Comparing No-Till and Tilled Wheat in Kentucky

James Herbek, Lloyd Murdock, John Grove, Larry Grabau, Dave Van Sanford, Jim Martin, John James and Dottie Call, Department of Plant and Soil Sciences; Don Hershman, Department of Plant Pathology; Doug Johnson, Department of Entomology

Historically, wheat planting in Kentucky has involved tillage. With conventional tillage practices, most residues from the previous crop are cut and buried prior to seeding wheat. No-till wheat planting eliminates tillage and reduces soil erosion, particularly on sloping soils, as well as reducing labor, machinery, and energy costs. No-till also increases the opportunity for timely planting of wheat, especially when wet fall weather creates a schedule conflict between harvest of corn and soybean and tillage for wheat establishment.

Many producers have been curious about no-tillage wheat but have expressed concerns about yield and management of the crop. Several projects have been undertaken by University of Kentucky researchers working with farmers to get a better understanding of no-tillage wheat. Most of these projects, which were funded by the Kentucky Small Grains Promotion Council, compared no-till wheat with tilled wheat. The following is a summary of the major lessons learned about no-till wheat from those projects.

Research Overview

Kentucky producers became interested in no-till wheat about 1980. Much of this interest was a result of the availability of narrow-row drills that were capable of placing seed directly through crop residue and into contact with the soil. Farmers were already using no-tillage practices in corn and soybeans. Many of the farmers who grew corn and soybeans also grew wheat. Moving wheat to a no-tillage system seemed like a logical step—as long as no-till would not reduce wheat yields.

Feasibility, Yield, and Management—As a result of the increased interest in no-till wheat in Kentucky, research studies were initiated in the mid-1980s to determine the feasibility, yield potential, and management practices required for its production. Although initial studies showed favorable results for no-till wheat, many producers remained skeptical and believed that yield potential would be sacrificed, wheat stand establishment would be difficult and irregular, pests (weeds, diseases, and insects) would intensify, and increased costs (nitrogen, weed control, and seed) would reduce profitability. To respond to these reservations, additional studies and on-farm tests were conducted over 20 years to define no-till wheat management practices and obtain long-term comparisons between tilled and no-till wheat for yield, profitability, and effects on succeeding crops in rotation with wheat.

Rotational Cropping—A long-term study was established in 1992 at the University of Kentucky Research and Education Center (UKREC) in Princeton to compare no-till and tilled wheat in a three-crop, two-year rotation of corn, wheat, and double-cropped soybean, which is a prevalent cropping system in Kentucky. Other studies were done on the UK Agronomy Research Farm (Spindletop) near Lexington. Nitrogen, disease, insect, and weed control management were compared for both wheat planting systems. The long-term effects of the two wheat tillage systems on the succeeding soybean and corn crops and on soil property changes were also evaluated (summer grain crops were no-till planted behind both wheat tillage systems).

Profitability—To determine profitability of no-till wheat, on-farm tests were conducted from 1997 through 2000. Additionally, on-farm tests were established in 2000 to substantiate the beneficial effects of no-till wheat on the yield of corn and soybean crops in rotation with wheat that occurred in University research studies.

Yield Comparisons

Some producers have a belief that no-tillage significantly reduces wheat yields. Yields were compared in the research studies and on-farm tests conducted in Kentucky over the past 20 years. Results of several studies and tests are reported in Tables 1-4.

Initial Research—Studies from 1984 through 1987 provided favorable yield results for no-till wheat (Table 1). Although slight yield differences occurred between the two wheat tillage systems in individual years, the average yields for the four-year period were very similar for no-till and tilled wheat following a corn or soybean crop. Climatic conditions seemed to determine the yearly difference between the wheat tillage systems. No-till wheat did better in warmer springs, and tilled wheat did better in cooler springs.

Subsequent on-farm research tests provided additional yield comparisons of no-till and tilled wheat (Table 2). Wheat management practices were conducted by farmer-cooperators.

On-Farm Test A—Eleven tests were conducted over three growing seasons (1997-2000). The average yield for tilled wheat was 4.2 bu/ac greater than for no-till (Table 2). Ten of the 11 tests resulted in greater yields for tilled wheat. However, the yield advantage for tilled wheat was quite different among growing seasons as well as growers, ranging from less than1 bu/acre to more than 12 bu/acre. Wheat management practices and the experience of the no-till producers varied across the tests and may account for the wide variation in yield differences among individual tests. It is our experience that better no-till wheat yields are achieved by experienced no-till wheat growers who have the management skills to be successful.

