Appendix 3

Greenhouse Gas Mitigation Program for Canadian Agriculture
Soil Conservation Council of Canada
Demonstration and Awareness Activities

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to

Ontario Greenhouse Gas Mitigation Committee

by

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Advancing Nitrogen Use Efficiency
on Livestock Farms

Advancing Nitrogen Use Efficiency on Livestock Farms

Executive Summary

This report summarizes the results of a 3 year study which evaluated fertilizer N (nitrogen) use efficiency for corn grown on fields that have recently received manure or have a history of manure use. The study consisted of 29 sites established in the springs of 2003(9), 2004(10) and 2005(10) across west-central and eastern Ontario. The accuracy of the OMAFRA General Recommendations and Presidedress Soil Nitrate-N Test (PSNT) were evaluated against actual experimentally determined Maximum Economic Rates of Fertilizer N (MERN). General results and conclusions are as follows:

1. On the 15 sites that received liquid cattle manure sometime over the previous 2 years, OMAFRA General Recommendations and the PSNT provided recommendations which averaged close to those actually required. The PSNT provided a slightly more profitable recommendation, primarily because of the accurate prediction of sites that did not require fertilizer N to produce the most economic yield.
2. Nitrogen recommendations provided by both OMAFRA General Recommendations and the PSNT both severely under predicted N requirements on the seven sites that received liquid hog manure over the past 2 years. The PSNT generally provided the lowest recommendations and as a result incurred unacceptably high economic losses because of less than adequate fertilizer N recommendations. The average economic loss incurred on the liquid hog sites was ~$55/ha if fertilizer N rates based on OMAFRA General Recommendations were used and $110/ha if the PSNT was used.
3. On the six sites that received solid poultry manure, both OMAFRA General Recommendations and PSNT under predicted requirements, but the financial liability associated with the recommendations was not as severe as shown for the hog sites because of the already low fertilizer N requirement to economically optimize yield on the poultry sites.
4. The cooperating farmers generally applied fertilizer N rates that exceeded 110 kg-N/ha, even when manure was applied the previous fall. On the liquid cattle sites, over application reduced profitability, by an average of $20/ha compared to if OMAFRA General Recommendations or the PSNT rates were used.
5. The end of season fall residual soil nitrate N concentrations clearly demonstrated that applying fertilizer N to corn in excess of MERN, elevates soil mineral concentrations in the fall. This unutilized (residual) soil mineral N is subject to environmental loss, including possibly conversion to nitrogenous greenhouse gasses and/or leaching.
6. This study suggests that fertilizer N rates suggested by OMAFRA General Recommendations or the PSNT on sites which have recently received liquid cattle manure were in line with the fertilizer N rates actually required to economically optimize corn yield. However, especially where liquid hog manure was recently applied, both the General Recommendations and the PSNT severely under predicted fertilizer N requirements resulting in unacceptably high financial losses. There appears to be a need to further evaluate fertilizer N requirements predicted by both OMAFRA General Recommendations and the PSNT for corn following hog manure in order to determine the accuracy of current recommendation assumptions associated with the application of hog manure.

Advancing Nitrogen Use Efficiency on Livestock Farms

Introduction

Accurate estimation of corn fertilizer N (nitrogen) requirements is essential in maintaining profitable yields while minimizing the amount of soil N not utilized by the corn crop. Unutilized N is subject to environmental losses; including the possibility for conversion to Greenhouse Gasses.
Unfortunately, accurate prediction of plant available N from manure is difficult because of variability (or uncertainty) associated with manure application rates, uniformity of application, N analysis of the manure, N losses due to leaching or volotization and conversion rates of the organic N fraction to plant available forms. Other factors such as soil type, incorporation timing and method and soil type differences also impact our ability to accurately determine fertilizer N recommendations required following the application of manure or from the historical use of manure.

A series of on-farm demonstration sites were established to assess overall N use efficiency on livestock farms and to evaluate technologies such as the soil nitrate-N test, as tools to advance this nitrogen use efficiency and to accurately predict corn fertilizer N requirements on fields where manure had been recently applied.

Study Description

The study was conducted on 29 sites during 2003(9), 2004(10) and 2005(10) throughout West-Central and Eastern Ontario. The county, long-term crop heat unit rating, soil texture, organic matter in the surface 15 cm of soil and previous crop for the various sites is detailed in Table 1. The sites were located in regions that received 2550 to 2850 CHU. The soil at the various sites were predominantly a loam or silt loam with organic matter contents in the plow layer that were typically in the 4 to 5 percent range. Organic matter contents were never less than 3.7%. The most frequent previous crop was soybeans (13 out of 29 sites), followed by wheat (9 sites) and then corn (7 sites).

The cooperating farmer's typical method of fertilizer N application, rate of fertilizer N that was applied to corn surrounding the experimental site and the historic average corn yield for the field are detailed in Table 2. Historic average corn yields ranged from 6.9 to 11.3 Mg/ha. One cooperator indicated that fertilizer N normally would not be applied to corn planted following recent application of manure. However, the majority of cooperators indicated that fertilizer N was applied to the corn surrounding the experimental site with most applying in excess of 100 kg-N/ha.

The type of manure applied on the various sites was liquid cattle (15 sites), liquid hog (8 sites) or solid poultry (6 sites). The type of manure, general timing of the last application, incorporation timing details of the last application and the N credit associated with manure applications which occurred over the previous 3 years at the various sites are detailed in Table 3. On the majority of sites (24) manure was broadcast applied during the late summer or fall of the previous year. On 4 sites at least one crop was planted since the last manure application (i.e. no manure application in the spring of corn seeding or the previous fall). On one site liquid hog manure was applied

Preplant in the spring just prior to corn planting. Sidedress application of dairy manure was evaluated on one site with the fertilizer N response portion of this site not receiving the sidedress application of manure, or any manure application in the previous 3 years. The majority of cooperators indicated that manure was not normally incorporated immediately and often more than five days elapsed between application and incorporation.

Corn was planted in early to mid-May at each of the sites using the normal production practices of the cooperating farmer; except for fertilizer N application. Typically starter fertilizer rates ranged from 0 to 34 kg-N/ha (Table 2). In 2003, two sites received a relatively low rate of broadcast N (50 or 62 kg-N/ha) across the entire experimental area.

Table 1. Location, long-term heat unit rating, soil texture, organic matter, and previous crop for the sites included in the evaluation of nitrogen use efficiency on livestock farms survey (2003-2005).

Site	Year	County	Corn Heat Units	Soil Texture	Organic Matter (%)	Previous Crop
GHG-L2003-LASF	2003	Stormont, Dundas, Glengarry	2850	Loam	5.8	Soybeans
GHG-L2003-LBWB	2003	Perth	2750	Silt loam	4.5	Wheat
GHG-L2003-LDCD	2003	Leeds and Grenville	2700	Sandy loam	5.0	Silage Corn
GHG-L2003-LJHS	2003	Stormont, Dundas, Glengarry	2650	Silt loam	4.4	Soybeans
GHG-L2003-LKBD	2003	Huron	2700	Silt loam	5.0	Soybeans
GHG-L2003-LLHB	2003	Wellington	2575	Loam	4.0	Soybeans
GHG-L2003-LSBD	2003	Stormont, Dundas, Glengarry	2850	Loam	4.5	Soybeans
GHG-L2003-LTBD	2003	Bruce	2650	Silt loam	4.6	Soybeans
GHG-L2003-LWJD	2003	Durham	2700	Loam	5.2	Wheat
GHG-L2004-L2AS	2004	Stormont, Dundas, Glengarry	2850	Loam	5.2	Soybeans
GHG-L2004-L2CW	2004	Perth	2750	Silt loam	4.8	Wheat
GHG-L2004-L2DC	2004	Leeds and Grenville	2700	Sandy loam	4.3	Silage Corn
GHG-L2004-L2DS	2004	Perth	2800	Silt loam	4.7	Soybeans
GHG-L2004-L2HV	2004	Perth	2800	Silt loam	4.5	Wheat
GHG-L2004-L2JK	2004	Perth	2750	Silt loam	5.9	Grain Corn
GHG-L2004-L2KB	2004	Huron	2800	Sandy Clay loam		Grain Corn
GHG-L2004-L2LH	2004	Wellington	2550	Silt loam	4.8	Soybeans
GHG-L2004-L2SE	2004	Wellington	2650	Silt loam	3.7	Soybeans
GHG-L2004-L2WJ	2004	Durham	2700	Loam	4.8	Wheat
GHG-L2005-L3AS	2005	Stormont, Dundas, Glengarry	2850	Loam	7.2	Soybeans
GHG-L2005-L3CW	2005	Perth	2800	Silt loam	3.8	Wheat
GHG-L2005-L3DC	2005	Leeds and Grenville	2700	Loamy Sand	4.5	Silage Corn
GHG-L2005-L3DS	2005	Perth	2800	Silt loam	4.2	Wheat
GHG-L2005-L3GV	2005	Huron	2800	Loam	4.8	Grain Corn
GHG-L2005-L3HV	2005	Perth	2800	Loam	4.2	Wheat
GHG-L2005-L3KB	2005	Huron	2800	Silt loam	4.7	Silage Corn
GHG-L2005-L3LH	2005	Wellington	2550	Silt loam	4.2	Soybeans
GHG-L2005-L3SE	2005	Wellington	2650	Silt loam	4.7	Soybeans
GHG-L2005-L3WJ	2005	Durham	2700	Loam	3.7	Wheat

Table 2. Summary of co-operating farmer fertilizer N application rates, their usual timing of fertilizer N application, and expected corn grain yield based on historic field average for the sites included in the evaluation of nitrogen use efficiency on livestock farms survey (2003-2005).

