Spatial/temporal yield response of intensively managed corn and soybean to variations in potassium fertilizer rate and placement

2004 Report on Activities and Progress

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Background

The trial was established in the fall of 2001. The field site is approximately 13 ha in size with a gentle simple slope of declining elevation from the southwest side of the field to a low spot in the center of the field then increasing elevation to the Northeast side of the field. The soil is classified as a London loam (27% sand, 56% silt and 17% clay) in the South west side of the field and as a Guelph loam (46% sand, 41 %silt and 13 % clay) in the northeast side of the field.

Average organic matter for the site (2001 measurements) were 3.77%, soil pH was 7.5, K_2O concentration was 80.1 mg L^{-1} (ammonium acetate extraction method), and P_2O_5 was 6.3 mg L^{-1} (extracted with 0.5 M $NaHCO_3$, pH 8.5)

A detailed (20 x 20 m) grid sampling of the soils was conducted on June 8, 2001. Geostatistical procedures have been conducted on the soil test P, K, Mg, pH, and depth of A horizon data. Topographical maps have been produced.

Yield potential of the location was assessed using long term (1975-1999) environmental data from the region and the Hybrid-Maize simulation model for corn growth and yield (H.S. Yang, A. Dobermann, K.G. Cassman, D. Walters Hybrid-Maize. A Simulation Model for Corn Growth and Yield (Version 2005.2.1) Department of Agronomy & Horticulture. Nebraska Cooperative Extension CD 9, University of Nebraska-Lincoln.) Three scenarios were simulated. All scenarios used default parameters and assumed optimal moisture and nitrogen conditions.

Scenario 1:

Assumptions: Planting date May 7. Growing degree days (GDD) - 2000. Population 30000 plants per acre
Best yield - 222.8 bu/ac
Median yield - 162 bu/ac
Key factors associated with best yield: 14 days earlier silking date, greater solar radiation, higher average temperatures.

Scenario 2:

Assumptions: Planting date April 28. Growing degree days - 2100. Population 38000 plants per acre
Best yield - 242 bu/ac
Median yield - 168 bu/ac
Key factors associated with best yield: 5 days earlier silking date (median silking date August 1), greater solar radiation, above average temperatures, 5 days longer grain fill period.

Scenario 3:

Assumptions: Planting date April 28. Growing degree days - 2100. Population 38000 plants per acre, silking date occurs 122 GDD earlier than Scenario #2
Best yield - 267 bu/ac
Median yield - 191 bu/ac
Key factors associated with best yield: 13 days earlier silking date (median silking date

July 29), greater solar radiation, higher average temperatures.

GDD to silking, and GDD required for maturity appear to be key factors for increasing yields at this location. For a 2200 GDD hybrid, median maturity would occur October 17, and median silking date on July 16. Silking date of corn typically occurs in the last week of July in this region. Growing a longer season hybrid while simultaneously achieving an earlier silking date would require 1) average temperatures early in the season, 2) management to increase soil temperature, 3) management to facilitate early planting, 4) management to ensure rapid emergence 5) management to reduce early season stress.

Trial Objective

To assess changes in yield and physiology of corn and soybeans across a field landscape in response to intensive management and its interaction with high rates and deep placement of potassium fertilizer.

Experimental Design and Treatments

Treatments (corn- Appendix 1, soybean - Appendix 2) were initiated in the fall of, 2001. Treatments are replicated three times and randomized within blocks for corn and soybean. Corn and soybean blocks are rotated each year. 2004 represents the third growing season for this trial. Field length plots were sampled at three slope positions (upper, middle and lower).

Trial Management, 2004

Fertility and tillage treatments for the 2004 growing season were established in the fall of 2003. Corn and soybean treatments were established on corresponding soybean and corn treatments of 2003 treatments. Key trial management activities are summarized below.

Management Activity	Date(s)
Chop corn stalks	November 26, 2003
Fall zone tillage and fertilizer application	November 26, 2003
Fall chisel plow	December 9, 2003
Trans-till, secondary tillage - corn treatments	April 29, 2004
Plant corn	April 30, 2004
Burndown herbicide - corn and soybean	May 6, 2004
Corn herbicide application	May 6, 2004
Secondary tillage - soybeans treatments	April 29, May 19, 2004
Plant soybeans (Monarch)	May 21, 2004

Plant soybeans (OAC Oxford)	May 28, 2004
Soybean herbicide application	May 28, 2004
UAN application	June 16, 2004
Postemergent herbicide - soybeans	July 9, 2004
Soybean harvest	October 4-5, 2004
Corn harvest	October 26, 2004
Fall zone tillage and fertilizer application	November 23, 2004
Chisel Plow	November 29, 2004

Corn was planted using a 4-row JD 1750 MaxEmerge planter. Coulters and row cleaners were used for all treatments. Planter applied fertilizer was applied as per Appendix 1. Given the relatively cool conditions at planting, and relatively early planting date, planting depth was set at approximately 3.5 cm. Conditions following planting were cool and wet. While emergence was delayed, corn had good emergence and stand uniformity.

