places, beyond their farm gate, for spreading manure.

Cash-grain operators, on the other hand, are facing ever-increasing costs of fertilizer. In 2005 nitrogen fertilizer prices are expected to rise between 11% and 15% from 2004 prices (Hergert, 2005). Thus, cash-grain growers have an incentive to use alternative nutrient sources, such as dairy manure. In addition to providing N, P, K, Zn, Mg, and other nutrients, manure also serves as a soil conditioner by improving porosity and water-holding capacity, and when added over long periods of time, has been reported to increase soil organic matter (Motavalli and Miles, 2002; Anderson et al., 1990).

The Linking Farms Project attempts to address these issues, by studying the agronomic effects of including manure from dairy farms into cash-grain rotations. Specifically, the Linking Farms Project is looking at three critical issues:

- The impact of manure additions on corn grain yield and soil test values;
- The impact of manure additions on weed pressure; and,
- The impact of manure spreading on soil compaction;

In this article, we focus on grain yields, nutrient budgets and soil test values. The first section covers the on-farm trials, and in the second section, the research conducted on the Wisconsin Integrated Cropping Systems Trial is described.

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SECTION A: ON-FARM TRIALS

MATERIALS AND METHODS

Fall Plot Layout:

Manure spreading for the on-farm work was initiated at five sites in the fall of 2003 (for the 2004 season), and eleven sites in the fall of 2004 and spring of 2005 (for the 2005 season)—see **Table 1**. Three dairy farms supplied manure to the sites in 2003-2004, and six dairies participated in 2004-2005. Due to poor corn establishment, results from only four of the five sites in 2004 were reported here. The on-farm trials were established using a randomized complete block design, with 3 repetitions at each site. The two treatments tested were manured plots versus non-manured plots. Plots were between 30 and 60 feet wide, and 200 to 500 feet long. Plot sizes were determined according to the farmer-participants' corn planting and harvesting equipment, as well as to the spray or injection width of the manure application trucks. Baseline soil fertility samples (0-6" and 6-12", 5 cores/plot) were taken preceding manure application and analyzed for pH, organic matter (OM), soil test phosphorus and potassium levels at the Soil and Plant Analysis Laboratory (SPAL) in Madison.

Manure was then spread following wheat or soybean harvest. Slurry (10,000-16,000 gal/a) was used at the majority of sites, while solid manure (bedding pack and barnyard scrapings), spread at 18-20 tons/acre, was used at a few sites. In all cases the manure was injected or incorporated within 3 days of application. Samples of manure were taken from each spreading event for analysis at the University of Wisconsin Soil and Forage Analysis Laboratory (SFAL) in Marshfield.

Fall nitrate soil cores were taken (3-foot depth) on those trials where manure had been applied in the late summer, soon after wheat harvest. Three cores per plot were combined for each sample, and analyzed for nitrate nitrogen at the SPAL in Madison.

Spring Procedures:

Corn was planted on the 2004 sites, with seed selection, population, planting date, herbicide, and starter fertilizer decisions left to the farmer-participants. Nitrogen fertilization was discouraged until a pre-sidedress nitrate test (PSNT) could be made

One-foot soil cores were taken when corn was between 6 and 12 inches tall, or between the V4 and V6 stages (Anderson and Urbanowicz). Composite samples were composed of 6 cores per plot. Use of the PSNT allowed the researchers to see how much nitrogen was actually available for plant uptake at the critical V6 stage, and then follow University of Wisconsin Extension's (UWEX) recommendations of how much additional nitrogen should be applied.

Harvest/Post-harvest Procedures:

Corn was harvested in November, and corn quality was assessed at the SFAL in Marshfield using wet chemistry for dry matter, phosphorus, calcium, potassium, and magnesium assays, and NIRS for crude protein. Following harvest, another series of soil samples was taken for routine fertility (0-6" and 6-12") and 3-foot depth fall nitrate levels. Simple nutrient budgets for N, P_2O_5 and K_2O were calculated by summing legume, fertilizer, and manure credits, then subtracting

crop off-take. Crop off-take was calculated by multiplying grain yield by percent N, P, and K. Percent N was estimated by dividing crude protein by 6.25.

Soil fertility, nitrate levels, corn yields, and corn quality were analyzed on an individual-site basis, using PROC means and PROC mixed of SAS software.

RESULTS AND DISCUSSION

Characterization of Site soils:

The experimental sites were on predominantly silt loam soils, with a few cases of loam or sandy loam soils (see **Table 1**). Typical of soils in the area, soil test phosphorus levels were in the mid- to high-ranges; eight of the fifteen sites were below 50 ppm, which according to the newest draft of the Nutrient Management Standard 590, would allow for manure additions up to the next crop's nitrogen requirements (NRCS, 2004). Five of the fifteen sites ranged between 50 and 100 ppm P, qualifying them for manure applications not to exceed total crop P removal in the following four years. Soil test potassium levels were generally high, with 6 sites in the Excessively High range (>140 or 150), 7 sites in the High range (approximately 101—140 ppm) and only 2 sites in the Optimal range (81—100 ppm). These ranges were according to UWEX recommendations (Kelling et al., 1998) for corn/soybean rotations. Thirteen of the sites had organic matter greater than 2.0% on average, and 9 sites had pH levels above 6.3, the level considered optimum for corn/soybean rotations (Kelling et al, 1998).