Site	Starter N Rate (kg-N/ha)	Application Timing (field)	Uses PSNT	Application Rate (Field) (kg-N/ha)
GHG-L2003-LASF	0	Preplant	No	146
GHG-L2003-LBWB	13	Sidedress	No	101
GHG-L2003-LDCD	3	Sidedress	min. of PSNT or, 56 kg-N/ac	59
GHG-L2003-LJHS	62	Sidedress	No	95
GHG-L2003-LKBD	2	Preplant	No	112
GHG-L2003-LLHB	21	Preplant	No	123
GHG-L2003-LSBD	11	Preplant	No	157
GHG-L2003-LTBD	6	Preplant	No	112
GHG-L2003-LWJD	50	Preplant	No	112
GHG-L2004-L2AS	0	Preplant	No	146
GHG-L2004-L2CW	34	Sidedress	No	101
GHG-L2004-L2DC	3	Sidedress	min. of PSNT or, 56 kg-N/ac	59
GHG-L2004-L2DS	7	Sidedress	No	168
GHG-L2004-L2HV	7	Preplant	No	165
GHG-L2004-L2JK	0	Preplant	No	179
GHG-L2004-L2KB	2	Preplant	No	112
GHG-L2004-L2LH	16	Preplant	No	123
GHG-L2004-L2SE	0	Preplant	No	0
GHG-L2004-L2WJ	31	Preplant	No	112
GHG-L2005-L3AS	0	Preplant	No	146
GHG-L2005-L3CW	0	Sidedress	No	101
GHG-L2005-L3DC	31	Sidedress	min. of PSNT or, 56 kg-N/ac	95
GHG-L2005-L3DS	34	Sidedress	No	168
GHG-L2005-L3GV	0	Preplant	No	162
GHG-L2005-L3HV	7	Preplant	No	165
GHG-L2005-L3KB	2	Preplant	No	112
GHG-L2005-L3LH	25	Preplant	No	123
GHG-L2005-L3SE	0	Preplant	No	0
GHG-L2005-L3WJ	32	Preplant	No	112

+ Farmer application rate is based on a Presidedress Soil Nitrate-N test and if recommendation is less than 56 kg-N/ha (50 lb-N/ac) then a minimum of 56 kg-N/ha was sidedress applied.

Four rates of fertilizer N (0, 56(50), 112(100), and 168(150) kg-N/ha(lbs-N/ac)) were established by sidedressing the appropriate rate of U.A.N (28%) sometime during the latter part of June. The yields from the various fertilizer N strips were used to estimate the maximum economic N rate (MERN). The starter (or any broadcast applied N) was added to the sidedress N rate and the total N rate was used to calculate the yield response curves. The economic assumptions for MERN and profitability calculations are based on a nitrogen fertilizer price of $0.99/kg-N ($0.45/lb-N) and a corn price of $132.00/tonne ($3.36/bu) (Nitrogen:Corn price ratio of 7.5).

Table 3. Summary of manure type applied, application, and incorporation timing associated with the most recent manure application and the manure credit based on application of manure over the previous 3 years for the sites included in the evaluation of nitrogen use efficiency on livestock farms survey (2003-2005).

Site	Manure Type	Last Application	Incorporation Timing	Manure Credit (kg-N/ha)
GHG-L2003-LASF	Liquid Beef	Previous Fall (Early)	Greater than 5 days	29
GHG-L2003-LBWB	Solid Poultry	Previous Summer (Late)	Greater than 5 days	49
GHG-L2003-LDCD	Liquid Dairy	Previous Fall (Early)	Greater than 5 days	0
GHG-L2003-LJHS	Liquid Hog	Late Fall (2 Yr Previous)	Not incorporated	6
GHG-L2003-LKBD	Liquid Dairy	Previous Fall (Early)	Greater than 5 days	66
GHG-L2003-LLHB	Solid Poultry	Previous Fall (Early)	Within 1-2 days	103
GHG-L2003-LSBD	Liquid Dairy	Previous Fall (Early)	Greater than 5 days	55
GHG-L2003-LTBD	Liquid Dairy	Previous Spring (Preplant)	Greater than 5 days	6
GHG-L2003-LWJD	Liquid Dairy	Previous Fall (Early)	Not incorporated	72
GHG-L2004-L2AS	Liquid Beef	Previous Fall (Late)	Within 1-2 days	70
GHG-L2004-L2CW	Solid Poultry	Previous Summer (Late)	Greater than 5 days	98
GHG-L2004-L2DC	Liquid Dairy	Previous Fall (Late)	Greater than 5 days	91
GHG-L2004-L2DS	Liquid Dairy	No Manure Previous 3 Yr	Injected	149
GHG-L2004-L2HV	Liquid Hog	Previous Summer (Late)	Greater than 5 days	37
GHG-L2004-L2JK	Liquid Hog	Previous Fall (Late)	Greater than 5 days	101
GHG-L2004-L2KB	Liquid Dairy	Previous Fall (Early)	Greater than 5 days	78
GHG-L2004-L2LH	Solid Poultry	Previous Fall (Late)	Within 3 hours-1 day	95
GHG-L2004-L2SE	Liquid Hog	Previous Fall (Early)	Within 3 hours-1 day	26
GHG-L2004-L2WJ	Liquid Dairy	Previous Fall (Early)	Not incorporated	77
GHG-L2005-L3AS	Liquid Beef	Previous Fall (Late)	Within 3 hours-1 day	85
GHG-L2005-L3CW	Solid Poultry	Previous Summer (Late)	Greater than 5 days	21
GHG-L2005-L3DC	Liquid Dairy	Previous Spring (Preplant)	Within 3 hours-1 day	22
GHG-L2005-L3DS	Liquid Hog	Sidedress (3 Yr Previous)	Injected	1
GHG-L2005-L3GV	Liquid Hog	Previous Fall (Early)	Greater than 5 days	46
GHG-L2005-L3HV	Liquid Hog	Previous Summer (Late)	Greater than 5 days	37
GHG-L2005-L3KB	Liquid Dairy	Previous Fall (Early)	Within 3-4 days	72
GHG-L2005-L3LH	Solid Poultry	Previous Fall (Late)	Within 1-2 days	77
GHG-L2005-L3SE	Liquid Hog	Preplant	Within 3 hours-1 day	56
GHG-L2005-L3WJ	Liquid Dairy	Previous Fall (Early)	Not incorporated	76

Corn Yield Response to Nitrogen

Corn yield response to fertilizer N is based on machine harvested strips consisting of the header width of the commercial combine (6 or 8 30" rows) by a strip length of 300 to 450 meters (1000 to 1500 ft). All yield estimates are based on weigh wagon weights and adjusted to a moisture content of 15.5%.

A summary of the regression curve equations, fertilizer N rates that maximized yield, cv and statistical significance of yield response are presented in Table 4. Generally, the cv at the majority of the sites was less than 2% and never exceeded 10%; indicating that reliable estimates of corn nitrogen requirements were obtained at each of the sites. When estimates of Maximum

Economic Rate of Nitrogen (MERN) were not 0 (the linear regression coefficient exceeded 7.5), the yield response model was almost always statistically significant at the 5% probability level.

The regression analysis indicated that 3 sites did not have a yield response to nitrogen (Non-Responsive) (Table 4) and at another four sites the yield response was not large enough to economically justify fertilizer N application at a nitrogen:corn price ratio of 7.5 (Table 5). The various 29 sites were relatively productive with plateau (i.e. maximum) yields which averaged 10.3 Mg/ha with a range of 9.2 to 12.3 Mg/ha (Table 4). The maximum Economic rate of N (MERN) averaged 69 kg-N/ha with a range of 0 to 156 kg-N/ha (Table 5). The average

Table 4. Summary of yield response curve equation coefficients, statistical significance of regression model, goodness of fit (cv), and the fertilizer N rate which maximizes yield for the sites included in the evaluation of nitrogen use efficiency on livestock farms survey (2003-2005).