Due to a cool wet May, soybeans were not planted until May 29. Soybeans were planted using a modified twin-row JD7000 planter. This planter continues to have difficulty handling levels of corn residue encountered in the strip-tillage treatments. Stalks were chopped in the previous fall to reduce this problem, however, residue flow through the planter remains a concern.

Weather Conditions, 2004

Growing conditions in May were poor due to cool wet conditions. Rainfall in July and September was below average. While rainfall and temperature conditions were very good for corn and soybean growth, air temperatures were below average and development of both corn and soybeans was considerably delayed relative to previous years. Silking date of corn occurred approximately the last week of July. Grain filling of corn extended into September. In 2004, September had above average temperatures. Higher temperatures during this time period provided good growing conditions for the grain filling period of corn.

Table: 2004 Monthly Rainfall, Woodstock, Ontario

Month	Rainfall (cm)
April	56.4
May	166.2
June	75.2
July	52.2
August	74.6
September	34.8
October	56.2
November	110.6

September 13, NK3030bt was displaying more advance senescence than Pioneer 38A25 due to severe foliar disease. Corn stalk quality was excellent with minimal lodging in any of the treatments.

Results:

Interactions between corn hybrid and management system were significant (p=.02). The interaction was probably due to foliar diseases indicated above and represented a difference in magnitude of response. Maximum treatment yields of 11331 kg ha^{-1} (180.7 bu ac^{-1}) were achieved with Pioneer38A25 grown under treatment 5 management (Table 1). Maximum yields achieved within the field length strips of treatment 5 averaged 14396 kg ha^{-1} (220 bu ac^{-1}) (Table 2). Maximum yields did not appear to be associated with slope position in the field, which was also evidenced by the fact that slope position was not significant for hand harvested yields. Soil A horizon depth was not affected by slope position at this site and analysis of root growth also indicated no effect of slope. The site tends to be a well drained and there is little evidence of moisture runoff to lower slope positions.

Yield levels in 2004 did not approach yield potentials calculated above. Yields were in 2004 were probably limited by reduced levels of rainfall in the late July-early August time period.

Under both levels of management both corn hybrids consistently responded to higher levels of potassium fertility. Potassium fertility tended to reduce yield variation. Increasing input intensity tended to increase yield variation with maximum yield levels increasing to a greater extent than minimum yield levels. These same trends were observed in other corn measurements including silking biomass, plant height and leaf area index. In 2002 and 2003, potassium concentration (Table 5) and uptake (Table 3) was greater when broadcast versus deep-placed and was also increased with higher levels of management intensity (Table 4).

Table 1: 2004 corn yields, biomass, height and leaf area index.

Treatment	Combine grain yield October 26 (kg/ha @15.5%)		Moisture October 26 (%)	Hand harvest yield October 18 (kg/ha @ 15.5%)	Harvest Index October 18 (%)	Silking biomass August 3	Plant height June 21 (cm)	Leaf area index July 29
	Pioneer 38A25	NK303BT		NK303BT	NK303BT	NK303BT	NK303BT	NK303BT
1	9105	7803.5	20.69	7826.7	50.8	7557	68.7	1679
2	9703.9	8886.4	22.58	9011.3	52.1	7510	66.933	1785
3	10228	9346.4	22.80	9725.1	53.6	8636	71.667	1852
4	10548	9614	20.49	10177	51.5	9662	76.733	2308
5	11331	10246	21.65	10559	53.0	9119	75.567	2300
6	10067	9671.4	20.53	10314	51.9	8563	75.433	2198
7	10939	10291	21.73	10562	52.4	9142	74.733	2381
lsd p<.05)	373	364	0.41	609	1.1	998	2.18	189

Table 2: 2004 maximum, minimum and standard deviation of corn yields.

