Project title: Long-term effect of nitrogen rates on in corn – 2010 Interim Report

Researchers: Bill Deen, Ken Janovicek (Department of Plant Agriculture), John Lauzon (School of Environmental Science), Greg Stewart (Ontario Ministry of Agriculture, Food and Rural Affairs).

Contact:
Bill Deen, Associate Professor, Cropping Systems
Department of Plant Agriculture
University of Guelph
50 Stone Rd, Guelph, Ontario N1G 2W1
(519)824-4120 x53397
(519)823-3455 (cell)
(519)763-8933 (fax)
bdeen@uoguelph.ca

Date: January 21, 2011

Executive Summary

This report summarizes results from year 2 of a 10 year field trial designed to evaluate long-term effect of timing and rate of fertilizer N on grain corn yield and associated economics. The trial also evaluates the long-term impact of duration (over years) of various fertilizer N rates on corn yield potential, natural N supply and soil organic matter levels. The 2010 growing season represented the second year that the various N rate treatments were imposed on this trial. Any economic results in this summary are based on grain corn price of $189/Mg ($4.80/bu) and N cost of $1.32/kg-N ($0.60/lb-N) (Nitrogen:Corn price ratio=7).

Timing of fertilizer N application (preplant or sidedressed 1 month later) affected fertilizer N requirements in 2010 with sidedress applications associated with 75 – 90% less fertilizer N to attain maximum economic yields. The duration of fertilizer N rates also impacted fertilizer N response to timing of application with corn response where the N rates were applied for 2 consecutive years requiring 75% of the preplant rate to attain maximum economic yields. When previous year's N application was uniform, MERN was 219 kg-N/ha for preplant and 198 kg-N/ha for sidedress with maximum economic yield estimated at 10.9 Mg/ha. Economic fertilizer N rates were about 40 kg-N/ha higher in 2010 when compared to 2009.

Fertilizer N requirements in 2010 were about 75 kg-N/ha higher than recommended by general recommendations based on a 10 Mg/ha yield goal for a silt-loam soil in a 2650 CHU area following grain corn. Soil N test recommendations for 2010 were about 95 kg-N/ha less than required for preplant and 60 kg-N/ha for sidedress in 2010. Applying recommended N rates in 2010 would have resulted in significant economic losses estimated at between $90/ha to $190/ha. When more site years of data are available from this site, attempts to correlate fertilizer N requirements to weather events will be conducted to determine if recommendation models can be improved based on known, and perhaps, anticipated weather events or trends.

The 218 kg-N/ha N rate produced the highest observed corn N uptake with an apparent fertilizer N recovery of about 50%. Applying the recommended N rate (145 kg-N/ha was associated with an apparent fertilizer N recovery of 59%. Grain yield increase per unit of N applied over the 30 kg-N/ha starter rate associated with application of the Maximum Economic N Rates (MERN) was

28 kg-grain/kg-N for preplant and 30 kg-grain/kg-N for sidedress (when the same N rate was applied the previous year). Applying non-N limited rates, over the starter rate of 30 kg-N/ha, increased potential yield by a factor of about 2.0 and total plant and grain N uptake by a factor of 2.4 and 2.6, respectively.

Introduction and Description of Production Practices

A long-term trial was initiated at the Elora Research Station, Elora ON CA to evaluate the effect that duration (over years), timing of application (Preplant and sidedress) and rate of nitrogen fertilizer has on long-term corn productivity. The 2010 year represents the second year where the various N treatments were imposed. The trial is designed to evaluate corn grain yield response, and associated economics, to duration (over years), rate and timing of fertilizer N application. The fertilizer N treatments were duplicated so that the same application rate and timing combination is applied on some plots for the entire duration of the trial and on other plots the fertilizer N rate treatments are applied on plots which received 145 kg-N/ha the previous year. Comparison of the continuous (long-term) fertilizer N treatments to those imposed on plots with uniform 145 kg-N/ha application the previous year will enable the evaluation of long-term effects of various fertilizer N application rates and timings on organic matter levels, natural N supply and corn yield response. This was the second year that N timing and rate treatments were imposed on this trial, so results for the plots in 2010 which received continuous fertilizer N rates had the same fertilizer N rates applied for the second consecutive year in 2010.