Site	Response Type	cv	Regression	Intercept	Linear	Quadratic	Maximum N Rate	Maximum Yield
			Pr>F	kg/ha			kg-N/ha	kg/ha
GHG-L2003-LASF	No Response	1.5	1.0000	11666	0.00	0	0	11666
GHG-L2003-LBWB	Curvilinear	2.9	0.0209	7515	30.38	-0.138333	110	9184
GHG-L2003-LDCD	Curvilinear	1.6	0.0461	9686	19.79	-0.149354	66	10341
GHG-L2003-LJHS	Curvilinear	2.0	0.0018	89	173.04	-0.733231	118	10299
GHG-L2003-LKBD	Curvilinear	4.8	0.0290	7996	36.12	-0.148936	121	10186
GHG-L2003-LLHB	Curvilinear	2.3	0.6780	8965	2.87	-0.009014	159	9194
GHG-L2003-LSBD	Curvilinear	3.2	0.0385	10435	27.67	-0.100874	137	12332
GHG-L2003-LTBD	Curvilinear	1.0	0.0010	7844	41.85	-0.282745	74	9392
GHG-L2003-LWJD	No Response	2.4	1.0000	9590	0.00	0	50	9590
GHG-L2004-L2AS	Linear	1.9	0.7141	11672	1.09	0	168	11856
GHG-L2004-L2CW	Curvilinear	2.4	0.0082	7906	32.38	-0.094607	171	10677
GHG-L2004-L2DC	Curvilinear	1.1	0.3367	9070	5.38	-0.045627	59	9229
GHG-L2004-L2DS	Curvilinear	3.8	0.0027	6183	55.65	-0.190165	146	10255
GHG-L2004-L2HV	Curvilinear	2.2	0.0009	6885	49.24	-0.170443	144	10441
GHG-L2004-L2JK	Curvilinear	4.6	0.0522	8790	29.54	-0.131883	112	10445
GHG-L2004-L2KB	Curvilinear	3.4	0.0174	7976	33.29	-0.151856	110	9800
GHG-L2004-L2LH	Curvilinear	0.8	0.0275	8692	27.01	-0.187551	72	9664
GHG-L2004-L2SE	Curvilinear	0.8	0.0007	8215	21.20	-0.094631	112	9402
GHG-L2004-L2WJ	Curvilinear	0.7	0.0372	10547	6.07	-0.0175	173	11073
GHG-L2005-L3AS	Curvilinear	3.2	0.0367	10387	26.67	-0.119075	112	11881
GHG-L2005-L3CW	Curvilinear	3.1	0.0382	10763	19.53	-0.058696	166	12387
GHG-L2005-L3DC	Curvilinear	4.2	0.0136	4844	152.07	-0.873947	87	11459
GHG-L2005-L3DS	Curvilinear	0.9	0.0001	4959	57.67	-0.160298	180	10145
GHG-L2005-L3GV	Curvilinear	3.8	0.0042	6490	46.41	-0.178127	130	9513
GHG-L2005-L3HV	Curvilinear	7.5	0.0350	6664	36.95	-0.105042	176	9914
GHG-L2005-L3KB	Curvilinear	1.1	0.0039	9813	12.24	-0.028715	213	11117
GHG-L2005-L3LH	Curvilinear	1.9	0.2794	9308	9.05	-0.039489	115	9827
GHG-L2005-L3SE	Curvilinear	1.3	0.0102	9431	14.51	-0.064796	112	10244
GHG-L2005-L3WJ	No Response	10.9	1.0000	9111	0.00	0	32	9111

+ Probability that regression model could be the result of random chance.

maximum economic yield was 10.2 Mg/ha with a range of 9.0 to 12.1 Mg/ha. The median reduction in fertilizer N rate from maximum to MERN rates at a price ratio of 7.5 across the 29 sites is 31 kg-N/ha with the MERN rate producing yields that averaged only 0.14 MG/ha (1.4%) less than the average plateau yield.

Table 5. Summary of maximum economic rate of nitrogen (MERN) and associated yield (MEY), fertilizer N recommendations with and without manure using OMAFRA General Recommendations and soil nitrate-N concentration in surface 30cm with associated Presidedress Soil Nitrate-N test recommendation for the sites included in the evaluation of nitrogen use efficiency on livestock farms survey (2003-2005). The MERN, MEY and OMAFRA general recommendations are based on a corn price of $132.00/Mg and a nitrogen cost of $0.99/kg-N (Nitrogen:Corn price ratio of 7.5).

Site	Manure	Maximum Economic		General Recommendation	
		N Rate	Yield	Without Manure	With Manure
		kg-N/ha	kg/ha	kg-N/ha	kg-N/ha
GHG-L2003-LASF	Cattle	0	11666	99	70
GHG-L2003-LBWB	Poultry	83	9082	91	52
GHG-L2003-LDCD	Cattle	41	10247	140	51
GHG-L2003-LJHS	Hog	113	10279	82	76
GHG-L2003-LKBD	Cattle	96	10091	76	23
GHG-L2003-LLHB	Poultry	0	8965	82	0
GHG-L2003-LSBD	Cattle	100	12192	82	27
GHG-L2003-LTBD	Cattle	61	9343	58	54
GHG-L2003-LWJD	Cattle	0	9590	106	49
GHG-L2004-L2AS	Cattle	0	11672	99	29
GHG-L2004-L2CW	Poultry	132	10528	99	17
GHG-L2004-L2DC	Cattle	0	9070	140	49
GHG-L2004-L2DS	Cattle	127	10181	95	95
GHG-L2004-L2HV	Hog	122	10359	105	75
GHG-L2004-L2JK	Hog	84	10338	112	31
GHG-L2004-L2KB	Cattle	85	9708	141	71
GHG-L2004-L2LH	Poultry	52	9589	71	0
GHG-L2004-L2SE	Hog	72	9253	54	33
GHG-L2004-L2WJ	Cattle	0	10547	103	41
GHG-L2005-L3AS	Cattle	81	11763	99	14
GHG-L2005-L3CW	Poultry	102	12147	93	77
GHG-L2005-L3DC	Cattle	83	11443	144	122
GHG-L2005-L3DS	Hog	156	10058	115	114
GHG-L2005-L3GV	Hog	109	9434	106	69
GHG-L2005-L3HV	Hog	140	9780	115	85
GHG-L2005-L3KB	Cattle	82	10627	99	42
GHG-L2005-L3LH	Poultry	20	9471	72	8
GHG-L2005-L3SE	Hog	54	10027	84	40
GHG-L2005-L3WJ	Cattle	0	9111	103	42

+ Soil nitrate concentration (surface 30 cm) was adjusted to an expected concentration for June 1 by linear interpolation of actual concentrations measured on May and June sample dates. Actual data is presented in Table 7.

Evaluation of the Accuracy and Profitability of Fertilizer N Prediction Methods
Accuracy and profitability of fertilizer N prediction methods were distinctly different at the various sites based on the manure type applied. Therefore, accuracy and profitability will be discussed by manure type applied. The site which received Preplant hog manure or the impact of sidedress dairy manure application on fertilizer N requirements of corn will be discussed separately and were not included in the general summary of results presented in Table 6.

Manure applied the previous fall or earlier
Corn response to fertilizer N was evaluated on 28 sites where the last manure application was the previous fall or earlier. The average fertilizer N requirement was 50 kg-N/ha on the 15 liquid cattle sites, 114 kg-N/ha on the seven liquid hog sites and 65 kg-N/ha on the six solid poultry sites (Table 6). When maximum economic N rates were applied, corn yields tended to be above historic averages with an average yield increase of 1.0 Mg/ha (11%) on the liquid cattle sites, 0.8 Mg/ha (9%) on the liquid hog sites and 1.4 Mg/ha (16%) on the solid poultry sites. The net return to maximum economic fertilizer N rates over the cooperator's starter rate (i.e. maximum potential return to sidedressed N) averaged $96.30/ha on the liquid cattle sites, $226.37/ha on the liquid hog sites and $53.39/ha on the solid poultry sites.

Accuracy of OMAFRA General Recommendations
Fertilizer N rates suggested by general recommendations without applying the manure credit averaged 105 kg-N/ha on the liquid cattle sites, 98 kg-N/ha on the hog sites and 85 kg-N/ha on the poultry sites (Table 5). The average suggested manure credit was 63 kg-N/ha on the liquid cattle sites, 36 kg-N/ha on the liquid hog sites (excluding the site where liquid hog manure was applied Preplant) and 74 kg-N/ha on the solid poultry sites (Table 3).

General recommendations on the liquid cattle sites suggested N rates which, on average, were similar to economic N rates (Table 6). In contrast, suggested N rates averaged 45 kg-N/ha less than requirements on the liquid hog sites and 39 kg-N/ha less than requirements on the solid poultry sites. Nitrogen rates suggested by general recommendations were less than actual requirement to economically optimize yield on all seven liquid hog sites and on five out of six solid poultry sites. On the liquid hog sites, under prediction of N requirements by general recommendations was often larger than the manure credit assigned to the application of manure. This suggests that the general recommendation model was probably recommending insufficient fertilizer N rates to optimize yields on the liquid hog sites, even when a manure credit was not applied or ignored.

Under prediction of N requirements resulted in average losses in potential yield of 0.3 Mg/ha (3%) on the liquid cattle sites, 0.7 Mg/ha (7%) on the liquid hog sites, and 0.5 Mg/ha (5%) on the solid poultry sites (Table 6). The yields produced by following recommended rates relative to maximum economic yield for the various sites are illustrated in Figure 1. Clearly, there is a tendency for yields on most of the liquid cattle sites to differ less from the maximum economic yield when compared to most of the liquid hog and solid poultry sites.