On-Farm Test B—Yield comparisons for no-till and tilled wheat were obtained from 12 fields over a six-year period (2001-2006). Side-by-side comparisons were made on farmer's fields, with tillage treatments being blocks of 20+ acres. All of the needed wheat management practices were conducted by the farmer-cooperators with their own equipment. Average yield was similar for no-till and tilled wheat (Table 2).

Long-Term Study—In the fall of 1992, a study was established at the UKREC in Princeton to obtain long-term yield comparisons. The study involved a rotational cropping system of corn, wheat, and double-cropped soybean. Wheat (tilled and no-till) was planted after corn harvest, followed by no-till planted soybean immediately after wheat harvest, then planting of no-till corn the following year (second year of rotation). The study was designed for the two-year cropping system rotation so that yields for the two wheat tillage systems, as well as succeeding soybean and corn crops, could be compared annually.

Sixteen years of wheat tillage yield comparisons (1993-2008) have been completed for the above study at UKREC (Table 3). The 16-year average yield for tilled wheat was 1.6 bu/acre greater than for no-till wheat. The relative yield differences between the two wheat tillage systems varied each year depending on climactic conditions, which seem to have a larger impact on no-till wheat. (Tilled wheat yields tend to be greater when freeze damage or cool conditions occur.) On a yearly basis, tilled wheat had significantly greater yields five of the 16 years (primarily due to spring freeze damage or winter injury to no-till wheat); no-till wheat had significantly greater yields three of the 16 years; no significant yield differences occurred for the other eight years. The yield results from this long-term study provide a good comparison for the relative yield potential of tilled and no-till wheat because the study has been conducted over a 16-year period at the same site, which was subjected to varying climatic conditions.

During the last 10 years (1999-2008) of the above study, the average yield of the two wheat tillage systems was almost identical, with no-till wheat averaging 0.8 bu/acre more than tilled wheat (Table 3). On a yearly basis, yields were higher for tilled wheat in two years, higher for no-till wheat in three years, and no different in five years. Results from the last 10 years may be an indication that the yield potential of the two wheat tillage systems had become more equivalent. It may be due to improved soil structure that has occurred under no-till, a better understanding of no-till wheat management, less occurrence of unfavorable weather, or a combination of these factors.

Wheat Variety Trials—Additional wheat tillage yield comparisons were obtained from the University of Kentucky Wheat Variety Trials. Yield data was obtained from 17 wheat varieties grown each season for three growing seasons (1998-

Table 1. Wheat Yield Response to Tillage following Corn and Soybean Crops (1984-87)

Tillage System	Following: Corn	
	Corn	Soybean
	Yield (bu/ac)	
No-Till	70	76
Tilled	71	76

Table 2. On-Farm Research Comparisons of No-Till and Tilled Wheat

Tillage System	Test A[a]	Test B[b]
	Yield (bu/acre)[c]	
No-Till	77.9	82.6
Tilled	82.1	82.9
Tilled Yield (+ or -)	(+4.2)	(+0.3)

a 11 tests were conducted over three growing seasons (1997-2000).
b Included 12 fields over six growing seasons (2001-2006) with side-by-side comparisons.
c Yield averaged over multiple tests (location x years).

Table 3. Long-Term Yield Comparisons of No-Till and Tilled Wheat

Tillage System	1993-2008	1999-2008
	Average Yield (bu/ac)	
No-Till	96.6	102.0
Tilled	98.2	101.2
Tilled Yield (+ or -)	(+1.6)	(-0.8)

NOTE: Studies were conducted on long-term plots located at the University of Kentucky Research and Education Center at Princeton.

Table 4. Yield Comparisons of No-Till and Tilled Wheat in the University of Kentucky Wheat Variety Trials, 1998-2000

Tillage System	Shelby County	West Kentucky
	Yield (bu/ac)[a]	
No-Till	74.8	72.9
Tilled	71.9	69.8
No-Till Yield (+ or -)	(+2.9)	(+3.1)

a Yield is the mean of 17 varieties common in the tests all three years.

2000). During each growing season, a tilled trial was compared to a no-till trial at each of two locations in Kentucky.

When the yield of all 17 wheat varieties was averaged together over the three growing seasons, no-till wheat yield was about 3 bu/acre greater than for tilled wheat (Table 4).

Conclusion—The yield data from all of the studies indicate that yields for no-till wheat are about equal to those for tilled wheat. Average no-till wheat yields were about 1% less than tilled wheat yields. No-till yields ranged from 4% more than tilled wheat yields to 5% less, depending on year and location of the study. Sometimes no-till wheat will yield 3-4% less than tilled wheat for the first few years as a change is made from tilled to no-till wheat production, with the average yield of the two wheat tillage systems becoming equivalent after the first few years. The lower wheat yields for no-till wheat are likely offset by the reduced costs and labor associated with no-till wheat.