Manure Analyses:

Results from the manure analyses showed that there was much variation in percent dry matter and nutrient concentration among the samples taken, particularly in the slurry manure. **Tables 2** and **3** display summary data for the combined 2004 and 2005 season manure analysis results for slurry and solid manure, respectively. This heterogeneity was typical for manure analyses and was due to pit agitation, dilution after heavy rains, and variation in bedding materials (e.g. straw vs. sand). Variability of nutrient concentration, especially with slurry, could complicate the task of nutrient crediting of manure by cash-grain operators.

Fall nitrate levels after manure application:

The purpose of fall nitrate sampling was to see if late-summer application of manure at the six sites (2003 + 2004) following wheat harvest increased the risk of nitrate leaching over winter. As shown in **Figure 1**, higher levels of nitrates were found in the manured treatments in every on-farm site, with levels statistically higher in four of the six sites ($\alpha = 0.10$). However, in only three sites were nitrate levels markedly higher than the standard "background" level found in non-agricultural land of 50 lbs NO_3 per acre. The results of the initial fall nitrate tests indicated that early fall applications of manure that had a high concentration of nitrogen (e.g. the manure at JB I and KS I) were particularly likely to raise soil nitrate levels in the late fall.

Pre-Sidedress Nitrate Test Results:

Results of the pre-sidedress nitrate test (PSNT) taken in Spring 2004 indicated that nearly all the manured plots at all sites needed a full rate of 160 pounds nitrogen per acre (**Table 4**). This was unexpected, as N-additions via manure applications in the previous fall ranged from 95 to 160 lbs. The most likely explanation was that nitrogen from the manure did not have enough time to mineralize before the PSNT was taken, due to the cold, wet conditions of Spring 2004. A second explanation was that some nitrate leaching occurred between the time that manure was applied, and the time of the PSNT. Interestingly, technicians at the SPAL who ran the nitrate analyses commented that PSNT results from most of their clients had been very low that year. Dr. Bundy, a UW soil fertility specialist, in fact, advises growers to use anticipated N-credits from the manure in addition to the results of the PSNT analysis when it is a cool spring (Andraski and Bundy, 2002).

Corn grain yields and quality:

Corn grain yields from the on-farm trials in 2004 averaged between 181 and 215 bu/a and were not significantly different between manured and non-manured treatments (see **Figure 2**). This was surprising as the manured plots received manure plus a full rate of sidedressed N fertilizer. This indicates that either something besides nitrogen was limiting yields in the manured plots, or the manure-nitrogen was not available to the corn crop during this first year after application (**Table 5**). The 2004 corn yields demonstrated the potential unavailability of manure nitrogen under wet and cold conditions in the spring.

Corn grain quality analyses were similar to the yield results. While crude protein percentages of the corn grain from the manured plots were arithmetically higher at all on-farm sites, probably due to greater nitrogen additions, no significant differences were detected (**Figure 3**).

Post-Harvest Fall Nitrates and Nitrogen Nutrient Budgets:

As shown in **Figure 4**, post-season nitrate levels were very low at all sites, in both treatments. This event was in stark contrast to the high net balance of nitrogen credits in the manured plots, as calculated in the nitrogen budget (**Table 5**). The combination of low fall nitrates and high net N balance could be a further indication that much of the nitrogen from the manure did not mineralize during the cool 2004 season. There is a good chance, however, that this organic nitrogen will become available in subsequent years through continued mineralization. Another possibility was that the low post-season nitrate levels were an indication of nitrogen losses to the environment, such as ammonia volatilization. Leaching loss seemed unlikely, since it would be highly unusual to see downward movement below the 3-foot depth analyzed in the nitrate test in such a short time span.

Nutrient Budgeting—Phosphorus and Potassium:

Phosphorus (phosphate) and potassium (potash) nutrient budgets are shown in **Tables 6** and **7**, respectively. At all sites, there was a positive phosphate balance and potash balance on the manured plots, and a low or negative balance on the non-manured plots. These results were not surprising, since manure was proportionally higher in phosphorus and potassium, as compared to nitrogen, so typical N-based spreading rates would cause these nutrients to accumulate. Unlike

nitrates and phosphates, high soil potassium levels were not a primary concern for groundwater or surface water contamination.

SECTION B: WICST STUDY

METHODS AND MATERIALS:

Fall Plot Layout:

The experimental design at the WICST site was very similar to that of the on-farm studies. The study however, began in Spring 2003 and has run for two seasons to date (2003 and 2004), with the 2005 season currently in place. Plots were delineated on the corn phases of the three grain-based cropping systems: CS 1 (Continuous Corn), CS 2 (No-till Corn-Soybeans) and CS 3 (Organic Corn-Soybeans-Winter Wheat/Red Clover).