The highest financial liabilities (losses) associated with following general recommendations occurred on the liquid hog sites where the average loss in potential returns was $52.57/ha (Table

6). Liabilities for the liquid cattle and solid poultry sites were similar at about $30.00/ha;
potential economic yield, categorized according to the type of manure applied for the sites included in the evaluation of nitrogen use efficiency on livestock farms survey (2003-2005). The line represents the yield obtained if the Maximum Economic N rate was applied.

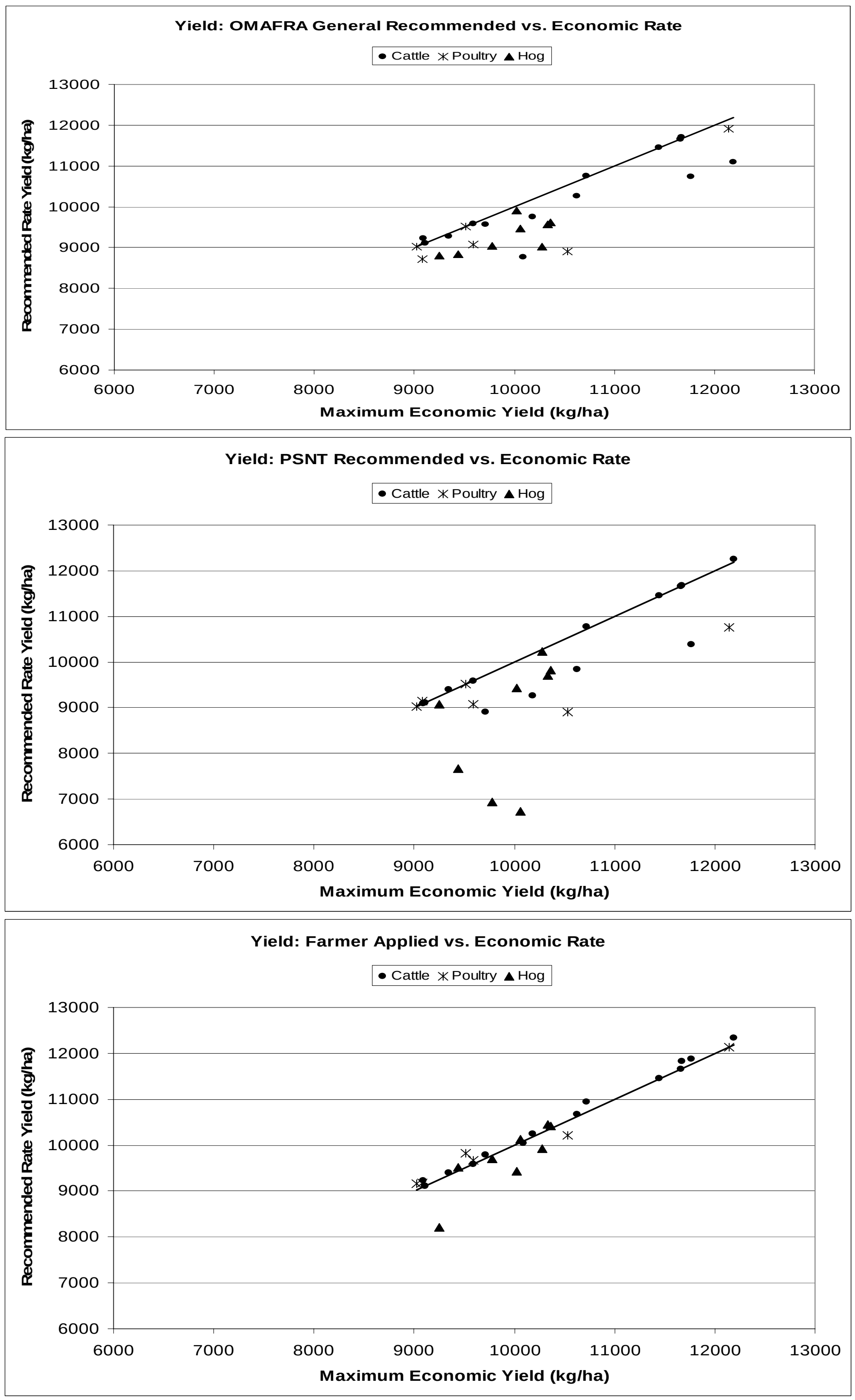


Figure 1. Grain corn yield associated with applying fertilizer N rates based on OMAFRA general recommendations, OMAFRA PSNT, or the co-operator fertilizer N rate, relative to the maximum

however, the liabilities were almost entirely due to loss of economically significant yield for the poultry sites whereas on the liquid cattle sites it was due to both loss of economically significant yield on some sites or application of rates of N that were not economically justified on other sites. The dollar return to applying N rates over the starter rates, relative to the maximum potential return, for the various sites is illustrated in Figure 2. There is a tendency for the liquid hog sites to have the largest difference between returns associated with recommended rates and maximum potential returns. Also, the liquid cattle sites have some sites with negative returns; suggesting that the cost of applying recommended rates of N on some sites was greater than the value of the corn yield increase associated with applying recommended N rates.

Accuracy of the Presidedress Soil Nitrate-N Test (PSNT)
On most sites, two spring sample dates were available, the first in mid to late May and another approximately 4 to 5 weeks later (June 5 to 22). Soil nitrate concentrations varied greatly among the various sites and sample dates, ranging between 11 to 40 ppm (Table 7). Ammonium concentrations were usually much less than nitrate concentrations, with less variability among sites and sample dates, with concentrations at most sites ranging between 1 to 5 ppm.

The PSNT recommendations were based on expected soil nitrate concentrations on June 1 (Table 5). At sites where two samples were available the estimated June 1 soil nitrate concentration was calculated using linear interpolation.. At sites with only one spring sample the actual nitrate concentration associated with the single sample date was used. The actual soil nitrate concentrations for the various sample dates used to derive the PSNT soil nitrate concentrations in Table 5 are presented in Table 7. The average soil nitrate-N concentrations on June 1 were estimated at 22 ppm for the liquid cattle sites, 18 ppm for the liquid hog sites and 26 ppm for the solid poultry sites.

The relationship between soil nitrate concentration and maximum economic N rate is illustrated in Figure 3. The line represents the PSNT calibration relationship between soil nitrate N and PSNT predicted maximum economic N rate. The liquid cattle sites tended to have less deviation between maximum economic N rates and the N rates suggested by the PSNT when compared to either the liquid hog or solid poultry sites.

The PSNT suggested N rates which were less than actual requirements at 6 out of 15 liquid cattle sites, all seven liquid hog sites and 4 out of 6 solid poultry sites (Table 6). The PSNT tended to suggest N rates that were less than general recommendations, with the difference between the two recommendations averaging 10 kg-N/ha on the solid poultry sites, 15 kg-N/ha on the liquid cattle sites and 20 kg-N/ha on the liquid hog sites.

The PSNT, on average, under predicted N requirements on the liquid hog sites by 64 kg-N/ha which resulted in an estimated loss in grain corn yield of 1.3 Mg/ha (13%) relative to when economic rates of N were applied (Table 6). The relationship between PSNT recommended N rate yield, relative to yields obtained when maximum economic N rates were applied for the various sites, are illustrated in Figure 1. As with general recommendations, the smallest differences in yield between the PSNT recommended and maximum economic N rates occurred on the liquid cattle sites, somewhat larger differences tended to occur in the solid poultry sites and the largest differences tended to occur in the liquid hog sites. Yield losses associated with

Table 6. Summary of nitrogen rates, associated yields, and economic returns averaged according to manure type applied for actual experimentally determined fertilizer nitrogen requirements, OMAFRA general fertilizer nitrogen recommendations, OMAFRA presidedress soil nitrate-N test (PSNT) recommendations and the fertilizer N rates that the co-operator farmers applied to corn surrounding the experimental area for the sites included in the evaluation of nitrogen use efficiency on livestock farms survey (2003-2005). Maximum Economic Rate of N, OMAFRA General Recommendations, and economic return calculations are based on a corn price of $132.00/Mg and a nitrogen cost of $0.99/kg-N (Nitrogen:Corn price ratio of 7.5).