2010 production practices:

Previous Crop: Grain Corn

Tillage: Fall Chisel plow with spring secondary tillage

Corn: Pioneer 38B14 planted in 0.76 m rows on May 4 at 79,000 seeds/ha

Fertility: On April 29 40 kg-P_2O_5/ha as 0-46-0 and 60 kg-K_2O/ha as 0-0-60 was broadcast applied and incorporated just prior to planting using a field cultivator.

Starter 200 kg/ha 15-15-15-2Zn starter was banded through planter 5 cm beside, 5 cm below seeding depth (Nutrient rates of 30 kg/ha of N, P2O5 and K2O plus 4 kg-Zn/ha).

Early application timing (Preplant) of N was banded mid-row as UAN on May 13 at treatment related rates of 0, 28, 57, 115, 188, and 230 kg-N/ha.

The late application timing (sidedress) was June 18 with N application treatments that were the same as described for the early date.

Site Fertility

Soil fertility sampling to a depth of 15 cm was taken prior to corn planting on April 15. The results are presented in Table 1. The site in 2009 has soil test P and K levels that are in the medium range and efforts will continue in 2011 to increase P and K fertility at this site.

Soil ammonium and nitrate concentrations in the surface 30cm for the May 7 and June 14 sample dates were not affected by the length of time (duration) that fertilizer N treatments had been imposed (data not shown). Site average spring soil NO_3-N concentration in the surface 30cm for the preplant sample date (May 7) was 8.1ppm (Standard Error=0.28, Sample Number=37) and for the PSNT sample date (June 14) soil nitrate-N concentration was 9.0 ppm (Standard Error=0.29, Sample Number=40). Soil NO_3-N test recommendations for Ontario are 124 kg-N/ha for the Preplant sample and 139 kg-N/ha for the Presidedress sample. The 2010 spring soil nitrate-N values, and associated N-Test recommendations, were similar to those observed for 2009.

Grain Corn Yield and Economic Response to Fertilizer N

Ontario Corn general N recommendations for this site following grain corn with a 10 Mg/ha expected yield and when N is applied preplant is 145 kg-N/ha when the Nitrogen:Corn price ratio is 7. The sidedress recommendation is 120 kg-N/ha. Economic analysis in this summary is based on a Nitrogen:Corn price ratio of 7 with a corn price of $189/tonne ($4.80/bu) and N cost of $1.32/kg-N ($0.60/lb-N).

Four yield response equations to applied fertilizer N were calculated for 2010 based on the timing of N application and the length of time (duration) that fertilizer N rates were continuously applied. Yield response equations are presented in Table 2 and the preplant regression where N rates were imposed for 2 consecutive years is illustrated in Figure 1.

When N was applied preplant, the length of time that N treatments were imposed did not affect yield response to fertilizer N rate with the non-N limited yield (i.e. plateau yield) estimated at 11.1 Mg/ha with a fertilizer N requirement to attain the plateau yield estimated at about 250 - 264 kg-N/ha (Table 2). Maximum Economic Rate of Nitrogen (MERN) at price ratio 7 when N was applied preplant was estimated at 219 - 230 kg-N/ha and Maximum Economic Yields (MEY) were 99% of the non-N limited (plateau) yields.

Sidedress application of N was associated with lower fertilizer requirements to reach plateau (non-N) limited and maximum economic yields. When the sidedress N rates were imposed continuously for 2 years, fertilizer N requirements were about 75% of preplant with the sidedress application resulting in slightly lower yields (0.3 Mg/ha) (Table 2). When sidedress N treatments were imposed for only 1 year, fertilizer N requirements were about 90% of preplant with both application timings producing similar plateau and maximum economic yields.