Manured strips were created on the eastern-most 15 feet of each plot going into corn, and were compared against the remaining 45 feet check strips. Between 11,000 and 12,000 gallons of slurry were applied before the corn phase of each season (on 4/28/03, 11/25/03 and 12/03/04). Each system was replicated four times.

The Pre-Plant Nitrate Test (PPNT) was used in the first season at WICST in order to determine fertilizer rates on the non-manured strips. In the case of the manured strips, manure nutrient credits were estimated and subtracted from the total N requirement. The difference in manure nitrogen credits and crop requirements, as well as the PPNT results from the non-manured strips, were both used when figuring the best fertilizer rates on the manured strips. The Pre-Sidedress Nitrate Test (PSNT) was used for both manured and non-manured strips in the 2004 season.

Late replanting of the initially poor stand on the CS3 plots in 2004 resulted in harvesting the corn as snaplage. Thus, the data from this system was not included in this report.

RESULTS AND DISCUSSION

Characterization of Site soils:

Plano silt loam created the base of the WICST plots, and this prairie-derived soil was relatively high in organic matter (ranging from 3.9 to 4.5) and had a neutral pH (between 6.5 and 6.9). Soil test phosphorus levels were rated Excessively High (ranging between 45 ppm and 91 ppm) and STK levels were rated between Optimum and Excessively High (ranging from 95 to 226) (Kelling et al., 1998).

Manure Analyses:

Table 8 displays the analyses of the liquid manure spread prior to corn planting. Variability was slightly less than seen across all on-farm manure analyses. This was not surprising, since the manure for the WICST study came from either the East or Center pits from the on-station Blaine dairy.

Pre-Plant and Pre-Sidedress Nitrate Test Results:

This latter test came back with outcomes very similar to the on-farm trials; namely, little to no credit was gained from the manure (**Table 9**). These results indicated once again that due to the cold, wet spring of 2004, nitrogen in the form of plant-available nitrate was absent due to either slow mineralization, or leaching below the one-foot level.

Corn grain yields and quality:

Manure tended to increase corn yields on the WICST plots. In 2003, systems CS 1 and CS 3 had better yields on the manured plots, whereas CS 2 had poorer yields. It was hypothesized that the spring application of manure (as opposed to a fall spreading) and the high dry matter content of the manure (12%), resulted in a rougher field surface. We believe that due to the inadequate adjustment of the no-till planter, this resulted in a poorer stand in the manured versus non-manured plots in CS 2. In the following season, when manure was fall-spread, manure increased yields in systems CS1 and CS 2 (see **Figures 5a** and **5b**).

Crude protein percentage was significantly higher on the manured plots in CS 1 and CS 3 in 2003. This was not the case in 2004 (**Figures 6a** and **6b**).

These results once again indicated that while adding manure into a grain system could potentially raise crude protein percentage, there was little guarantee that this outcome would occur.

Post-harvest Fall Nitrates and Nitrogen Nutrient Budgets:

In 2003, although the net N balance was higher on the manured plots (**Table 10**), fall nitrate levels were significantly lower than the non-manured plots (**Figure 7**). These surprising results conflict with results from 2004, as well as with the 2004 on-farm data.

Although the 2004 PSNT indicated that full rates of N fertilizer were necessary on CS1 and CS2 in the manured plots, fall nitrate readings suggested that the plots were over-fertilized. Higher levels of nitrates in the top three feet indicated that more nitrogen was available in the system than could be used by the corn crop (**Table 10**). It appeared that more of the manure nitrogen must have mineralized after the PSNT and that adding full fertilizer N rates was probably not necessary on the WICST plots in 2004.

Nutrient Budgeting—Phosphorus and Potassium:

As with the on-farm trials, in both 2003 and 2004, there was a greater phosphorus (**Table 11**) and potassium (**Table 12**) balance on the manured plots than the non-manured plots. Although the phosphate and potash balances in the manured plots appeared high, it was assumed that the crops would draw down P and K accumulation in the soil in subsequent years.

CONCLUSIONS

A number of important issues came to our attention during this first phase of our research:

1. Manure in general, and slurry in particular, is a variable source of nutrients. Farmers are encouraged to take manure samples for lab analysis, as opposed to relying solely on standardized book values.

2. Mineralization of manure may be delayed in cool spring weather making it difficult to anticipate the availability of nitrogen to the corn crop. Thus, a combination of taking manure credits, following recommendations of the Pre-Sidedress Nitrate Test, and common sense is probably the best method of deciding on nitrogen fertilizer rates.

3. The application of manure in early fall (after a small grain) may result in a build up of fall nitrates that could leach during the winter months. Thus, it is recommended to plant a fall cover crop following the small grain harvest in order to trap nitrates for use in the next season.

4. At least initially, soil test P and K will probably increase in the manure-amended soils due to the high concentration of these nutrients. Theoretically, these higher levels would be drawn down by future crop off take.

