

Tillage and Fertility Placement Aspects of Root Zone Optimization for Corn

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January 10, 2008**

Abstract

Management decisions about root zone optimization should not be limited to corn hybrid selection, because even triple-stacked hybrids with corn rootworm resistance will not produce satisfactory yields if soil structure or chemical properties limit corn growth or nutrient uptake. Growing high yield corn is possible without intensive tillage systems, as numerous studies have shown no-till yielding equal to chisel or moldboard plowing for corn following soybean. Although maintaining soil-test P and K concentrations well above critical levels is important to achieving optimum corn yields, strip-till corn has not yielded consistently higher when P and K fertilizers were deep-banded versus broadcast applied. The relative yield benefits associated with broadcast versus deep-banded application of these nutrients seems to be related to soil moisture availability in the zones of nutrient placement during growing periods when plants take up the majority of their P and K requirements. Corn roots and plant populations suffer when corn rows are positioned too close to anhydrous ammonia or urea ammonium-nitrate N sources incorporated to shallow depths. Precision guidance is very beneficial for optimum corn row positioning at least 5 inches removed from the N fertilizer zone following spring pre-plant N application at high rates. The primary way to improve stress tolerance (e.g. tolerance to drought, high plant density, or delayed nutrient availability) in corn plants of a given hybrid is to achieve optimum root zones for unimpeded growth in a given soil and climate situation.

Tillage Aspects:

The long-term yield potential of corn with different tillage systems on dark prairie soils of the Corn Belt has been studied intensively for both the typical corn-soybean rotation as well as for continuous corn. One such study has been conducted near West Lafayette, IN since 1975 (Table 1). While equipment, cultivars, and seeding rates were changed periodically, tillage treatments were not altered during the 32 years of this continuing experiment. The results in Table 1 suggest that:

1. Corn yields are greater in rotation than in continuous cropping for all tillage systems. The positive response to rotation is greatest for no-till corn (18% higher than for the same tillage system when corn follows corn). The positive response to rotation is least with moldboard plowed corn (just 4% higher).
2. When corn follows soybean, yields with plow and chisel are likely to be about the same. Yields from the ridge system may be slightly better (3%) than plow and chisel, but not as much superior as one would think given the complete avoidance of traffic on the ridges (rooting zones) over this long-term study. No-till corn yields may be slightly reduced (2%) compared to plow and chisel, but the relative yields of no-till

are much lower 114% yield reduction compared to moldboard plowing when corn is grown continuously. Yield reductions with no-till corn are not due to lower plant populations, but to inherently higher plant-to-plant variability (Boomsma and Vyn, 2007a). Avoiding soil compaction in no-till corn might be one way for root growth not to be constrained by high soil density.

Table 1. Corn yield response to tillage and rotation, Long-term Tillage Study on a dark prairie silty clay loam soil near West Lafayette, IN, 1975-2006.

Tillage	Corn/Soybean		Continuous Corn		Yield Gain for Rotation %
	Bu/ac	% of plow yield	Bu/ac	% of plow yield	
Plow	179.7	- - -	172.3	- - -	4
Chisel	180.0	100	167.7	97	7
Ridge*	184.3	103	169.1	98	9
No-till	175.2	97	148.3	86	18

*Since 1980

Root zone optimization is inherently more difficult to achieve in fields where corn follows corn. However, strip tillage systems can result in corn yields equal to those after chisel plowing even in continuous corn systems (Vyn, 2006).

One aspect of the influence of tillage systems on root zones is the changes in organic matter concentrations at various depths. We recently have observed that although continuous no-till for 28 years improved soil organic matter near the surface, organic matter in moldboard plowed systems is actually enhanced relative to no-till in the zone from 12 to 20 inches below the soil surface (Gál et al., 2007). We understand from previous research at Purdue University that rooting systems tend to be shallower in no-till than in conventional tillage, but the extent of root proliferation in no-till and strip tillage systems with modern hybrids has not been sufficiently evaluated.

Fertility Placement Aspects:

Continued improvements in fertilizer management practices for corn are warranted because of the linear increase in corn yields since 1950, rapid adoption of less soil-inverting tillage systems since 1990, and a relatively high percentage of low-medium testing P or K soils in the Eastern Corn Belt states. Broadcast application of non-nitrogen fertilizers remains the most common method throughout the Corn Belt states, but this practice could conceivably increase vertical stratification of less mobile nutrients such as P and K when used in conjunction with reduced tillage.

Strip tillage represents a promising tillage system aimed at improving the seedbed environment for early corn growth compared to no-till systems. This new management practice plus the simultaneous deep banding of P and K could also build soil-test levels in the intended corn row area to potentially improve fertilizer use efficiency by reducing nutrient adsorption and possibly by maximizing plant nutrient uptake. We provided some

guidelines for situations where deep banding of P and K might be an advantage in a recent paper (Boomsma et al., 2007).