The average rate of grain yield increase per unit of preplant applied fertilizer N was 28 kg-grain/kg-N when the N rates were imposed continuously or just for 1 year. When N was applied sidedress the average rate of grain yield increase per unit of applied N was 35 kg-grain/kg-N when N rates were applied continuously and 30 kg-grain/kg-N when N rates were applied just for 1 year. The 2010 average rates of grain yield increase were higher than those observed for 2009 which were 21 kg-grain/kg-N for preplant and 25 kg-grain/kg-N for sidedress. The average rate of grain yield increase was calculated by determining the estimated yield response between the starter N rate (30 kg-N/ha) and MERN and then dividing by the amount of fertilizer N required over the starter rate to obtain MERN.

Applying preplant and sidedress nitrogen increased corn yields by 5.0 to 5.6 Mg/ha with slightly higher yield increases observed where fertilizer N treatments were imposed continuously (Table 2). The net return to applying fertilizer N, over the starter rate, was about $790/ha when the N treatments were imposed continuously and about $720/ha to $750/ha when N treatments were imposed for 1 year.

The OMAFRA N recommendations based on a 10 Mg/ha yield goal were about 75kg-N/ha less than calculated MERN for 2010 where the N rates were applied for 1 year (Table 2). Following N recommendations resulted in an estimated yield reduction of about 1.2 Mg/ha (11%) and a loss of potential return of $120/ha when N was applied preplant and $150/ha when N was applied sidedress. Higher than expected yields can partially explain under recommendation of N, but even when 2010 yields are used to develop general recommendations the estimated losses are $80/ha for preplant and $120 for sidedress.

The under prediction of fertilizer N requirements in 2010 were much larger compared to 2009 when preplant requirements were about 20 kg-N/ha greater than recommended and sidedress requirements were about 40 kg-N/ha greater than recommended. Economic losses associated with following general N recommendations in 2009 were also much lower and were about $10/ha for the preplant recommendations and $35/ha for the sidedress recommendations.

Ontario soil NO_3-N test recommendations also were less than the estimated MERN for 2010 with the preplant recommendation about 95 kg-N/ha less than MERN and the sidedress (PSNT) recommendation about 60 kg-N/ha less than MERN when fertilizer N treatments were imposed for 1 year (Table 2). Following preplant soil nitrate-N test recommendations resulted in an estimated yield reduction of 1.7 Mg/ha (15%) and loss of potential returns of $190/ha. The losses associated with PSNT recommendations were not as severe with an estimated yield reduction of 0.9 Mg/ha (8%) and loss of potential profit of about $90/ha.

The soil nitrate-N test recommendations in 2010 were similar to 2009; and in both years the soil N test under predicted corn fertilizer N requirements and provided a recommendation that was substantially less than actual N requirements. Failure of the soil nitrate-N test to recommend appropriate fertilizer N rates may suggest that the site may have lower than average capacity to supply natural N.

Impact on Timing and Rate of Fertilizer N on Corn Development, Yield and N Uptake

Corn response data summarized in this section evaluate corn development, yield and N uptake for total N rates of 30, 57, 87, 145 and 218 kg-N/ha which were applied either preplant or sidedress and with the N treatments imposed for 1 year or continuously for the duration of the trial. The analysis was conducted to evaluate the average effect of fertilizer N rate, application timing and duration of N treatments. The statistical analysis also evaluates the impact, or interaction, on corn response that N rate, timing of application and N treatment duration have on each other. There also was a continuously applied 260 kg-N/ha rate which was not included in the above analysis but was compared to the 218 kg-N/ha rate to determine if there was a response to applying 260 kg-N/ha.

The magnitude of corn development, yield and N uptake response to timing and rate of N application usually was not affected by duration of N treatments. In 2010, the continuous N treatments were imposed for only 2 years and it is anticipated that differences in the magnitude, and perhaps type, of response will become larger in later years where N treatments are imposed for 1 year compared to continuously. The magnitude, or type, of corn response to N rate was usually not significantly affected by timing of application which suggests that corn response to N rate was similar for both application methods. Therefore, presentation of 2010 data will be comprised of the overall average effects of N treatment duration, application timing and total N rates.

