Corn Response to Intensive Crop Nutrition

By Bill Deen, John Lauzon, and Tom Bruulsema

A 5-year study of a corn/soybean rotation in Ontario, Canada, shows that increasing inputs above recommended levels significantly increases yield and changes physiology. Transforming physiological changes into economically and environmentally sustainable yield increases will require further research.

Rising global needs for food, fuel, and fiber are driving up the demand and prices for corn. At the same time, the world's people want to limit the impact of cropland on the natural environment, both by limiting the expansion of cropland and the effects of crop production on water quality. These goals require research exploring intensive management for increased yields.

For the past 5 years, we monitored a corn/soybean rotation with varied management levels in a producer's field in south-central Ontario. Our objective was to assess changes in yield and physiology in response to intensive management and its interaction with high rates and deep placement of K fertilizer. Part of the goal was to determine the feasibility of manipulating input levels to increase yields closer to the genetic potential of current corn hybrids.

The main hypothesis we wanted to test was whether response to higher K inputs would increase with higher overall input levels and yields. The trial consists of seven management combinations: three varying K rates at the producer's level of inputs (which are generally close to recommended practices for Ontario), and four at an intensive input level, varying both K rates and placement of P and K fertilizers. Details of the applied treatments are shown in **Table 1**.

The soil is a London loam with good drainage. Soil pH was 7.5, and soil test P and K levels were 8 ppm Olsen P (low), and 107 ppm ammonium-acetate extractable K (medium). The first five treatments used the same conservation tillage practice of the producer: fall chisel plow with spring secondary tillage. The last two treatments used fall zone tillage followed by spring zone tillage. All plots consisted of strips the full length (1,000 to 1,500 feet) of the field; eight rows wide, with two hybrids in each: Northrup King 3030 Bt and Pioneer 38A25. The site was rated as having 2850 Ontario Crop Heat Units, roughly equivalent to 1,800 growing-degree-days.

Yield increases in response to the management levels imposed were modest. While the differences were significant statistically ($p<0.05$) and indicated interesting changes in corn

For the field scale research on sustainable intensification, this photo of 2004 harvest shows an AGCO R42 combine equipped with a Juniper Systems Inc. High Capacity Grain Gauge.

physiology, no combination of input intensity and K rates was more economically viable than the producer's current level of management (treatment 2), even with the high corn prices prevailing in early 2007. Nevertheless, average yields at the high K level were consistently higher than those at the grower's K level over all 5 years (**Figure 1**).

The intensive treatments produced higher yields than the control (**Figure 2**). Differences were largest in the third and fifth years. While both K and input intensity generally increased yields, we found no evidence of interaction between the two factors. There was no greater requirement for K with higher input intensity.

Averaged over the 5 years, fall zone tillage did not differ from fall chisel plowing, but in 2004 it produced lower yields and in 2005, higher yields (**Figure 2**). This interaction with years indicates that the relative benefit of tillage method and nutrient placement depends on the growing season.

While we have not yet been able to assess the full environmental impacts, the intensive treatments did not result in higher soil residual NH_4^+ and NO_3^- levels following the 2006 harvest (**Table 2**). Treatment means were not significantly different at

Table 1. Fertilizer, seed, and tillage management treatments applied for corn.

Treatment	Fertilizer $N\text{-}P_2O_5\text{-}K_2O$, lb/A: Fall	Seed-placed	Starter	Side-dress	Total	Seeds per acre
1. Control, zero K	–		10-50-0	120-0-0	130-63-3	
2. Control, grower K			10-50-27		130-63-30	30,000
3. Control, high K	0-0-150[1]				130-63-180	
4. Intensive, grower K	0-117-0[1]	3-13-3			250-180-30	
5. Intensive, high K	0-117-150[1]				250-180-180	
6. Intensive, zone-till, grower K	0-117-0[2]		36-50-27	210-0-0	250-180-30	40,000
7. Intensive, zone-till, high K	0-117-150[2]				250-180-180	

[1] Broadcast before fall chisel plow tillage to 6 in. depth. [b] Placed 10 in. deep with fall zone tillage.

Abbreviations and notes for this article: K = potassium; P = phosphorus; ppm = parts per million; N = nitrogen; NH_4^+ = ammonium; NO_3^- = nitrate.

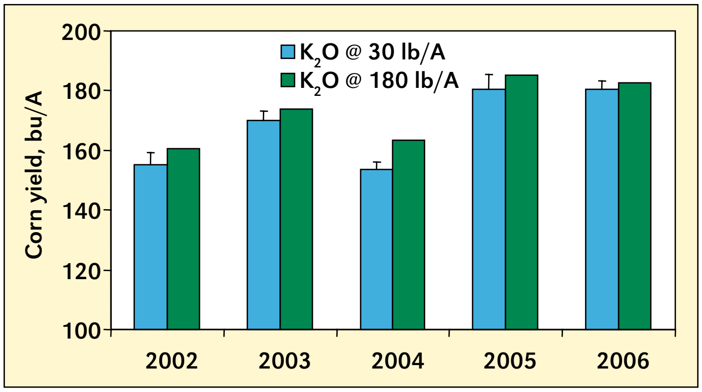

Figure 1. Corn yields at 30 and 180 lb K_2O/A, over 5 years.
Error bars represent least significant difference at the 5% level of probability.