Parameter	Cattle	Hog	Poultry
Total Observations	15	7	6
Historic Site Yield (kg/ha)+	9479	9112	8572
Maximum Economic N Rate (kg-N/ha)	50	114	65
Maximum Economic Yield (kg/ha)	10496	9929	9980
Maximum Potential Return ($/ha)	90.30	226.37	53.59
OMAFRA General Recommendation			
Sites Under Recommended	7	7	6
Recommended N Rate (kg-N/ha)	52	69	26
Average Under Recommendation (kg-N/ha)	1	-45	-39
Probability difference=0	0.9072	0.0001	0.0658
Yield at Recommended Rate (kg/ha)	10221	9194	9524
Estimated Yield Loss (kg/ha)	275	734	456
Return ($/ha)	60.01	173.80	24.67
Net Loss ($/ha)	30.30	52.57	28.92
OMAFRA PSNT			
Sites Under Recommended	6	7	4
Recommended N Rate (kg-N/ha)	36	50	16
Average Under Recommendation (kg-N/ha)	-14	-64	-49
Probability difference=0	0.2455	0.0156	0.0895
Yield at Recommended Rate (kg/ha)	10132	8594	9402
Estimated Yield Loss (kg/ha)	363	1335	577
Return ($/ha)	62.88	112.84	14.47
Net Loss ($/ha)	27.42	113.54	39.12
Co-operator Rate			
Sites Under Applied	1	3	2
N Rate (kg-N/ha)++	117	133	112
Average Under Application (kg-N/ha)	62	1	44
Probability difference=0	0.0003	0.9714	0.1286
Yield at Applied Rate (kg/ha)	10569	9762	10026
Estimated Yield Loss (kg/ha)	-73	167	-47
Return ($/ha)	41.22	184.94	17.20
Net Loss ($/ha)	49.08	41.44	36.38

+ Historic or expected corn yield

++Actual requirement for farm rate comparisons were adjusted to Preplant rate equivalents for sites where farm applied N rates were applied Preplant. The adjustment was based on the assumption that Preplant availability is 80% of sidedress on loam and silt loam soils, 90% on sandy loam and sandy clay loam soils and 100% on sand and loamy sand soils.

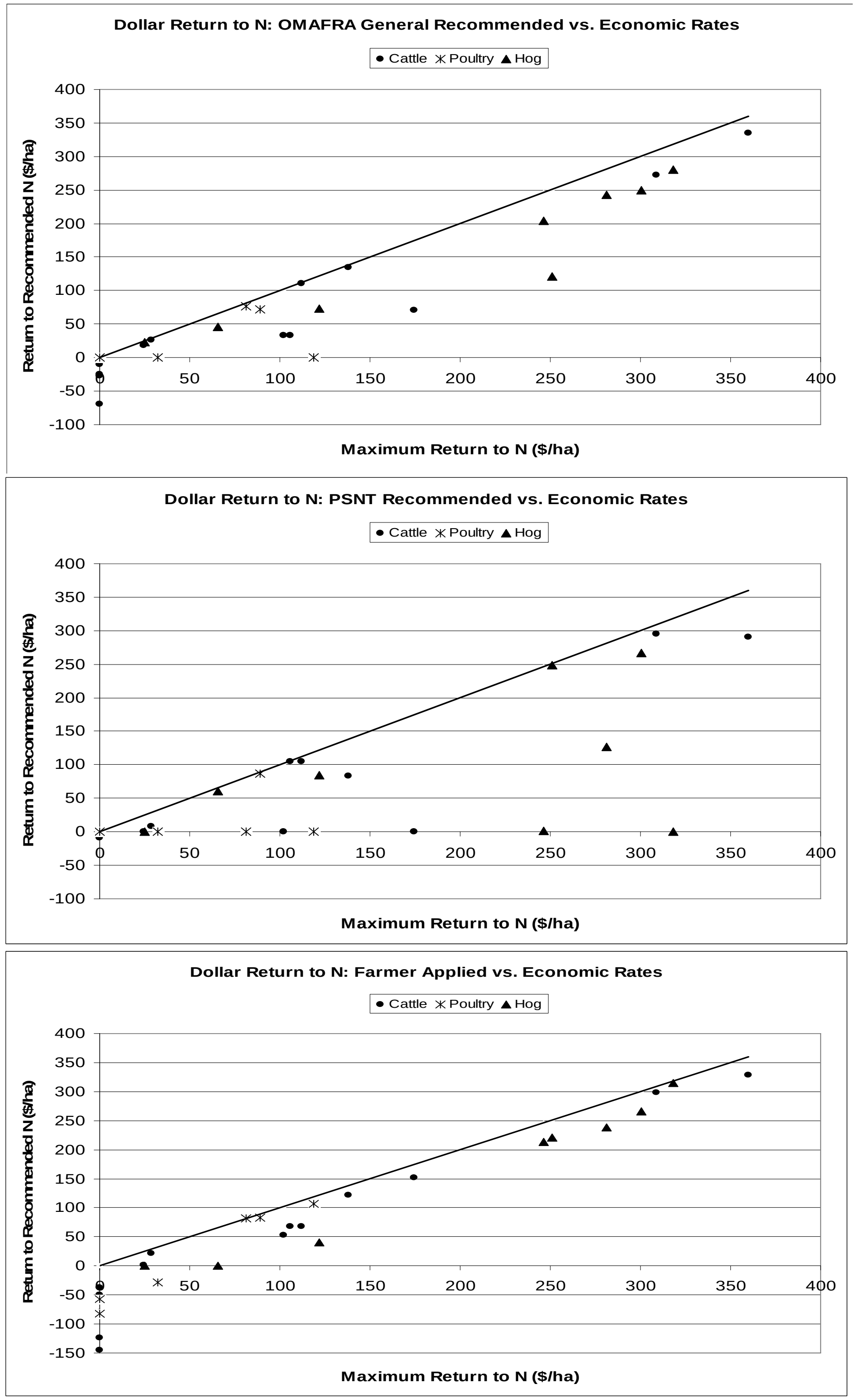


Figure 2. Economic return associated with applying N rates based on OMAFRA general recommendations, OMAFRA PSNT, or the co-operator fertilizer N rate, relative to the maximum potential economic return, categorized according to the type of manure applied for the sites included in the evaluation of nitrogen use efficiency on livestock farms survey (2003-2005). The line represents the maximum economic return obtained if the Maximum Economic N rate was applied.

following PSNT recommendations, instead of general recommendations, were marginally larger on the liquid cattle and solid poultry sites with average yield losses, relative to maximum economic yields, of 0.4 Mg/ha (4%) on the liquid cattle sites and 0.6 Mg/ha (6%) on the solid poultry sites.

The PSNT recommendations were associated with the least liabilities (losses relative to maximum potential returns) on the liquid cattle sites (Table 6). In fact, estimated liabilities using the PSNT were about $2.90/ha less than liabilities estimated for general recommendations; most of which could be attributed to the PSNT correctly identifying sites that did not need additional N (or at least recommending less N than general recommendations). The relationship between returns associated with PSNT recommended and maximum economic N rates are illustrated in Figure 2. As with general recommendations, the smallest differences between PSNT and maximum potential returns tended to occur on the liquid cattle sites, with the largest differences occurring on the liquid hog sites. On average, PSNT liabilities were $113.54/ha on the liquid hog sites; which were more than two times greater than the liabilities associated with applying general recommendation N rates. The increase in PSNT liability for the solid poultry sites was not as great, averaging $10.20/ha over the liability associated with applying the general recommendation rates.

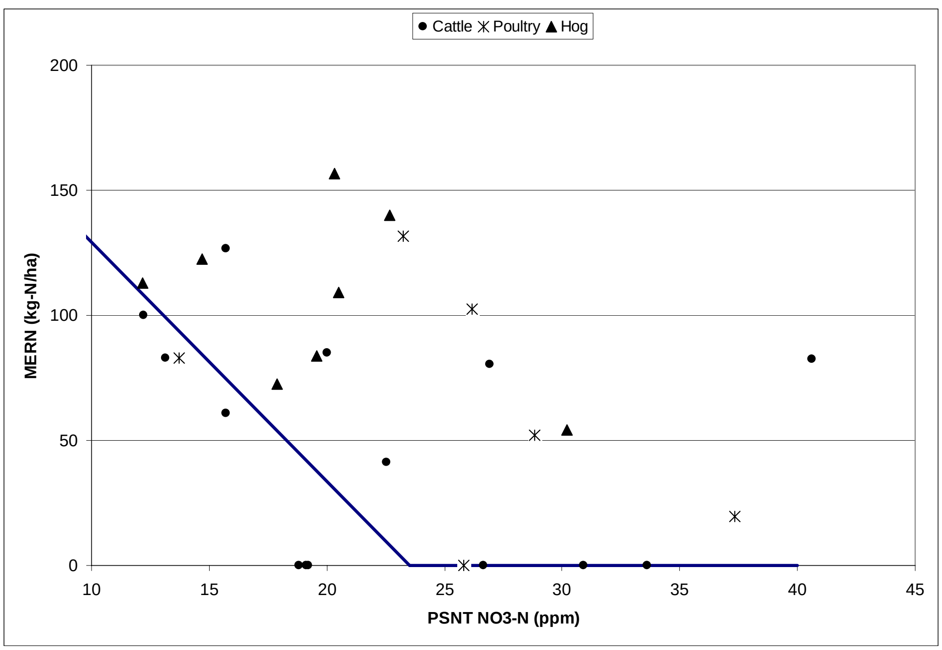


Figure 3. Relationship between June soil nitrate N concentrations in the surface 30cm and Maximum Economic fertilizer N rate categorized by manure type. The line represents the fertilizer N requirement as a function of soil nitrate N as recommended by the Presidedress Soil Nitrate-N test for the sites included in the evaluation of nitrogen use efficiency on livestock farms survey (2003-2005).