Corn development and final yield measurements were, for the most part, not substantially affected by duration of N treatments (Table 3). Only harvest grain moisture showed a significant effect with harvest moisture where N treatments were imposed continuously averaging 0.3% lower than when N treatments were imposed for 1 year.

Timing of N application generally did not have a significant effect on corn development and final yield measurements (Table 3).

Increasing N rate tended to reduce the number of days required for 50% silking (table 3). Applying at least 145 kg-N/ha reduced days required for 50% silking by 2 days compared to where only starter N was applied.

Grain yield, total corn biomass and stover biomass responded to increasing fertilizer N rates with the highest yield and biomass values observed for the 218 kg-N/ha rate (Table 3). Harvest index, the percentage of total corn plant biomass which is grain, also increased as total N rate increased with the highest harvest index associated with the 218 kg-N/ha rate as well. Total above ground biomass in Table 3 was estimated based on a calculation using the dry grain corn yield (0% moisture) and harvest index. The Stover yield in Table 3 represents the mass, at 0% moisture) of the above ground plant material not including the grain or cobs.

Applying 260 kg-N/ha resulted in similar silking date, harvest moisture content and harvest index as the 218 kg-N/ha rate which also was applied continuously (data not shown). Grain yield, stover biomass and total biomass for the continuous 260 kg-N/ha rate was increased slightly (2.5 – 2.8%) over the 218 kg-N/ha rate (data not shown).

The concentration and content on an area basis of nitrogen for grain and stover was not affected by duration of N treatments (table 4). Similarly, timing of N application also did not affect nitrogen concentration and content for grain. Slightly higher stover N content was observed when N was applied sidedress, however the effect was small compared to the N rate response.

Grain and Stover N concentration steadily increased, as fertilizer N rate increased from the starter rate (30 kg-N/ha) to 218 kg-N/ha (Table 4). Applying 218 kg-N/ha increased grain N concentration by a factor of about 1.4 and stover N concentration by a factor of about 1.3 over where just the 30 kg-N/ha starter rate was applied.

Stover n concentration was slightly increased (actual increase=0.06%) for the 260 kg-N/ha rate when compared to the continuous 218 kg-N/ha rate (data not shown). Grain N concentration for the 260 kg-N/ha rate was not increased over the continuous 218 kg-N/ha rate.

Total corn nitrogen content, which represents total N uptake in the above ground portion of the plant, was increased by a factor of about 2.4 at the 218 kg-N/ha rate when compared to the starter only (30 kg-N/ha) rate (Table 4). Grain N content, which represents N removal, increased by a factor of about 2.6 for the 218 kg-N/ha rate when compared to the starter only rate. Stover N content, which represents the amount of N remaining in the corn residue after harvest, increased by a factor of about 2.0 for the 218 kg-N/ha rate when compared to the starter only rate.

Applying 260 kg-N/ha did not increase grain N content over the continuous 218 kg-N/ha rate and only resulted in a slight increase (5 and 6 kg-N/ha) for stover and total N content, respectively.

Applying recommended fertilizer N rate (145 kg-N/ha) increased total N content (Grain & Stover) by about 68 kg-N/ha with an apparent fertilizer N recovery of about 59% for the 115 kg-N/ha that was applied in addition to the starter N. In 2009 the response was similar with the 145 kg-N/ha rate increasing total N content by 60 kg-N/ha with an apparent fertilizer N recovery of about 53%. The 218 kg-N/rate in 2010 increased total N content by about 94 kg-N/ha with an apparent fertilizer N recovery of about 50% for the 188 kg-N/ha of fertilizer N that was applied in addition to the starter N. Again, similar results were observed in 2009 where the 218 kg-N/ha rate increased total N content by 90 kg-N/ha with an apparent fertilizer N recovery of 49%.

Late Season Soil N.

