Optimizing Strip-Till and No-Till Systems for Corn in the Biofuel Era

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Abstract:
Recent developments in biofuel demand and the rapid adoption of modern transgenic hybrids are changing production systems towards more corn after corn, more intensive tillage, higher plant populations, and ever higher crop residue levels at harvest. Meeting society's needs for food, feed, and fuel from grain corn, and in the future from corn stover, requires continued refinement of tillage systems to sustain soils and optimize the uniform development of corn plants in all kinds of stressful environments (whether from cool temperatures, drought, nutrient deficiencies, or compaction). The standard chisel plow system used in continuous corn may be the least sustainable of all tillage systems over a 30-year timeframe. Achieving high corn yields with less tillage requires achieving stands with more uniformity in the growth of adjacent corn plants. New developments including precision automatic guidance, strip-till in continuous corn, nutrient banding in no-till and strip-till, and operation timeliness can improve the success rate of these two effective soil conserving systems even when crop rotations involve more corn than a decade ago.

Corn Yield Responses to Alternate Tillage Systems on Various Soils:

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, 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 (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). Tillage, plant populations, random versus controlled wheel traffic, and

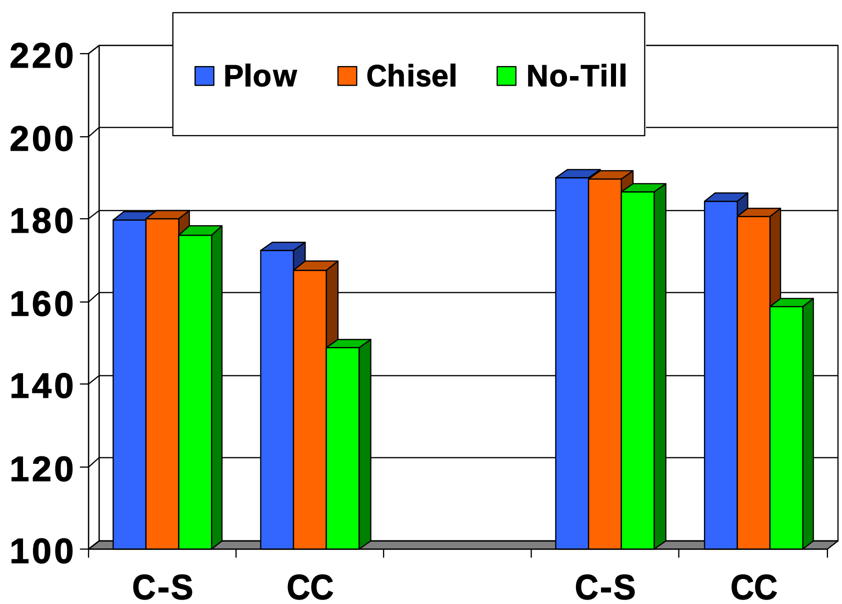
nutrient management all affect the extent of variability of corn plants within a row during rapid vegetative and early reproductive growth.

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
[#] Data from T.D. West and T.J. Vyn

Figure 1. Corn yield response to tillage in a corn-soybean (CS) rotation versus continuous corn (CC) over 32 years versus the last 10 years on a dark prairie silty clay loam soil near West Lafayette, IN. (1975-2006 on left versus 1997-2006 on right).



The degree of yield advantage for corn in rotation in the last 10 years is slightly less in the moldboard and chisel systems now compared to the overall 32 year history of this experiment (Figure 1). The rotation advantage was 3% for plow, and 5% for chisel from 1997 to 2006, versus 4% for plow and 7% for chisel from 1975 to 2006. The yield advantage for rotation in no-till corn has remained constant at about 18%.

Strip-till corn after corn has yielded equal to chisel plowing even when corn follows corn at our location in Northern Indiana (Table 2). This 11 bushel per acre yield advantage for strip-till versus no-till in continuous corn is significant, and it illustrates the potential of the strip-till system even when corn yields are close to 200 bushels per acre. No-till corn seems to be a superior option when corn follows soybean; because yields are only 2% lower with no-till, farm profit would likely be highest with no-till on soils like these.

