Tillage and Fertility Placement Aspects of Root Zone Optimization for Corn

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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—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 optimal 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 seem 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 (UAN) N sources incorporated to shallow depths. Precision guidance is very beneficial for optimal 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 optimal 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 ongoing near West Lafayette, Indiana, since 1975 (Table 1). Although equipment, cultivars, and seeding rates were changed periodically, tillage treatments have not been altered during the 32 years of this continuing experiment. The results in Table 1 suggest the following:

- 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).
- When corn follows soybeans, 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 good 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 (14% 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, Indiana, 1975–2006.

	Corn/soybean		Continuous corn		Yield gain for rotation
Tillage	Bu/A	% of plow yield	Bu/A	% 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- to 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 inches), banded K alone (6–8 inches), and banded P alone (6–8 inches)] were spring applied (2001, 2002, and 2003) or fall applied (2004, 2005, and 2006) 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 fertilizer (based on 9-18-9) was included at planting, with the exception of 2006–2007, when the starter fertilizer (10-34-0) did not include K. The P_2O_5 rate was 88 pounds per acre, and the K_2O rate was 115 pounds per 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 inches) 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 two 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.

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

TABLES 2A AND 2B • Effects of deep banding and broadcast fertilizer treatments on strip-till corn yields near West Lafayette, Indiana, 2001–2006.

	YEAR 2001		2003			2005	
Treatment			Yield (bu/ac)				
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**	207	
Pi 34B24	212	**Pi 34M95**	240		**Pi 31G68**	191	

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

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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 Antonio 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 0.5 inch 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-inch band). However, starter fertilizer was helpful in improving corn yields in the control plots and those with deep-band K alone.

The most precise, GPS-controlled automatic guidance system currently available for agricultural equipment is the RTK (real time kinematic) system, which 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 past 2 years, we have evaluated optimal corn row positions following pre-plant UAN application at various N rates. We applied UAN bands with three N rates (50, 100, and 200 pounds per acre) at a depth of 4 inches 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 two locations in north central and northwest 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 optimal 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.

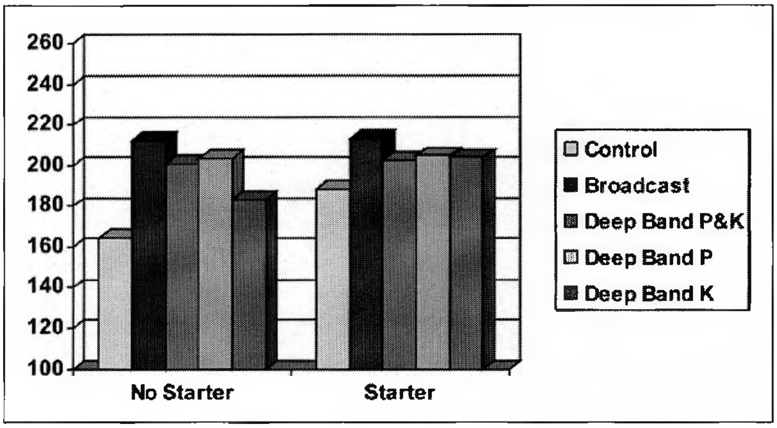

FIGURE 1 • Effects of deep banding and broadcast fertilizer treatments on strip-till corn yields with and without starter fertilizer application near West Lafayette, Indiana, 2007.

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 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 it 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 and 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 under way in the Corn Belt over the past 2 decades, because 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 optimal overall conditions for root development on a field basis but uniform soil physical and chemical conditions within the corn row area is even more essential at high plant densities.

Automatic guidance systems provide new opportunities for implementing controlled traffic systems within a field during a given 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 that are adequately fertilized and planted to elite hybrids. Avoiding 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 when corn is grown in the same field (as is possible with RTK guidance) is also

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

Pre-plant N rate and placement	Stand 4 weeks	Plant height V8	Harvest moisture	Yield at 15.5%
	ppa	*in.*	*%*	*bu/A*
0 pre-plant UAN	34306a	17.3a	24.9abc	171.6a
50 lb on-row	32833a	16.9a	24.5bc	169.2a
50 lb 5 in.	34417a	17.8a	24.6bc	171.6a
50 lb 10 in.	34500a	17.5a	24.6bc	168.3a
100 lb on-row	24417b	14.0b	25.5ab	135.4b
100 lb 5 in.	33861a	17.0a	24.7bc	174.0a
100 lb 10 in.	33944a	17.5a	23.9c	173.2a
200 lb on-row	13306c	9.9c	26.3a	92.6c
200 lb 5 in.	34556a	17.1a	24.8abc	172.0a
200 lb 10 in.	34472a	18.5a	24.4bc	170.8a
LSD (5%)	3809	2.2	1.5	17.8
Significance level	0.01	0.01	NS	0.01

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

an important question to investigate in studies that include detailed root investigations of root prolificacy.

References

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