Table 1: Characterization of 2004 and 2005 On-Farm Sites

Site	Crop Season	County	Soil Series (Predominantly silt loams)	Previous Crop	Manure Type	Manure Application Date
JB I	2004	Dane	St. Charles / Ringwood	Wheat	Slurry	8/15/03
DF I	2004	Walworth	Plano	Wheat	Solid	10/20/03
NH I	2004	Columbia	Virgil	Soybeans	Slurry	10/31/03
RJ I	2004	Columbia	Plano/ Dodge	Wheat	Solid	8/26/03
JB II	2005	Dane	St. Charles silty clay loam	Wheat	Slurry	9/10/04
DF II	2005	Walworth	Plano	Wheat	Solid	10/06/04
NH II	2005	Columbia	Pella silty clay loam	Soybeans	Slurry	11/03/04
RJ II	2005	Columbia	Plano	Wheat	Slurry	11/03/04
TK I	2005	Columbia	Plano	Soybeans	Slurry	10/14/04
TM I	2005	Columbia	Plano	Wheat	Slurry	10/14/04
CP I	2005	Walworth	Kidami silt loam	Corn	Slurry	4/18/05
SS-Alf I	2005	Walworth	Rotamer loam	Alfalfa	Slurry	4/27/05
SS-Sb I	2005	Walworth	Lamartine	Soybeans	Slurry	4/27/05
SS-W I	2005	Walworth	Kidder loam	Wheat	Slurry	10/9/04
KS I	2005	Jefferson	Kidami silt loam	Wheat/Clover/ Alfalfa	Slurry	9/20/04

Table 2: 2004 and 2005 Season Slurry Manure Analyses, Estimated 1st Year Available Nutrients

Site	Season	Dry Matter %	N lbs/1000 gal	P_2O_5 lbs/1000 gal	K_2O lbs/1000 gal
JB I	2004	11.5	12.3	6.8	22.5
NH I	2004	6.2	8.3	5.6	16.3
JB II	2005	9.1	10.2	6.5	20.2
NH II	2005	9.5	13.1	7.1	21.8
RJ II	2005	9.7	14.1	7.3	22.6
TK I	2005	10.1	9.6	5.6	16.3
TM I	2005	14.8	11.0	4.9	17.7
CP I *	2005	8.1	7.8	3.4	15.2
SS-Alf I *	2005	4.2	8.0	3.4	12.5
SS-Sb I *	2005	4.8	8.0	3.9	13.2
SS-W I	2005	6.3	7.8	3.9	15.7
KS I	2005	10.3	12.6	7.2	20.4
Average		*8.7*	*10.2*	*5.5*	*17.9*
Book Values		*6.0*	*10.0*	*5.0*	*16.0*

Notes: All samples were taken at time of spreading, in the fall previous to the stated season. Lightly-shaded cells designate nutrient-poor manure; darker-shaded cells highlight nutrient-rich manure. Site averages and "book values" (standardized ratios determined by UWEX) are at the bottom of the table (Nutrient Management Fast Facts, 2003).

* Manure was spread on these sites in the spring prior to corn planting.

Table 3: 2004 and 2005 Season Solid Manure Analyses, Estimated 1st Year Available Nutrients

Site	Season	Dry Matter %	N lbs/ton	P_2O_5 lbs/ton	K_2O lbs/ton
DF I	2004	27.0	5.9	6.5	21.2
RJ I	2004	35.9	5.2	2.9	15.3
DF II	2005	23.8	4.8	5.6	8.1
Averages		*28.9*	*5.3*	*5.0*	*14.9*
Book Values		*24.0*	*4.0*	*3.0*	*7.0*

Notes: All samples were taken at time of spreading, in the fall previous to the stated season. Shaded cells highlight especially nutrient-rich manure. Site averages and "book values" (standardized ratios determined by UWEX) are at the bottom of the table (Nutrient Management Fast Facts, 2003).

Table 4: 2004 On-Farm Nitrogen Credits Prior to Pre-Sidedress Nitrate Test (PSNT) and PSNT recommendations

Site	Trt.	Manure credit	Fertilizer + legume N credit prior to PSNT	Total N credits prior to PSNT	PSNT recommendations
JB I	M	148	39	187	60
	NM	0	199	199	0
DF I	M	106	19	125	160
	NM	0	19	19	160
NH I	M	96	48	144	160
	NM	0	130	130	160
RJ I	M	160	6	166	160
	NM	0	6	6	150

Notes: M = Manure, NM = No Manure. Manured treatments are shaded. All units in lbs N/acre.

Table 5: 2004 On-Farm Nitrogen Budgets

Sites	Trt.	N Inputs		Estimated Total N Input	N Off-take	Estimated Net N
		Manure + legume credits	Fertilizer			
JB I	M	148	92	240	137	103
	NM	0	199	199	148	52
DF I	M	105	159	265	118	146
	NM	0	159	159	108	51
NH I	M	126	63	189	130	59
	NM	30	145	175	128	47
RJ I	M	160	166	326	145	181
	NM	0	166	166	133	33

Notes: M = Manure, NM = No Manure. Fertilizer = starter + sidedressed N. Manured treatments are shaded. All units in lbs N/acre.