Assessment of Cooperator Fertilizer N Rates
Cooperator N rates were usually significantly higher than rates suggested by either the general recommendations or the PSNT. On average, cooperator rates were 117 kg-N/ha on the liquid cattle sites, 133 kg-N/ha on the liquid hog sites and 112 kg-N/ha on the solid poultry sites. Cooperator rates tended to exceed economic requirements with under application occurring on only one liquid cattle site, 3 liquid hog sites and 2 solid poultry sites. On average, the estimated rate of over application was 62 kg-N/ha on the liquid cattle sites, 1 kg-N/ha on the liquid hog sites and 44 kg-n/ha on the solid poultry sites.

The cooperator rates tended to produce yields that usually did not differ from the maximum economic rates (table 6) indicating that the N rates applied are at, or at least very close, to the N rate that will maximize yields. The relationship between yields produced using cooperator N rates vs. maximum economic rates are illustrated in Figure 1. Clearly, most of the yields obtained using cooperator rates did not deviate far from the yield obtained using the most economic rates.
However, maximizing yields does not necessarily mean that profits are maximized. On the liquid cattle sites, profits associated with applying cooperator rates were about $20.00/ha less than if either OMAFRA general recommendation or PSNT rates were applied (Table 6). This loss of profit was due to the application of fertilizer N at rates that were above those required to maximize returns. In contrast, the cooperator rates on the liquid hog sites were associated with lower losses compared to using either OMAFRA general recommendations or the PSNT rates because the cooperator rates were usually closer to the actual rates required. On the solid poultry sites, applying cooperator rates was associated with losses that averaged slightly higher than those estimated when general recommendation rates were applied and slightly lower when PSNT rates were applied. The relationship between returns based on cooperator and maximum economic returns is illustrated in Figure 2.

Preplant hog manure
Liquid hog manure was applied on 1 site (GHG-L2005-L3SE) in 2005 (Table 3). The manure was incorporated within 1 day with an estimated available N content of 56 kg-N/ha. Fertilizer requirements to economically optimize yield at a price ratio of 7.5 was 54 kg-N/ha producing a yield of 10.0 MG/ha with a net maximum return to applied N of $25.11/ha. The N rate suggested by OMAFRA general recommendation with manure credit was 40 kg-N/ha (16 kg-N/ha less than the actual requirement to economically optimize yield) with a loss in return relative to the maximum potential of $1.77/ha.

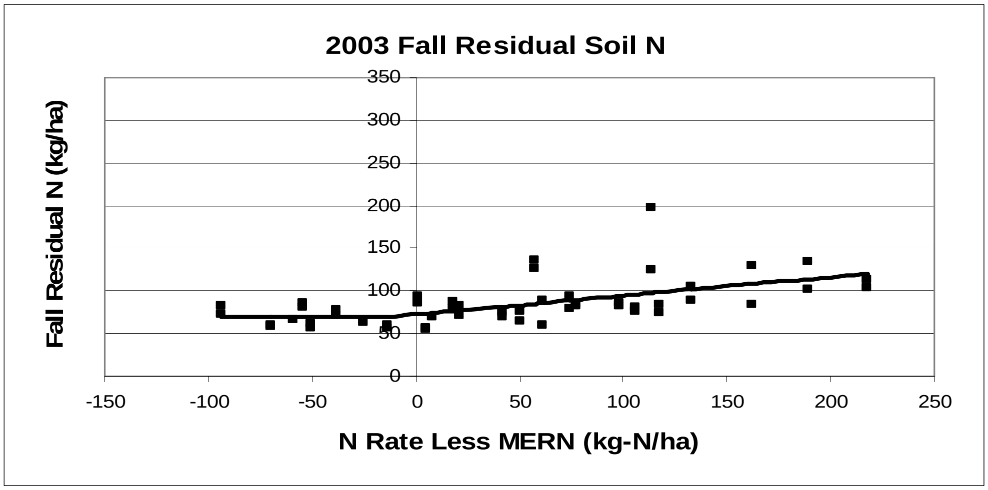
Early June soil nitrate-N concentration in the surface 30cm was 30 ppm and as a consequence additional fertilizer N would not be recommended (Table 5). However, since the PSNT is designed not to be used soon after significant application of N, PSNT recommendations probably have little meaning at this site and should be ignored.

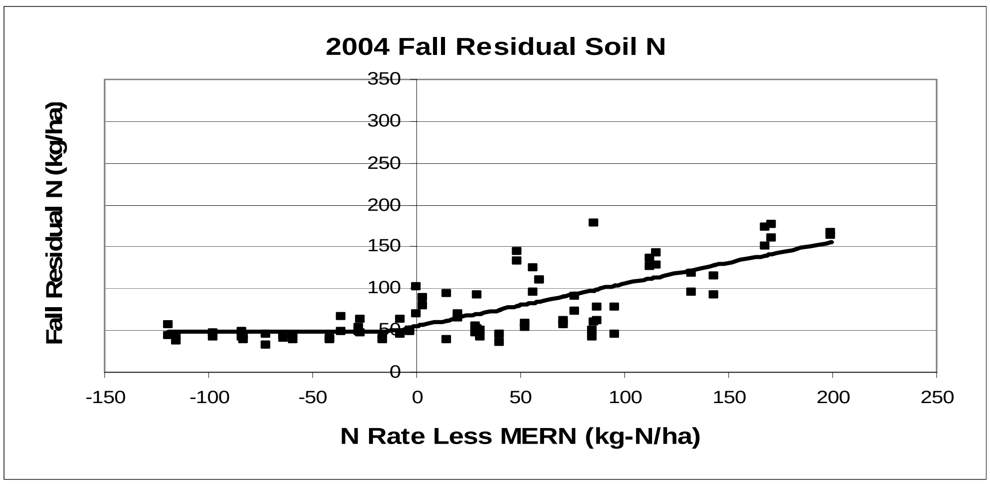
The cooperator indicated that he would normally not be applying nitrogen fertilizer following spring application of liquid hog manure (Table 2). In this case, applying the OMAFRA general recommendation suggested rate would have improved net profits by $23.33/ha, which is about 90% of the maximum potential return to applied N at this site.

Sidedressed Liquid Cattle Manure
Sidedress liquid cattle manure was evaluated at one site (GHG-L2004-L2DS). The site did not receive manure in the previous 3 years (Table 3) and had a site requirement of 146 kg/ha of fertilizer N to maximize yield (Table 4) and 127 kg/ha of fertilizer N to economically optimize yield at a nitrogen:corn price ratio of 7.5 (Table 5). On the fertilizer N response plots, sidedress manure was not applied. The yield when optimal fertilizer N was applied was 10.2 Mg/ha. Fertilizer N recommendations for the site, without the addition of sidedress manure, was 95 kg-N/ha using OMAFRA general recommendations and (economic loss associated with general recommendations was $24.45/ha) and 74 kg-N/ha using the PSNT (economic loss associated with PSNT recommendations was $69.70/ha).

Sidedress manure was applied in mid-June into standing corn at an application rate which delivered 149 kg-N/ha of plant available N; a N rate which should have been more than sufficient to optimize yields. The yield obtained with sidedressed manure averaged 11.2 Mg/ha, or 1.0 Mg/ha (10%) over the maximum economic yield obtained with fertilizer application. Higher yields with manure application probably were not due to nutrients other than the N applied with the manure since plant available P was 68 ppm and soil-test K was 206 ppm; soil test values which clearly indicate that neither P nor K was limiting to yield potential at this site. The yield response to applied manure was 4.6 kg-N/ha over where manure or fertilizer N was not applied with a gross value of $607.20/ha ($132.00/ha). If it is assumed that conducting sidedress manure application is $25.00/ha more than applying fertilizerN and the value of fertilizer N to optimize yields at this site is $125.73/ha (127 kg-N/ha @ $0.99/kg-N), then the net economic benefit of the sidedress manure at this site was $707.93/ha (assuming a manure value of $0.00 since it is a resource which needs to be disposed of anyway and its cost should be assessed to the livestock budgets).

Assessment of Fall Residual N
Application of fertilizer N in excess of crop requirements can lead to higher soil N concentrations at the end of the growing season. Figure 4 illustrates the trend in post-harvest soil N concentrations as the fertilizer rate applied exceeds the requirements for each year of this study. On the fertilizer rate strips where the fertilizer N rate applied was less than the economic requirement (the negative rate applied values), soil mineral N concentrations remained relatively constant, averaging about 50 to 70 kg/ha of residual soil nitrate N in the surface 30 cm for each of the 3 years (Fig. 4). Soil residual N levels started to increase when application rates of N exceeded the maximum economic N rate. On strips where fertilizer application exceeded economic requirements, the average mineral N content in the surface 30cm increased from 50 to 70 kg/ha to 125 to 175 kg-N/ha. Clearly, application of fertilizer N in excess of economic requirements contributes to greater soil N concentrations at the end of the growing season. This residual soil N is subject to environmental losses, including conversion to Greenhouse Gasses and/or leaching depending on soil type and various other factors.