	Maximum Yield (kg/ha @ 15.5%)							
	NK3030BT				Pioneer 38A25			
Treatment	Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
1	9286	9814	10083	9727	11221	11076	10602	10966
2	10264	12165	10375	10934	11121	11082	11167	11124
3	10920	10015	11021	10652	12474	11596	11575	11882
4	11339	12231	12286	11952	11540	13399	12655	12531
5	11506	12276	12923	12235	13674	15463	14051	14396
6	11147	12650	13968	12588	12169	13074	12252	12499
7	11508	12792	13115	12471	12764	12392	12502	12553
Mean	10853	11706	11967	11509	12138	12583	12115	12279

	Minimum Yield (kg/ha @ 15.5%)							
	NK3030BT				Pioneer 38A25			
Treatment	Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
1	6330	7020	6835	6728	8458	7822	8023	8101
2	7504	8073	7316	7631	8586	8940	9197	8908
3	8414	7854	8052	8107	9667	8796	9241	9234
4	8250	8213	8522	8328	9380	9063	9464	9302
5	8748	8496	8854	8699	10235	10311	9415	9987
6	7532	8405	8682	8206	7202	7765	8943	7970
7	8817	8463	8451	8577	10376	10091	7926	9464
Mean	7942	8075	8102	8040	9129	8970	8887	8995

	Standard Deviation of Yield (kg/ha @ 15.5%)							
	NK3030BT				Pioneer 38A25			
Treatment	Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
1	802	623	730	718	639	832	599	690
2	765	879	827	823	649	489	489	542
3	615	552	623	596	591	484	514	530
4	777	819	900	832	591	857	712	720
5	684	953	863	834	748	1092	782	874
6	798	809	1101	902	964	844	664	824
7	609	850	871	777	553	543	845	647
Mean	721	784	845	783	676	735	658	690

Table 3:

Table. Effect of methods of potassium placement on corn total potassium uptake at the Hart site, Ontario, 2002 and 2003.

Potassium placement	Year 2002 Total K uptake (kg ha^{-1})	Year 2003 Total K Uptake (kg ha^{-1})
Broadcast	94.8	118.5a
Deep-placed	94.5	108.9b
LSD	NS	9.04
SE	0.53	0.34
K levels x placement	NS	NS

*, ** Significant at the 0.05 and 0.01 probability levels, respectively; NS = not significant at P = 0.05.
= Means within a column followed by the same letter are not statistically different at the 0.05 probability level according to LSD test

Table 4:

Table. Effect of input levels on corn total potassium uptake at the Hart site, Ontario, 2002 and 2003.

Input levels	Year 2002 Total K uptake (kg ha^{-1})	Year 2003 Total K Uptake (kg ha^{-1})
Low[1]	80.2b	108.4
High[2]	94.8a	118.5
LSD	**	NS
SE	0.54	0.63
K levels x inputs	NS	NS

*, ** Significant at the 0.05 and 0.01 probability levels, respectively; NS = not significant at P = 0.05.
= Means within a column followed by the same letter are not statistically different at the 0.05 probability level according to LSD test

[1] OMAF recommended rates of P (70 kg P_2O_5 ha^{-1}) and N (150 kg N ha^{-1}), 75,000 seeds/ha, conventional tillage.

[2] **high rates of P (200 kg P_2O_5 ha^{-1} broadcast in the fall) and N (280 kg N ha^{-1}) application, and 100,000 seeds/ha, conventional tillage**

Table 5:

Table. Effect of methods of potassium placement on corn earleaf, grain and stover potassium concentrations at the Hart site, Ontario, 2002 and 2003.

Potassium Placement	Year 2002 Earleaf K conc. (% DM)	Year 2002 Grain K conc. (%DM)	Year 2002 Stover K conc. (%DM)	Year 2003 Earleaf K conc. (% DM)	Year 2003 Grain K conc. (%DM)	Year 2003 Stover K conc. (%DM)
Broadcast	1.58	0.43	0.72	2.11	0.47	0.94
Deep-placed	1.64	0.42	0.74	1.99	0.44	0.87
LSD	NS	NS	NS	NS	*	NS
SE	0.30	0.40	0.33	0.50	0.32	0.55
K level x placement	NS	NS	*	NS	NS	NS
30 x Broadcast			0.70			
30 x deep-placed			0.67			
200 x Broadcast			0.75			
200 x Deep-placed			0.82			

*, ** Significant at the 0.05 and 0.01 probability levels, respectively; NS = not significant at P = 0.05.
= Means within a column followed by the same letter are not statistically different at the 0.05 probability level according to LSD test

Table 6:

Table: Effect of land slope positions on corn root distributions and A-horizon depth at the Hart site and at the Woodstock site, Ontario, 2002 and 2003.