Table 6: 2004 On-Farm Phosphorus Budgets

Sites	Trt.	P_2O_5 Inputs		Total P_2O_5 in	P_2O_5 Off-take	Net P_2O_5
		Manure	Fertilizer			
JB I	M	82	10	92	51	41
	NM	0	10	10	46	-36
DF I	M	116	34	150	43	107
	NM	0	34	34	36	-2
NH I	M	64	46	110	41	68
	NM	0	46	46	42	4
RJ I	M	90	19	109	52	58
	NM	0	19	19	41	-21

Notes: M = Manure; NM = No Manure. Manured treatments are shaded. All units in P_2O_5 lbs/a.

Table 7: 2004 On-farm Potassium Budgets

Sites	Trt.	K_2O Inputs		Total K_2O In	K_2O Off-take	Net K_2O
		Manure	Fertilizer			
JB I	M	270	10	280	43	237
	NM	0	10	10	47	-37
DF I	M	379	115	494	41	453
	NM	0	115	115	39	76
NH I	M	187	60	247	42	205
	NM	0	60	60	40	20
RJ I	M	475	0	475	42	433
	NM	0	0	0	36	-36

Notes: M = Manure; NM = No Manure. Manured treatments are shaded. All units in K_2O lbs/a.

Table 8: 2003—2004 WICST Slurry Manure Analyses, 1st year Available Nutrients

System	Crop Season	Dry Matter %	N lbs/1000 gal	P_2O_5 lbs/1000 gal	K_2O lbs/1000 gal
CS 1 CS 2 CS 3	2003	12.3	13.0	7.6	20.1
CS 1 CS 2	2004	6.1	8.6	5.2	16.2
CS 1	2005	8.4	11.2	6.1	16.9
CS 2	2005	8.7	11.0	6.0	17.2
CS 3	2005	8.6	10.9	6.3	16.7
Book Values		*6.0*	*10.0*	*5.0*	*16.0*

Notes: Book values from Nutrient Management Fast Facts, 2003. Shaded cells highlight especially nutrient-rich manure.

Table 9: 2003 and 2004 WICST Nitrogen Credits prior to Nitrate Tests and Nitrate Test Recommendations (lbs/acre)

System	Season	Trt.	Manure credits	Fertilizer + legume credits prior to sidedressing	Total N credit prior to sidedressing	Nitrate Test Recommendations
CS 1 (1)	2003	M	143	5	148	-
		NM	0	5	5	90
CS 2 (1)	2003	M	143	45	188	-
		NM	0	45	45	90
CS 3 (1)	2003	M	143	118	261	-
		NM	0	118	118	-
CS 1 (2)	2004	M	95	5	100	160
		NM	0	5	5	160
CS 2 (2)	2004	M	95	45	140	160
		NM	0	45	45	160

Notes: M = Manure, NM = No Manure. Manured treatments are shaded.

(1) On NM treatments, Pre-Plant Nitrate Test (PPNT) used for determination of fertilizer rates. On the M treatments, manure credits were subtracted from the total nitrogen requirement (160 lbs/a), and the difference, plus the PPNT results from the NM plots were used to determine fertilizer rates. No nitrate test taken at CS 3 plots.

(2) Pre-Sidedress Nitrate Test used on M and NM treatments to determine fertilizer rates.

Table 10: 2003 and 2004 WICST Nitrogen Budgets (lbs/acre)

System	Season	Trt.	N Inputs		Estimated Total N input	N Off-take	Estimated Net N
			Manure + legume credits	Fertilizer			
CS 1 (1)	2003	M	143	45	188	143	46
		NM	0	105	105	120	-14
CS 2 (1)	2003	M	183	5	188	91	97
		NM	40	85	125	119	6
CS 3 (1)	2003	M	261	0	261	83	178
		NM	118	0	118	68	50
CS 1 (2)	2004	M	95	165	260	154	105
		NM	0	165	165	135	30
CS 2 (2)	2004	M	135	165	300	146	154
		NM	40	165	205	131	74

Notes: M = Manure, NM = No Manure. Manured treatments are shaded. Fertilizer = starter + sidedressed N.

(1) On NM treatments, Pre-Plant Nitrate Test (PPNT) used for determination of fertilizer rates. On the M treatments, manure credits were subtracted from the total nitrogen requirement (160 lbs/a), and the difference, plus the PPNT results from the NM plots were used to determine fertilizer rates.

(2) Pre-Sidedress Nitrate Test used on M and NM treatments to determine fertilizer rates.