Fertilizer N treatment duration did not significantly affect soil mineral N content in the surface 30cm on either the silking or harvest sample dates (Table 5). Similarly, timing of fertilizer N application did not significantly affect soil mineral N contents on these dates.

Soil mineral N content in the surface 30cm was higher for the 218 kg-N/ha rate when compared to the lower N rates for both the silking and harvest sample dates (Table 5). Soil mineral N contents did not significantly vary for the 30, 58, 87 and 145 kg-N/ha rates for either sample date. The lack of differences in soil mineral N contents between the 30 to 145 kg-N/ha rates observed on the silking and harvest sample dates indicate that corn N requirements for fertilizer N were substantially higher than 145 kg-N/ha in 2010.

Table 1. Soil nutrient test results for IPNI Elora ON CA site sampled April 15, 2010.

Nutrient Test	Apr-09
pH	7.6
P_2O_5 (ppm)	13.8
K_2O (ppm)	82
Mg (ppm)	417
K/Mg Ratio	0.2

Table 2. Summary of corn yield response equations for preplant and sidedress fertilizer N applied for a single year or continuously at a long-term fertilizer N rate trial located at Elora (2010). Summary includes estimates of net returns and losses associated with applying fertilizer N rates based on Ontario general recommendations and the soil nitrate-N test.

		Preplant		Sidedress	
Parameter	Unit	Continuous	Single Year	Continuous	Single Year
Response Equations					
Intercept	kg/ha	3800	4152	3388	4284
Linear		55.2	55.7	75.7	60.2
Quadratic		-0.1044	-0.1112	-0.1940	-0.1343
Model C.V.	%	6.2	8.8	7.9	7.9
Maximum N	kg-N/ha	264	250	195	224
Plateau Yield	Mg/ha	11.1	11.1	10.8	11.0
Maximum Economic N Rate	kg-N/ha	231	219	177	198
Maximum Economic Yield	Mg/ha	11.0	11.0	10.7	10.9
Net Return[+]	$/ha	794.22	749.29	791.37	717.76
General Recommendations					
Recommended N Rate	kg-N/ha	143	143	120	120
Estimated Yield	Mg/ha	9.6	9.8	9.7	9.6
Estimated Net Return[+]	$/ha	642.79	628.51	674.34	564.35
Estimated Loss+[+]	$/ha	-151.43	-120.78	-117.03	-153.41
Nitrate-N Test Recommendations					
Recommended N Rate	kg-N/ha	124	124	139	139
Estimated Yield	Mg/ha	9.0	9.3	10.1	10.0
Estimated Net Return[+]	$/ha	570.28	560.67	737.12	627.25
Estimated Loss[++]	$/ha	-223.94	-188.62	-54.25	-90.51

+ Estimated net return is calculated as the value of the yield ($189/Mg, $4.80/bu) increase associated with applying fertilizer N in excess of the 30 kg-N/ha starter rate less the cost of the nitrogen fertilizer ($1.32/kg-N, $0.60/lb-N).
++ Estimated loss represents an estimate of the reduction in profit associated with applying recommended rates instead of the maximum economic rate of N.

Table 3. Fertilizer nitrogen treatment duration, application timing and application rate effects on days required to reach 50% silking, harvest grain moisture, and final yields at Elora in 2010.

Group Treatment	50% Silking	Grain Moisture	Grain Yield	Harvest Index+	Total Biomass	Stover Biomass++
			-Mg/ha @		Mg/ha @	Mg/ha @
Duration	- Days -	- % -	15.5% -	- % -	0% -	0% -
Continuous	80.8	21.3	8.42	54.6	12.96	4.53
Current Year	80.7	21.6	8.48	54.7	13.03	4.53
Se	0.21	0.18	0.111	0.23	0.167	0.061
LSD(P=0.05)+++	ns	0.3	ns	ns	ns	ns
Timing						
Preplant	80.8	21.5	8.34	54.5	12.88	4.54
Sidedress	80.7	21.4	8.56	54.8	13.11	4.53
Se	0.21	0.18	0.111	0.25	0.167	0.061
LSD(P=0.05)+++	ns	ns	ns	ns	ns	ns
N Rate						
30 kg-N/ha	82.0	21.6	5.92	52.3	9.54	3.53
58 kg-N/ha	81.1	21.5	7.03	53.7	11.07	4.04
87 kg-N/ha	80.8	21.4	8.21	54.8	12.65	4.45
145 kg-N/ha	79.9	21.4	10.21	55.7	15.48	5.28
218 kg-N/ha	80.0	21.4	10.88	56.6	16.24	5.37
Se	0.33	0.20	0.175	0.36	0.257	0.096
LSD(P=0.05)+++	0.9	ns	0.50	1.0	0.71	0.27