Treatments	Hartsite-2002		Hartsite-2003		Woodstock-2003	
	A-horizon depth (cm)	Root segments (No.)	A-horizon depth (cm)	Root segments (No.)	A-horizon depth (cm)	Root segments (No.)
Slopes						
Bottom	24	11.5	23	7.9a	23.5	6.0a
Middle	21	9.8	20	6.1b	21.3	4.4b
Summit	25	12.1	17	6.3ab	21.0	5.0ab
LSD	NS	NS	NS	1.67*	NS	1.26*
SE	2.51	0.7	1.47	0.57	1.92	0.44
Soil depths						
10cm		28.0a		16.8a		12.7a
25cm		8.7b		6.3b		5.1b
40cm		5.3c		2.8c		2.3c
55cm		2.6d		1.1c		0.5d
LSD		2.36**		1.93**		1.45**
SE		0.81		0.66		0.50
Slope x depth		NS		NS		NS

= Means within a column followed by the same letter are not statistically different at the 0.05 probability level according to LSD test

Soybean yields in treatment 1 and 2 differed significantly (p=.004) from other treatments indicating a response to higher rates of potassium fertility and management level (Table 3).

Table 7: 2004 soybean grain yield averaged across two varieties (OAC Oxford and Monarch)

Treatment	Combine grain yield October (kg/ha @15.5%)
1	2648
2	2755
3	3064
4	2992
5	3134
6	3041
7	3112
lsd p<.05)	263

Appendix #1

Corn Treatment #1 - Zero K control

	Total	Seed-placed	side-band	broadcast	side-dress	deep
P (kg P_2O_5 ha^{-1})	70	15	55			
K(kg K_2O ha^{-1})	0		0			
N (kg ha^{-1})	150	4.4	11.6		134	

Corn Treatment #2 - Grower K control

	Total	Seed-placed	side-band	broadcast	side-dress	deep
P (kg P_2O_5 ha^{-1})	70	15	55			
K(kg K_2O ha^{-1})	30		30			
N (kg ha^{-1})	150	4.4	11.6		134	

Corn Treatment #3 - High K control

	Total	Seed-placed	side-band	broadcast	side-dress	deep
P (kg P_2O_5 ha^{-1})	70	15	55			
K(kg K_2O ha^{-1})	200		30	170 (fall)		
N (kg ha^{-1})	150	4.4	11.6		134	

Corn Treatment #4 - Grower K, high input

	Total	Seed-placed	side-band	broadcast	side-dress	deep
P (kg P_2O_5 ha^{-1})	200	15	55	130(fall)		
K(kg K_2O ha^{-1})	30		30			
N (kg ha^{-1})	280	4.4	40.6		235	

Corn Treatment #5 - High K, high input

	Total	Seed-placed	side-band	broadcast	side-dress	deep
P (kg P_2O_5 ha^{-1})	200	15	55	130(fall)		
K(kg K_2O ha^{-1})	200		30	170(fall)		
N (kg ha^{-1})	280	4.4	40.6		235	

Corn Treatment #6 - Grower K, high input, deep placed

	Total	Seed-placed	side-band	broadcast	side-dress	deep
P (kg P_2O_5 ha^{-1})	200	15	55			130(fall)
K(kg K_2O ha^{-1})	30		30			
N (kg ha^{-1})	280	4.4	40.6		235	

Corn Treatment #7 High K, high input, deep placed

	Total	Seed-placed	side-band	broadcast	side-dress	deep
P (kg P_2O_5 ha^{-1})	200	15	55			130(fall)

K(kg K_2O ha^{-1})	200		30			170(fall)
N (kg ha^{-1})	280	4.4	40.6		235	

Corn management:

Corn fertility: Phosphorus was seed placed in all treatments as 6-24-6. In treatment #1, phosphorus was side-banded as 11-52-0. In treatment 2-7, phosphorus and potassium were side-banded as a 07-35-19 mixture derived from a 2.12:1 mixture of 11-52-0 and 0-0-60. Potassium was broadcast and deep-placed as 0-0-60. Side-banded nitrogen was 11-52-0 (11.6 kg N/ha) in tmt 1-7 in a 5cmx5cm band and 28% UAN (29 kg N/ha) in a second 6.25cmx6.25cm band.. Deep-placed applications of K_2O and P_2O_5 were injected to a depth of 10 and 25cm during the fall strip till operation using a Gandy pneumatic fertilizer applicator (Gandy Company, 528 Gandrud Road, Owatonna, MN 55060-0528) that was attached to the trans-till unit and delivered fertilizer immediately behind each shank.

Corn - grower management (treatments: #1,2,3): 28,000 plants/ac (seed drop), 75 cm row spacing, Dual II + Marksman pre-emergent, fertility as indicated, Force insecticide applied in a T-band.