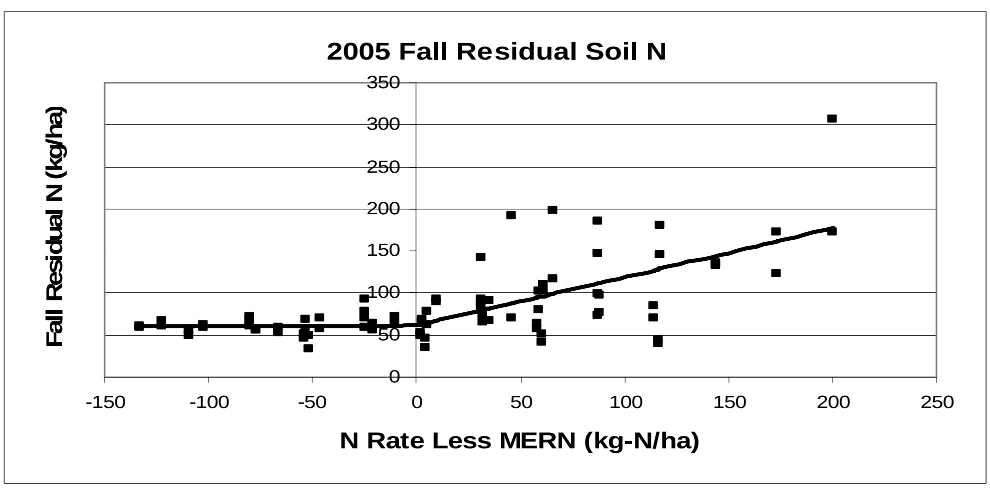


Figure 4. The effect of applying fertilizer nitrogen rates over MERN on fall residual soil nitrogen in the surface 30 cm for the sites included in the evaluation of nitrogen use efficiency on livestock farms survey (2003-2005).

Hog Manure Sidedress Activities

Two additional components of this project included a single day side dressing liquid hog manure demonstration conducted near Fullarton Ontario in June of 2005. The other component was an extensive side dressing manure study conducted by Dr. Bill Deen and his team near Drayton Ontario during the period 2003 through 2005.

Demonstration Day

The Fullarton Ontario hog manure demonstration day profiled 6 different tanker based side dress manure systems applying manure to 8-10 leaf corn. Units demonstrated included:
Houle Tanker with Manure Cover Dicks
Bodco Tanker with Aerway Injector
Huskey Tanker with TillTech Injector
Nuhn Tanker with Yetter Injectors and two trench closing attachments

Approximately 50 people attended this one day session to view the equipment in operation with hog manure being applied. Target rates were 4000 USgal/ac for all the equipement. Those attending witnessed the equipment in operation and viewed the incorporation, placement, tramping and other factors associated with the application. The systems demonstrated differed widely in the amount of soil disturbance, placement of the manure, covering of the manure and time required for exposed manure to absorb into the soil. The various incorporation equipments showed widely varying ability to incorportate and/or cover the applied manure. On the Nuhn unit with different closing attachments, it was obvious that straight injecting of the manure without some form of row covering was not as effective in hiding raw manure from exposure to air which could lead to odours and loss of ammonia. Dr. Dean Barry from the Land Resource Science Department of the University of Guelph setup ammonia traps in each units application area following the side dressing operation. Although this was an unreplicated single day demonstration it was interesting to see the differences in ammonia detected as evolving off the manure application from the different systems (Figure 5.). Those that resulted in complete covering or burial of the applied manure (Figure 6 and 7) had lower levels of ammonia detected.

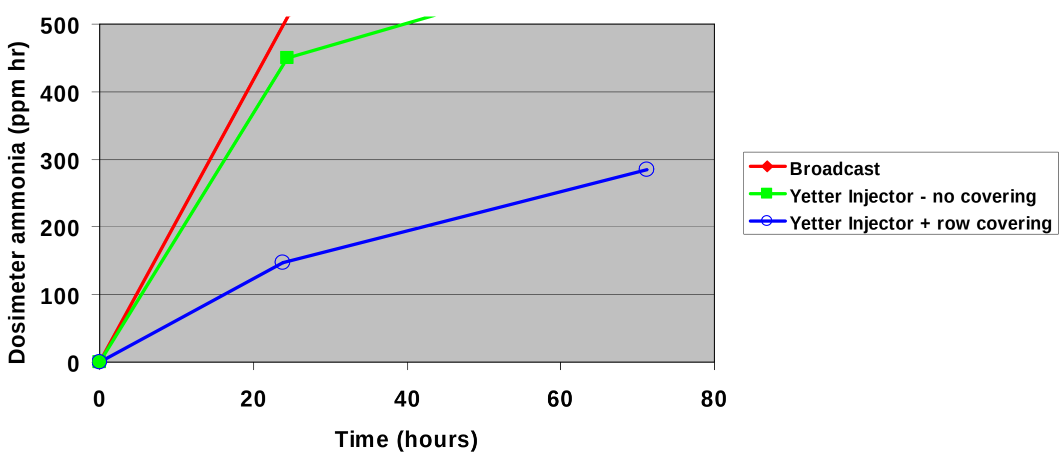


Figure 5. Ammonia Volatilation from Various Injection/Trench Closure Attachements

Figure 6. Various Row Closure Attachments on a Yetter Manure Injector

Figure 7. Example of Injector/Row Closure Options Available for Side Dress Manure Application

Three Year Side Dress Hog Manure Study

In this study, the University of Guelph team worked with a producer in the Drayton area of Ontario who was having excellent success with using side dress manure. Two rates of side dress manure application where chosen in each year and compared to various rates of side dress applied commercial N fertilizer as urea ammonium nitrate.

At the Drayton site corn response to side-dressed liquid hog manure was compared to four rates of UAN using the following treatments replicated three times:

1 Manure check - 0 gal/ac (Nuhn tank with injectors ran through the plot)
2 Manure - 2000 gal/ac (107 kg available N/ha)
3 Manure - 4000 gal/ac (215 kg available N/ha)
4 Check
5 UAN - 60 kg N/ha
6 UAN - 120 kg N/ha
7 UAN - 180 kg N/ha
8 UAN - 240 kg N/ha

Manure treatments were made June 28 using a Nuhn liquid manure tank with in-tank agitation and equipped with a Nuhn Row-Crop Injector. At the time of application the corn was approximately 50cm in height. UAN treatments were applied June 29.

Results:

- In-row soil bulk densities measured at 5cm and 20cm depth were not increased as a result of traffic by the liquid manure tank (data not shown)
- Soil nitrate levels of both the 2000 and 4000 USgal/ac manure treatments measured post harvest (November 10) were comparable to soil nitrate levels associated with UAN applications of 60-180 kg N ha/ha.
- Available nitrogen in liquid hog manure was equivalent to nitrogen from UAN (Figure 8) in terms of corn yield response

Figure 8 Corn Yield Response To UAN And Liquid Hog Manure (0, 2000, And 4000 Gallons/Ac) Applied At The Knee-High Stage, Wellington County, 2004

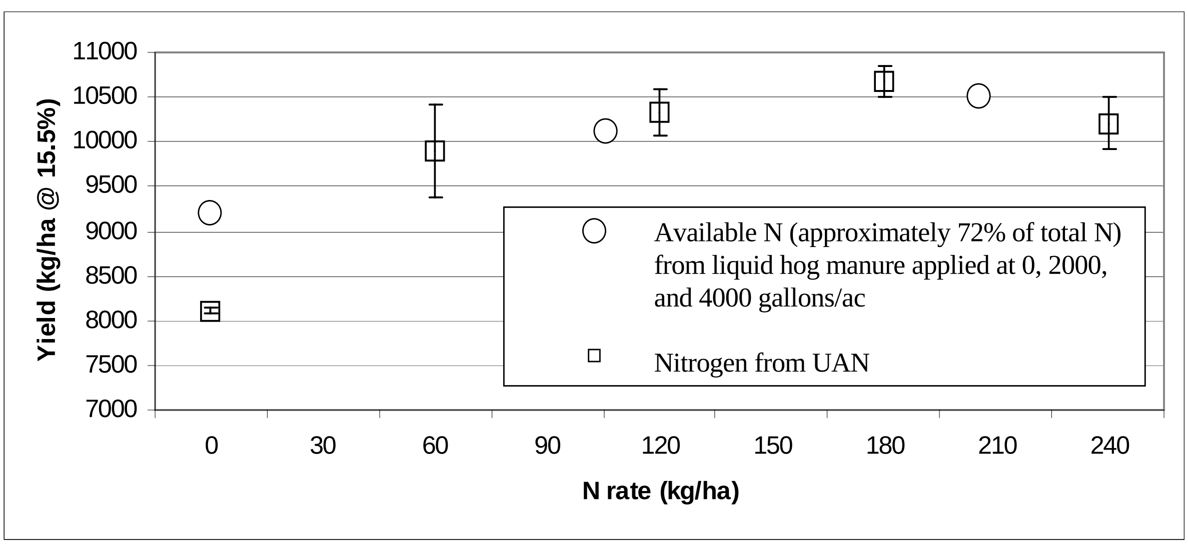


Table 7. Corn Yield, N Equivalence and Available N Associated with Sidedress Hog Manure Rates.				
Treatment	**Year 2005**			
	Rate (gal/ac)	**Available N (kg/ha)**	**Fertilizer Equivalent N (kg/ha)**	**Grain Yield (t/ha)**
Manure 1	2526	122	149+	10.29
Manure 2	5266	255	149+	10.27

Table 7 shows that the nitrogen needs of a corn crop can be met solely with side dress manure applications as evidenced by the corn response to manure and variable rates of fertilizer N compared in this study. Side dressing manure into a standing corn crop results in better utilization of applied manure since it is applied during the period preceding rapid N accumulation in the corn plant. Available N is not added to the system during the early part of the season when soil compaction, denitrification, leaching and other factors may contribute to reduced availability of manure N and loss in N use efficiency as a result.