Table 11: 2003 and 2004 WICST Phosphorus Budgets

System	Season	Trt.	P_2O_5 Inputs		Total P_2O_5 in	P_2O_5 Off-take	Net P_2O_5
			Manure	Fertilizer			
CS 1	2003	M	84	14	97	47	50
		NM	0	14	14	41	-26
CS 2	2003	M	84	6	90	39	51
		NM	0	6	6	40	-34
CS 3	2003	M	84	0	84	30	54
		NM	0	0	0	25	-25
CS 1	2004	M	57	14	71	51	20
		NM	0	14	14	43	-29
CS 2	2004	M	57	14	71	44	27
		NM	0	14	14	46	-32

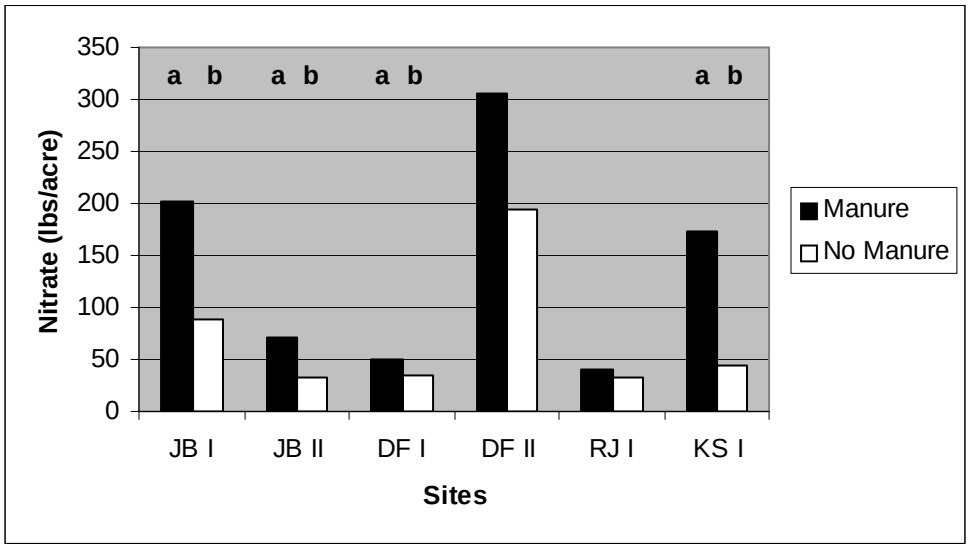
Notes: M = Manure; NM = No Manure. Manured treatments are shaded. All units in P_2O_5 lbs/a

Table 12: 2003 and 2004 WICST Potassium Budgets

System	Season	Trt.	K_2O Inputs		Total K_2O In	K_2O Off-take	Net K_2O
			Manure	Fertilizer			
CS 1	2003	M	221	42	263	40	223
		NM	0	42	42	36	6
CS 2	2003	M	221	68	289	32	257
		NM	0	68	68	36	33
CS 3	2003	M	221	0	221	27	194
		NM	0	0	0	25	-24
CS 1	2004	M	178	42	220	58	162
		NM	0	42	42	51	-9
CS 2	2004	M	178	91	269	55	213
		NM	0	91	91	51	40

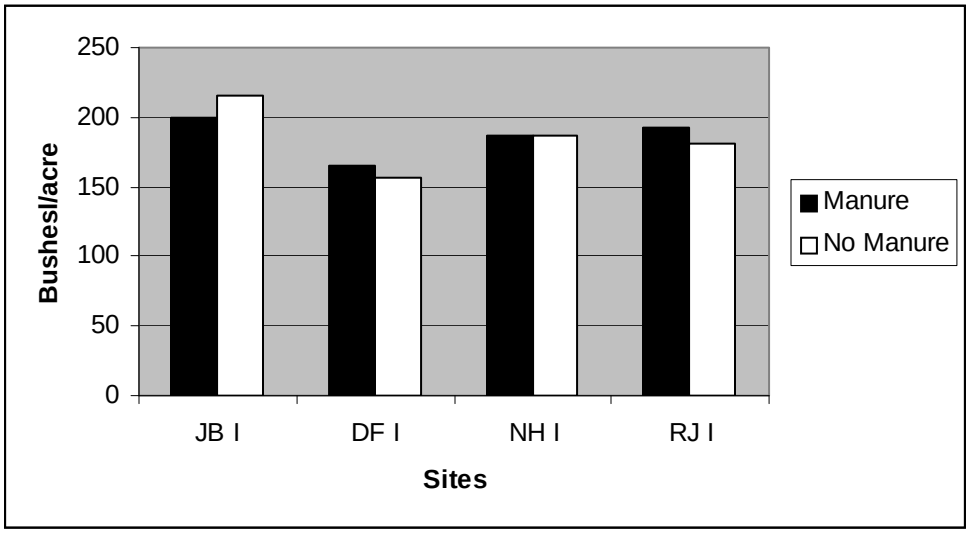
M = Manure; NM = No Manure. Manured treatments are shaded. All units in K_2O lbs/a.