Corn - high input treatments (#4,5,6,7): 40,000 plants/ac (seed drop), 75 cm row spacing, zinc and manganese, applied in UAN sideband, Dual II + Marksman pre-emergent (tmt 4 and 5, Dual II + Marksman+Roundup (tmt 6 and 7) pre-emergent. Force insecticide applied in a T-band.

Corn- tillage: Treatments 1-5 were fall chisel plowed (sweep tooth) followed by secondary cultivation (S-tine with rolling basket harrows) in the spring. Treatments 6-7 were fall strip tilled using a modified Trans-till (Row-Tech Inc 645N Germania Rd. Snover, MI 48472) that tilled strips 20cm wide and 25cm deep and created a 10cm high ridge using concave disc-hillers. In the spring, shanks were set at a 10cm depth, disc-hillers were removed and zone tillage on these strips was repeated. Tilled zones were spaced 76cm apart.

Corn hybrids: Northup King 3030 Bt, and Pioneer 38A25

Appendix #2

Soybean Treatment #1 - Zero K Control

	Total	Seed-placed	side-band	broadcast	deep
P (kg P_2O_5 ha^{-1})	40		40		
K(kg K_2O ha^{-1})	0				
N (kg ha^{-1})	8.5		8.5		

Soybean Treatment #2 - Grower K Control

	Total	Seed-placed	side-band	broadcast	deep
P (kg P_2O_5 ha^{-1})	40		40		
K(kg K_2O ha^{-1})	30		30		
N (kg ha^{-1})	8.5		8.5		

Soybean Treatment #3 - High K Control

	Total	Seed-placed	side-band	broadcast	deep
P (kg P_2O_5 ha^{-1})	40		40		
K(kg K_2O ha^{-1})	240		30	210 (fall)	
N (kg ha^{-1})	8.5		8.5		

Soybean Treatment #4 - Grower K, high input

	Total	Seed-placed	side-band	broadcast	deep
P (kg P_2O_5 ha^{-1})	200		40	160 (fall)	
K(kg K_2O ha^{-1})	30		30		
N (kg ha^{-1})	8.5		8.5		

Soybean Treatment #5 - High K, high input

	Total	Seed-placed	side-band	broadcast	deep
P (kg P_2O_5 ha^{-1})	200		40	160 (fall)	
K(kg K_2O ha^{-1})	240		30	210 (fall)	
N (kg ha^{-1})	8.5		8.5		

Soybean Treatment #6 - Grower K, high input, deep placed

	Total	Seed-placed	side-band	broadcast	deep
P (kg P_2O_5 ha^{-1})	200		40		160 (fall)
K(kg K_2O ha^{-1})	30		30		
N (kg ha^{-1})	8.5		8.5		

Soybean Treatment #7 - High K, high input, deep placed

	Total	Seed-placed	side-band	broadcast	deep
P (kg P_2O_5 ha^{-1})	200		40		160 (fall)
K(kg K_2O ha^{-1})	240		30		210(fall)
N (kg ha^{-1})	8.5		8.5		

Soybean fertility: In treatment #1, phosphorus was side-banded as 11-52-0. In treatment 2-7, phosphorus and potassium were side-banded as a 06-31-23 mixture derived from a 1.54:1 mixture of 11-52-0 and 0-0-60. Potassium was broadcast and deep-placed as 0-0-60. Deep-placed applications of K_2O and P_2O_5 were injected to a depth of 10 and 25cm during the fall strip till operation using a Gandy pneumatic fertilizer applicator (Gandy Company, 528 Gandrud Road, Owatonna, MN 55060-0528) that was attached to the trans-till unit and delivered fertilizer immediately behind each shank.

Soybean - grower management (treatments: #1,2,3): 400,000 plants/ac (seed drop), 75 cm twin-row spacing, Broadstrike Dual applied pre-emergent + First-Rate applied postemergent.

Soybean - high input treatments (#4,5,6,7): 400,000 plants/ac (seed drop), 75 cm twin-row spacing, Broadstrike Dual applied pre-emergent + First-Rate applied postemergent

Soybean tillage: Treatments 1-5 were fall chisel plowed (sweep tooth) followed by secondary cultivation (S-tine with rolling basket harrows) in the spring. Treatments 6-7 were fall strip tilled using a modified Trans-till (Row-Tech Inc 645N Germania Rd. Snover, MI 48472) that tilled strips 20cm wide and 25cm deep and created a 10cm high ridge using concave disc-hillers. In the spring, shanks were set at a 10cm depth, disc-hillers were removed and zone tillage on these strips was repeated. Tilled zones were spaced 76cm apart.

Soybean varieties: OAC Oxford and Monarch