A 7-year study (2001-2007) was established to address the feasibility of combining strip tillage and deep banding of P and K fertilizers. Five fertility placement alternatives (Control, Broadcast P+K, Banded P+K (6-8 in), Banded K alone (6-8 in), and Banded P alone (6-8 in)) were spring (2001, 2002, and 2003) or fall (2004, 2005, and 2006) applied simultaneously with the strip tillage operation. Two hybrids were evaluated each year from 2001 to 2006, and an application of N-P-K-Zn starter (based on 9-18-9) fertilizer was included at planting, with the exception of 2006-2007 when the starter fertilizer (10-34-0) did not include K. The P₂O₅ rate was 88 pounds/acre, and K₂O rate was 115 pounds/acre; these high amounts were intended to replace the nutrients removed by both corn and soybean in high-yielding situations over the 2-year rotation.

The study was located in two different fields which were characterized based on their soil-test P concentrations for the standard sampling depth (0-8 in) in Indiana as very high (>70 ppm) in the site on the even-numbered years, but intermediate (10-30 ppm) for the sites in the odd-numbered years. For that reason we chose to present and analyze the results separately into these 2 groups.

In most cases, yields for deep banding and broadcast treatments were not significantly different from each other (Tables 2a and b). Deep-banded P plus K yielded significantly more than Broadcast P plus K in only 1 out of 6 years (2004), and these treatments were equally likely to yield significantly more than the Check treatment (both yielded more than the Check in 3 of 6 years). A significant interaction between Hybrids and Fertilizer placement was never observed.

Table 2 a. Effects of deep banding and broadcast fertilizer treatments on strip-till corn yields near West Lafayette, IN (2001-2006).

Treatment	YEAR			Yield (bu/ac)	
	2001	2003	2005		
Broadcast P+K	220	242	a	213	a
Banded P+K	216	236	a	203	ab
Banded K	210	221	b	204	a
Banded P	224	239	a	190	bc
Check	211	221	b	184	c

Hybrid	Yield (bu/ac)				
	Pi 34M95	220	Pi 31N28	223	Pi 31N28
Pi 34B24	212	Pi 34M95	240	Pi 31G68	191

Means with different letters are significantly different (P<0.05)

(b)

Treatment	YEAR					
	2002		2004		2006	
	Yield (bu/ac)					
Broadcast P+K	189	b	234	b	231	a
Banded P+K	195	ab	243	a	227	ab
Banded K	197	a	235	b	228	a
Banded P	201	a	235	b	224	bc
Check	194	ab	235	b	223	c

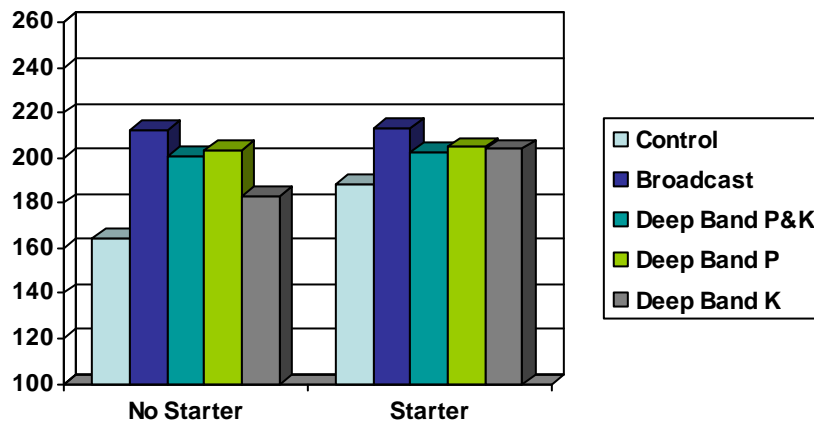
Hybrid	Yield (bu/ac)						
	Pi 34M95	191	b	Pi 31N28	236	Pi 31N28	230
Pi 34B24	200	a	Pi 34M95	237	Pi 31G68	223	b

Means with different letters are significantly different (P<0.05)

The small yield benefit noted from deep banding in 2004 was associated with a year with abundant rain and ample soil moisture availability for root growth and uptake in the zone of nutrient placement during critical growth periods. So, one factor in the relative benefit of deep banding may very well be moisture availability for root growth and nutrient uptake in zones of higher nutrient concentrations. Iowa research by Dr. Mallarino has demonstrated fairly conclusively that deep banding of K was most likely to improve corn yields when the month of June was dry. However, if small rainfall events (such as those of 0.5 inches or less) occur during an otherwise drier than normal month, the broadcast fertilizer may be more available simply because of enhanced moisture availability in the near-surface soil layers.

More recently, we have changed the experiment to test the benefit of deep banding when starter fertilizers are or are not present. The results from 2007 (Figure 1) indicate that corn yields from the broadcast-applied and deep-banded P and K plots were not changed by the presence or absence of starter fertilizer (20 gallons per acre of 10-34-0 in a 2" by 2" band). However, starter fertilizer was helpful in improving corn yields in the control and Deep-band K alone plots.