Conclusions

All years of the main livestock project study clearly demonstrated that applying fertilizer nitrogen in excess of crop requirements will result in significantly higher soil mineral N levels at the end of the growing season. The majority of nitrogen left over in the soil at the end of the growing season is susceptible to environmental losses, including conversion to greenhouse gases and/or leaching.

Nitrogen rates suggested by either OMAFRA general recommendations or the PSNT were most accurate and associated with the least liability following liquid cattle manure. Conversely, both methods under predicted requirements on sites which received recent liquid hog manure with the PSNT in particular resulting in unacceptably high economic losses due to under application of fertilizer N. The poultry sites also were under recommended by both methods, but the economic losses attributed to applying recommended rates were not as great as the liquid hog sites and comparable to the liquid cattle sites.

On average, cooperator application rates were greater than those suggested by both OMAFRA General Recommendations and the PSNT. The largest over application of fertilizer N by cooperating farmers tended to occur on the liquid cattle sites, with economic returns which averaged $20.00/ha less than those obtained using recommended rates. In contrast, the cooperator rates on the liquid hog sites were associated with substantially lower economic losses when compared to those obtained using either OMAFRA general recommendations or the PSNT rates, mainly because both general recommendations and the PSNT severely under predicted N requirements. The reason for under prediction on the liquid hog sites is not clear, but since both methods under predicted the requirements, it suggests that these sites had less than average capacity to mineralize N from natural sources. Further research may be warranted to assess the accuracy of current recommendation methods on fields regularly receiving liquid hog manure and, if necessary, determine how to adjust fertilizer nitrogen recommendations following the application of liquid hog manure. There also was a tendency for under prediction of N requirements on the solid poultry sites and further research may be warranted to assess current recommendation methods following poultry manure and, if necessary, make the appropriate changes to improve accuracy.

To date, this project has demonstrated that failure to reduce fertilizer N rates on livestock farms where actual requirement for fertilizer N is low will result in unacceptable high levels of residual soil mineral N at the end of the growing season. Unfortunately, it also called into question the ability of both the OMAFRA general recommendations and the PSNT to accurately predict N requirements on fields that recently received liquid hog manure and, to a lesser extent, those that recently received solid poultry manure. There is a need to continue to evaluate and refine fertilizer N recommendation methods so that a more accurate N recommendation is provided; especially when liquid hog or poultry manure was recently applied.

Properly calibrated general recommendations and/or PSNT will improve the economic returns of corn grown where manure was recently applied and will reduce the quantity of residual soil mineral N remaining at the end of the growing season. This will minimize the likelihood of soil N loss to the environment, including minimizing the production of Greenhouse Gasses and reduce leaching losses.

The demonstrations of side dress manure application showed that corn N requirements in their entirety can be met with in crop applied side dress manure. Various systems of equipment are available to efficiently apply side dress manure into standing corn without causing detrimental soil compaction or other negative effects. Where the side dress manure can be incorporated to reduce ammonia losses, significant reductions in odour and ammonia loss can be achieved which reduces neighbor complaints, GHG emissions and economic losses associated with volatilized ammonia that could otherwise by utilized by the corn crop.

Table 8. Summary of average spring soil ammonium and nitrate N concentrations in the surface 30 cm on available May and June sample dates for the sites included in the evaluation of nitrogen use efficiency on livestock farms survey (2003-2005).

	Mid to Late May						June					
Site	**Date**	**Samples**	**Nitrate**		**Ammonium**		**Date**	**Samples**	**Nitrate**		**Ammonium**	
			Average	**Std. Dev.+**	**Average**	**Std. Dev.+**			**Average**	**Std. Dev.+**	**Average**	**Std. Dev.+**
			ppm						**ppm**			
GHG-L2003-LASF-SD	May 30	16	32.1	6.80	2.1	0.55	June 12	16	42.0	8.81	2.2	0.55
GHG-L2003-LBWB-SD	May 22	12	12.1	1.76	1.7	0.61	June 16	12	16.2	2.94	2.5	1.11
GHG-L2003-LBWB-PP	May 22	3	11.8	0.29	1.7	0.65	June 16	3	12.6	1.34	2.3	0.21
GHG-L2003-LDCD-SD	May 29	12	21.6	2.89	1.4	0.36	June 18	12	27.7	4.63	1.0	0.23
GHG-L2003-LJHS-SD	May 19	16	12.2	1.66	3.9	0.59	July 10	8				
GHG-L2003-LKBD-SD	May 28	15	19.6	2.10	2.6	0.54		0				
GHG-L2003-LLHB-SD	May 19	16	25.7	4.02	2.1	0.56	June 17	16	25.9	5.08	3.0	0.65
GHG-L2003-LSBD-SD	May 19	16	11.3	2.09	2.5	0.79	June 20	15	13.6	2.49	2.1	0.53
GHG-L2003-LTBD-SD	May 19	16	14.5	1.32	3.8	1.33	June 17	16	17.2	2.26	1.9	1.14
GHG-L2003-LWJD-SD	May 23	20	17.7	2.99	2.0	0.79	June 20	20	22.3	3.66	1.4	0.41
GHG-L2004-L2AS-SD	May 12	12	26.1	5.57	1.6	0.30	June 22	12	27.2	2.83	17.5	28.78
GHG-L2004-L2CW-SD	May 17	12	21.5	11.46	3.6	2.54	June 11	12	24.5	4.61	3.4	0.91
GHG-L2004-L2DC-SD	May 14	12	31.6	5.97	0.6	0.11	June 30	12	29.9	5.67	0.6	0.25
GHG-L2004-L2DS-SD	May 17	12	12.5	3.79	4.4	1.06	June 10	12	17.7	4.60	4.6	1.91
GHG-L2004-L2DS-SD	May 17	12	12.5	3.79	4.4	1.06	June 10	12	17.7	4.60	4.6	1.91
GHG-L2004-L2HV-SD	May 20	12	11.3	1.95	3.5	0.78	June 11	12	17.5	2.31	2.1	0.67
GHG-L2004-L2JK-SD	May 20	12	16.8	3.29	4.2	1.02	June 14	12	22.5	3.80	3.4	1.47
GHG-L2004-L2KB-SD	May 11	12	14.5	1.65	3.2	0.83	June 11	16	22.6	2.88	3.4	1.11
GHG-L2004-L2LH-SD	May 11	12	23.1	4.82	4.3	0.96	June 14	3	32.4	8.26	3.0	1.19
GHG-L2004-L2SE-SD	May 18	12	14.2	2.74	2.5	0.90	June 11	12	20.5	2.48	3.0	2.13
GHG-L2004-L2WJ-SD	May 13	12	12.6	1.68	2.6	0.62	June 21	12	25.4	5.54	1.4	0.91
GHG-L2005-L3AS-SD	May 20	12	21.1	4.45	2.6	2.82	June 05	12	28.9	3.69	2.3	2.09
GHG-L2005-L3CW-SD	May 17	12	24.2	2.98	2.7	1.16	June 13	12	27.8	3.62	2.8	0.39
GHG-L2005-L3DC-SD	May 20	12	12.0	4.65	2.9	1.88	June 22	12	15.2	2.91	2.3	1.18
GHG-L2005-L3DS-SD							June 09	12	20.3	2.71	2.4	0.32
GHG-L2005-L3GV-SD	May 19	12	17.6	3.59	4.0	2.74	June 13	12	23.2	2.99	2.5	0.46
GHG-L2005-L3HV-SD	May 16	12	25.0	6.89	3.4	3.90	June 13	12	20.9	2.47	2.1	0.47
GHG-L2005-L3KB-SD							June 14	12	40.6	10.40	1.8	1.22
GHG-L2005-L3LH-SD	May 13	12	32.4	3.48	1.5	0.28	June 14	12	40.7	6.73	2.0	1.14
GHG-L2005-L3SE-SD							June 08	12	30.2	7.28	2.0	0.47
GHG-L2005-L3WJ-SD	May 12	12	20.5	3.99	1.2	0.35	June 06	12	18.9	1.54	1.3	0.60

standard deviation of the mean