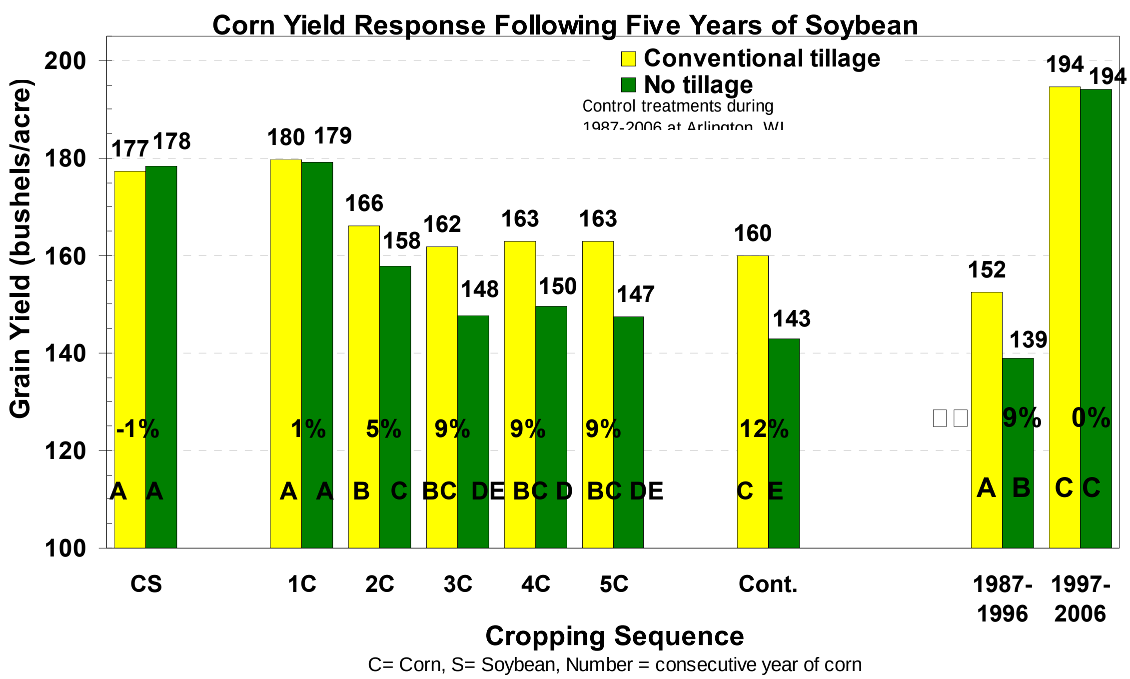
Table 2. Corn Yield Response to Tillage and Rotation, Long-term Tillage Study on Sebawa loam soil near Wanatah, IN (PPAC, 2001-2006) [#]

Tillage	Corn/Soybean		Continuous Corn		Yield Gain for Rotation
	Bu/ac	% of c/d/fc yield	Bu/ac	% of c/d/fc yield	%
Chisel/disk/field cultivator	201.5	- - -	187.7	- - -	7
Chisel/field cultivator	198.0	98	186.7	99	6
Disk/field cultivator	204.3	101	186.5	99	10
Strip-till	203.2	101	186.6	99	9
No-till	197.1	98	175.6	94	12

[#] Data from T.D. West and T.J. Vyn

Tillage research in Southern Wisconsin has observed that the yields of no-till corn tend to get progressively lower with each additional year that corn follows corn (Figure 2). Thus although no-till corn yielded as well as conventionally tilled corn when first-year corn followed a single year of soybean (CS rotation) or after 5 years of continuous soybean (1C), second-year no-till corn (2C) yields were 8 bushels/acre lower and third-year corn (3C) yields were 14 bushels/acre lower than conventional tillage. The latter factor plus the 4 bushel yield advantage in the conventional tillage system for second-year corn versus third-year corn means that second-year corn yields averaged 7 bushels/acre higher than third-year corn. No-till corn seems to be best adapted for corn following rotation crops other than corn.

Figure 2. Corn responses to tillage and rotation systems in Wisconsin (1987-2006). Data courtesy of Joe Lauer, University of Wisconsin.



Fertility Placement Aspects of Strip-till Corn:

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 P_2O_5 rate was 88 pounds/acre, and K_2O 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 3a 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 3 a. Effects of deep banding and broadcast fertilizer treatments on strip-till corn yields near West Lafayette, IN (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)

(b)

	YEAR								
	2002			**2004**			**2006**	
Treatment	**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	a
Pi 34B24	200	a	**Pi 34M95**	237		**Pi 31G68**	223	b

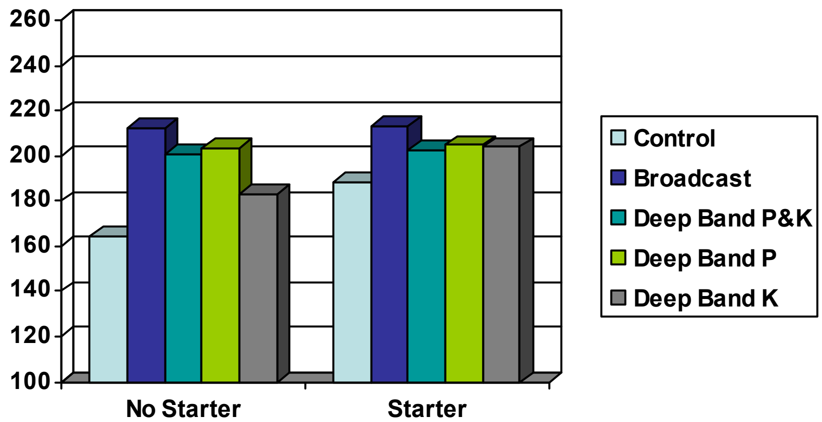
Means with different letters are significantly different (P<0.05)

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



Nitrogen Placement Aspects of No-till Corn:

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 4 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	Plant Height V8	Harvest Moisture	Yield @ 15.5%
	ppa	in	%	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.

Summary:

There clearly are soil quality and soil erosion concerns when rotations include more corn, and when the corresponding tillage choices are in the direction of more intensive tillage (Vyn, 2006). Although no-till doesn't always increase total soil carbon sequestration relative to moldboard plowed systems on level prairie soils (Gal et al., 2007), no-till is always going to be superior at providing erosion protection on sloping soils whether corn follows corn or soybean. Because no-till corn does not yield well when corn follows corn on many soils, strip-till corn holds considerably more promise for providing higher returns to corn farmers who want to plant corn after corn. We are still in the learning process of how to optimize no-till and strip-till systems with respect to nutrient placement and automatic guidance systems, but there seems to be new opportunities for precision management in no-till and strip-till corn that should lead to more confident adoption of these two soil-conserving systems.

References:

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