Figure 1. Effects of deep banding and broadcast fertilizer treatments on strip-till corn yields with and without starter fertilizer application near West Lafayette, IN (2007).



The most precise GPS-controlled automatic guidance system currently available for agricultural equipment is the RTK (Real Time Kinematic) system because it allows steering accuracy to within 1 or 2 inches. This tool provides new opportunities for varying crop row position relative to recent (or older) nutrient bands and prior crop rows.

Over the last 2 years, we have evaluated optimum corn row positions following pre-plant UAN application at various N rates. We applied UAN bands with 3 N rates (50, 100 and 200 pounds per acre) at a depth of 4" and seeded no-till corn within 24 hours in rows positioned 0, 5 or 10 inches from these bands. All plots, including a no pre-plant UAN control, received the same total 200 pounds per acre of N by adjustments made in side-dress UAN application after corn emergence.

In 2006, our first year of research at 2 locations in NC and NW Indiana, we determined that corn yields were enhanced by on-row or near-row seeding to the pre-plant UAN band at one location when no starter (10-34-0) was applied at planting. However, at another location, corn yields were reduced 22% at the 100 pound pre-plant N rate, and 54% at the 200 pound pre-plant N rate with planting directly over the UAN band (Table 3). Lower plant populations (aggravated by limited rainfall) seemed to be the primary cause of the latter yield reductions, though stunted early growth was also evident. We tentatively conclude that RTK guidance is advantageous when planting corn soon after banded UAN application, and that the optimum corn row position for a "safe" response shortly after UAN application at high rates is about 5 inches from, and parallel to, the UAN band. However, continued research in 2007 and 2008 will likely modify our recommendations somewhat.

Table 3. Corn response to pre-plant banded UAN application and RTK-guided corn row placement at Wanatah, IN, 2006.

Pre-plant N rate and Placement	Stand 4 weeks ppa	Plant Height V8 in	Harvest Moisture %	Yield @ 15.5% bu/a.
0 pre-plant UAN	34306a	17.3a	24.9abc	171.6a
50 lbs on row	32833a	16.9a	24.5bc	169.2a
50 lbs 5 inches	34417a	17.8a	24.6bc	171.6a
50 lbs 10 inches	34500a	17.5a	24.6bc	168.3a
100 lbs on row	24417b	14.0b	25.5ab	135.4b
100 lbs 5 inches	33861a	17.0a	24.7bc	174.0a
100 lbs 10 inches	33944a	17.5a	23.9c	173.2a
200 lbs on row	13306c	9.9c	26.3a	92.6c
200 lbs 5 inches	34556a	17.1a	24.8abc	172.0a
200 lbs 10 inches	34472a	18.5a	24.4bc	170.8a
LSD (5%)	3809	2.2	1.5	17.8
Significance Level	.01	.01	NS	.01

- Values followed by different letters are significantly different at P=0.05.

It is clear that excessive urea or anhydrous ammonia can stunt corn roots and corn shoots when dry soil situations prevail after planting, and when N application rates are high. Part of root zone optimization is ensuring that nutrient availability is optimized in the early development of corn plants. Nutrient limitations as well as nutrient excesses can both limit corn growth and development. Nitrogen placement is a key part of root zone optimization, and this is especially true in no-till and strip-till systems.

Future Recommendations

Future research in root zone optimization should be much expanded, and should be done with rootworm-tolerant hybrids as well as for hybrids without insect resistance traits. These studies are inherently labor intensive and costly, but we need to understand corn root responses to management and genotype interactions to provide valid recommendations to crop consultants and growers to advance our understanding of how to improve corn stress tolerance to drought and other limitations. It is deplorable how little corn root research has been underway in the Corn Belt over the past 2 decades as so many genetic and management factors have changed.

Perhaps the biggest factor of change in corn root architecture and development rate in a limited soil volume is not the adoption of conservation tillage systems or the rootworm resistant hybrids, but the continued increase in plant density. In the quest for higher yields with modern hybrids, plants, and therefore plant roots, are progressively more crowded. We know that adequate N availability is one means of ensuring that corn plants at progressively higher plant populations are less variable in per-plant grain yield (Boomsma and Vyn, 2007b). Maintaining not only optimum overall conditions for root development on a field basis, but uniform soil physical and chemical conditions within the corn row area are even more essential at high plant densities.

Automatic guidance systems provide new opportunities for implementing controlled traffic systems within a field/year and from year to year. Controlled traffic leads to lower soil compaction, and it is residual soil compaction from random grain buggies, combines and other field equipment that is perhaps the biggest yield constraint on corn fields which are adequately fertilized and planted to elite hybrids. The avoidance of root zone compaction is essential to improve stress tolerance and increase corn yields further. Whether the corn rows should be placed in exactly the same position from one year to the next that corn is grown in the same field (as is possible with RTK guidance) is also an important question to investigate in studies that include detailed root investigations of root prolificacy.

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