Figure 1: 2003 and 2004 Fall Nitrate Levels (lbs NO_3/3-foot depth)



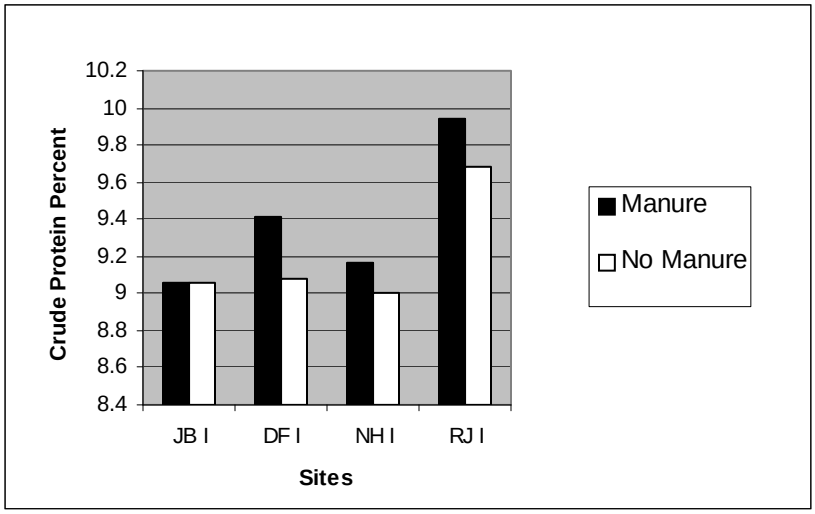
Note: Letters above histogram indicate significant differences (α = 0.10).

Figure 2: 2004 On-Farm Mean Corn Grain Yields



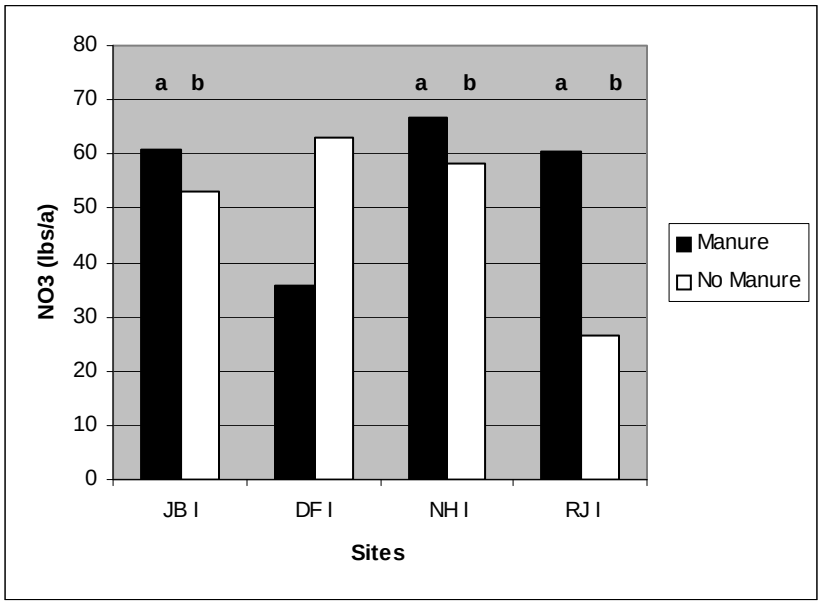
Note: No significant differences found (α = 0.10).

Figure 3: 2004 On-Farm Crude Protein Percentages



Note: No significant differences found (α = 0.10).

Figure 4: 2004 On-Farm Post-Harvest Fall Nitrate Levels



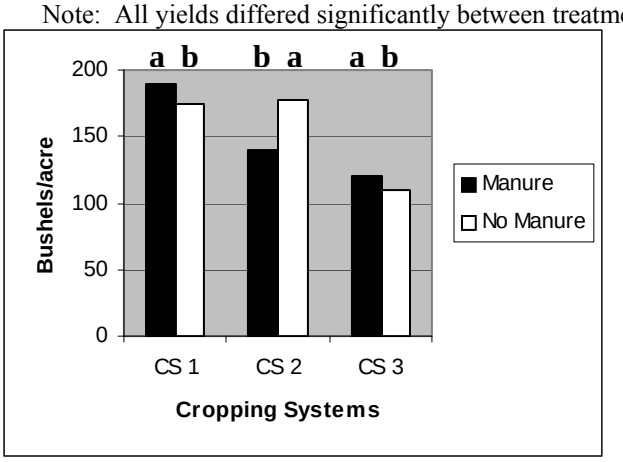
Note: Fall nitrate levels measured in the top 3 feet. Letters above histograms indicate significant differences (α = 0.10).

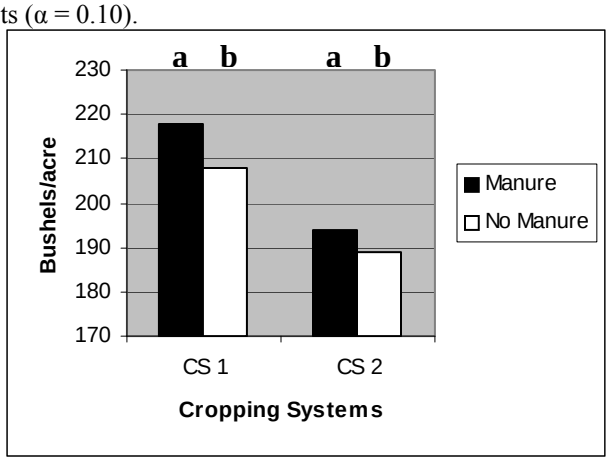
Figures 5a and 5b: 2003 and 2004 WICST Mean Corn Yields

Figure 5a: 2003 Corn Yields

Figure 5b: 2004 Corn Yields

Note: All yields differed significantly between treatments (α = 0.10).