+ Total biomass yields (at 0% moisture content) were calculated by dividing grain yield at 0% moisture by the harvest index expressed as a proportion (50% expressed as a proportion is 0.5).

++ Stover yields at 0% moisture were estimated by subtracting estimate of total ear yield at 0% moisture from the total dry biomass yield. Therefore, Stover yields do not include cobs.

+++ Least Significant Difference at the 5% level of probability. The symbol ns indicates that differences were not significant.

Table 4. Fertilizer nitrogen treatment duration, application timing and application rate effects on concentration and total content of N in grain and Stover at Elora (2010).

	Grain N		Stover+ N		Total N
Group Treatment	Concentration	Content - kg-	Concentration	Content - kg-	Content - kg-
Duration	- % -	N/ha -	- % -	N/ha -	N/ha -
Continuous	1.07	78.3	0.62	28.8	107.1
Current Year	1.05	77.4	0.64	29.4	106.7
Se	0.009	1.28	0.039	1.95	2.89
LSD(P=0.05)++	ns	ns	ns	ns	ns
Timing					
Preplant	1.05	75.9	0.63	29.2	105.1
Sidedress	1.07	79.7	0.63	29.0	108.7
Se	0.011	1.28	0.040	2.01	3.00
LSD(P=0.05)++	ns	3.5	ns	ns	ns
N Rate					
30 kg-N/ha	0.90	45.2	0.57	20.4	65.6
58 kg-N/ha	0.94	55.7	0.55	22.3	78.0
87 kg-N/ha	1.02	70.7	0.60	26.6	97.3
145 kg-N/ha	1.14	98.6	0.67	35.0	133.6
218 kg-N/ha	1.30	119.1	0.76	41.0	160.0
Se	0.013	1.98	0.041	2.13	3.56
LSD(P=0.05)++	0.03	5.5	0.05	3.1	7.6

+ Stover N concentration and content includes all above ground plant parts except grain and cobs.

++ Least Significant Difference at the 5% level of probability. The symbol ns indicates that differences were not significant.

Table 5. Fertilizer nitrogen duration, application timing and application rate effects on total soil mineral N content in the surface 30cm at silking and after harvest at Elora (2010).

Group Treatment	Silking	Harvest
Duration	--- kg-N/ha ---	
Continuous	39+	29
Current Year	33	28
Se	3.6	2.3
LSD(P=0.05)++	Ns	ns
Timing		
Preplant	37	29
Sidedress	35	29
Se	3.6	2.6
LSD(P=0.05)++	Ns	Ns
Rate		
30 kg-N/ha	31	26
58 kg-N/ha	30	27
87 kg-N/ha	31	24
145 kg-N/ha	35	27
218 kg-N/ha	53	38
Se	4.4	2.9
LSD(P=0.05)++	10	6

+ Soil mineral N content was calculated by multiplying the total mineral soil N concentration (NO3-N+NH4-N) by 4 to obtain an estimate in kg-N/ha units.

++ Least Significant Difference at the 5% level of probability. The symbol ns indicates that differences were not significant.

Figure 1. Grain corn yield response to fertilizer N that was applied preplant for 2 consecutive years at Elora 2010. Maximum Economic N Rate estimate is based on a Nitrogen:Corn price ratio of 7 ($4.80/bu corn, $0.60/lb-N nitrogen).