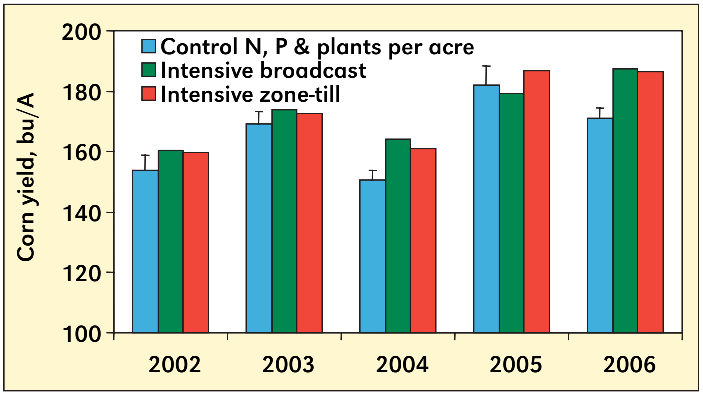

Figure 2. Corn yields with control and intensive input levels, over 5 years.
Error bars represent least significant difference at the 5% level of probability.

the 5% level. Considering the higher N rates of the intensive management levels, it is surprising that, first, so little available N was recovered in the top 18 in. of the soil, and second, that differences between management levels were not seen. The soil of this site is well-drained, and it is probable that some NO_3^- was lost by leaching, and the abnormally high rainfall in the fall of 2006 may even have made a major denitrification event a possibility.

Grain and stover N were essentially not influenced by treatments, averaging 1.41% and 0.89%, respectively, on a dry matter basis. Stover NO_3^- levels, however, increased significantly in response to K, intensive inputs, and zone tillage (**Table 2**). In 2006, grain moisture was significantly ($p<0.0001$) higher (25% vs. 24%) in the zone-tilled treatments compared to chisel-plowed.

The reason for the increased stover NO_3^- in response to K is not clear. The observed effects on stalk NO_3^- and grain moisture suggest differences in plant physiology and nutrient uptake patterns. Reduced lodging observed in the high K corn suggests better stalk integrity and less opportunity for loss of NO_3^- from the stalk by leaching. A slight delay in maturity in response to K may offer less susceptibility to loss of NO_3^- from stalks. Also, luxury uptake of K may induce increased uptake of NO_3^- as a counter-ion for charge balance. We measured root distributions, but did not observe any differences in response to applied K. However, it is possible that root system function may have been improved at higher levels of K.

Table 2. Residual N in soil and stover following the 2006 corn harvest.

Treatment	Soil residual N, lb/A[1]	Stover nitrate, ppm
1. Control, zero K	28	67
2. Control, grower K	33	228
3. Control, high K	34	448
4. Intensive, grower K	33	402
5. Intensive, high K	33	685
6. Intensive, zone-till, grower K	39	622
7. Intensive, zone-till, high K	33	772

[1] NH_4-N and NO_3-N in soil to 18 in. depth, sampled October 27, 2006.

Soil test levels have changed little where P and K inputs were at the producer's rates, but have increased significantly where higher rates were applied (**Table 3**). These rates resulted in net surpluses of P and net deficits of K over three crops of corn and two of soybeans, but neither had much influence on soil test levels. At the high rate of each nutrient, however, soil test levels have increased to the point where further soil test building is unlikely to benefit either corn or soybeans. About 30 lb/A of surplus P_2O_5 was required to increase soil test P by one ppm, and about 8 lb/A of surplus K_2O to do the same for soil test K. Soil test changes in the zone-tilled treatments differ, since the samples (collected 8 in. from the rows) only partly reflect the nutrient availability, owing to concentration of nutrients in the rows.

The University of Nebraska's Hybrid-Maize model predicts that the solar radiation and temperature regime for this site would result in a median potential corn yield of 191 bu/A, assuming no limitations from water or fertility. The intensive inputs of N, P, and K and increased plant population increased yields, but only by a small fraction of the gap between current and potential yields. Continued research is being planned, with changes in corn hybrids and other factors to determine whether the changes in soil fertility and quality accumulating over time can be exploited to greater benefit for sustainable productivity. BC

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Table 3. Soil test levels and nutrient balance following the 2006 corn harvest.

	Soil test, ppm		Nutrient balance, lb/A[1]	
Treatment	P	K	P_2O_5	K_2O
1. Control, zero K	10	76	50	-190
2. Control, grower K	9	77	50	-70
3. Control, high K	7	140	20	500
4. Intensive, grower K	26	91	470	-110
5. Intensive, high K	22	145	460	490
6. Intensive, zone-till, grower K	21	80	490	-100
7. Intensive, zone-till, high K	17	119	490	500

[1] Nutrients applied over 5 years minus nutrients removed in grain from 3 corn and 2 soybean harvests.