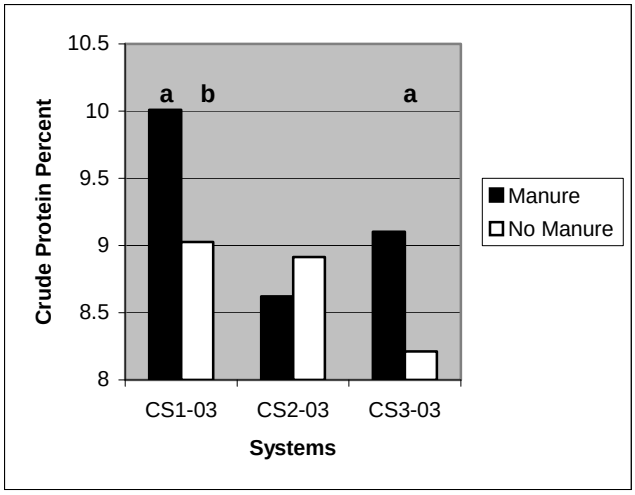


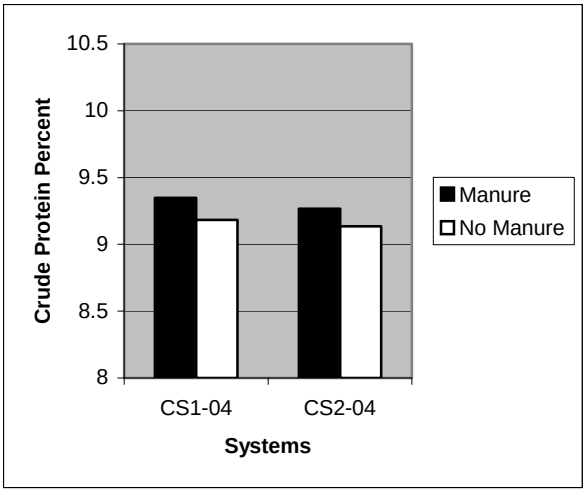


Figures 6a and 6b: 2003 and 2004 WICST Mean Crude Protein Percentages

Figure 6a: 2003 Crude Protein Percentage

Figure 6b: 2004 Crude Protein Percentage





Note: Letters above histogram indicate significant differences (α = 0.10).

Figure 7a and 7b: 2003 and 2004 WICST Fall Nitrate Levels (lbs NO_3/3-foot depth)

Figure 7a: 2003 Fall Nitrates

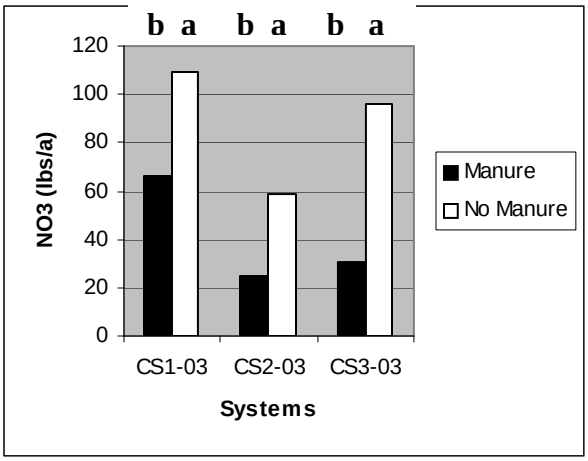
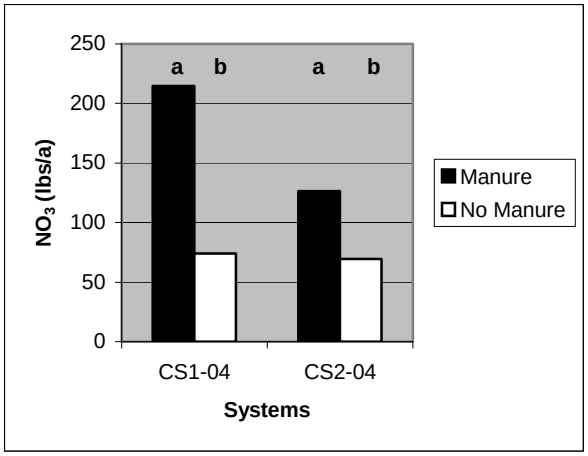


Figure 7b: 2004 Fall Nitrates



Notes: Fall nitrate levels measured in the top 3 feet. Letters above histograms indicate significant differences between nitrate levels ($\alpha = 0.10$).

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