Wheat Stand Comparisons

Stand establishment and seeding rate will change with no-till wheat production. Most wheat in Kentucky follows corn, which results in a large amount of residue that can hinder no-till wheat planting. No-till wheat stands are usually not perfect, and this is one of the reasons that some producers have been slow to adopt no-till. Their belief is that imperfect wheat stands reduce yield potential. However, with no-till planting experience, careful planting management, and proper no-till planting equipment, very acceptable wheat stands can be obtained (Table 5).

On-Farm Tests—The average no-till wheat stand was one plant/ft^2 less than that found for tilled wheat in the 11 tests conducted over three growing seasons (Table 5). However, comparative wheat stands achieved for the two wheat tillage systems differed among growing seasons and farmer-cooperators. In the 11 tests, stands were greater in four tests with no-till wheat, greater for five tests with tilled wheat, and equivalent in two tests. Although wheat seeding rates differed among the 11 on-farm tests, each farmer-cooperator used a higher seeding rate for no-till wheat. However, this higher seeding rate did not always result in stands greater than those for tilled wheat. These results are evidence that more careful planting management (including residue management, properly equipped no-till drills, and drill adjustments for existing planting conditions) is needed for successful no-till wheat stand establishment.

Long-Term Study—In a study conducted over 15 years using a similar seeding rate of 32 viable seeds/ft^2 for both tillage systems, the average no-till wheat stand was approximately 1 plant/ft^2 less than that for tilled wheat (Table 5). The comparative wheat stand difference between no-till and tilled wheat observed each year varied with planting conditions. In some years, no-till wheat achieved a higher stand. A no-till wheat stand of two to three plants/ft^2 less than that of tilled wheat can usually be expected. At optimal seeding rates of 30 to 35 viable seeds/ft^2, the no-till wheat stand that is achieved is usually sufficient for maximum yield potential, even though lower no-till wheat stands are expected.

Current recommendations are to increase the wheat seeding rate for no-till by 10 percent, particularly for inexperienced producers changing from tilled to no-till wheat, in fields where heavy corn residue exists, or where residue distribution is not very uniform. However, many experienced no-till wheat producers do not increase their seeding rate because they have knowledge and experience with management of no-till wheat planting and the adjustments needed for different planting conditions.

Irregular No-Till Wheat Stands—Irregularity in stands has not been proven to affect yield consistently. Many farmers use tramlines (unplanted rows) in their wheat to guide spray application equipment. Studies indicate that tramlines do not reduce yield, because the rows on each side compensate for the missing wheat. Thus, a no-till wheat field can probably tolerate a certain amount of stand irregularity.

Stand irregularity in no-till wheat is often the result of small skips in the row. A study in the 1999-2000 growing season looked at this. Soon after wheat emergence, plants were removed to establish within-row skips. Treatments included length of skip (6-18 inches) and also the percentage of area skipped (containing no plants). Variance in the percentage of area skipped resulted from varying the number of skips within a plot area. Additionally, two varieties that differed in tillering potential were compared.

Wheat yield (Table 6) was affected more by the percentage of area containing no plants (that is, percentage of area skipped) than the length of skip. When the percentage of area skipped remained the same but the length of skip increased, there was no significant

Table 5. Comparison of Stand Establishment in No-Till and Tilled Wheat

Tillage System	Desired Stand Plants/ft^2	On-Farm Tests (1998 – 2000)	Research Study (1993 – 2007)
		Average Stand (plants/ft^2)	
Tilled	25	29	28
No-Till	25	28	27

Table 6. Effect of Irregular Stands (skips within the row) on Wheat Yield (2000)

Area Skipped (%)	Length of Skip (inches)	Variety: Pioneer 25R26[a]	Variety: Pioneer 2552[b]
		Yield (bu/ac)	
0	0	110	107
5	12	109	102
10	12	105	108
10	18	108	108
15	12	109	101
15	18	106	101

a Pioneer 25R26 = prolific tillering potential.
b Pioneer 2552 = average tillering potential.

change in yield. However, the percentage of area skipped definitely had an effect on yield, which was also dependent on variety. The less prolific tillering variety (Pioneer 2552) did not show a significant yield reduction until 15% of the area was without plants, indicating that fields containing skipped areas of up to 10% could be tolerated. The more prolific tillering variety (Pioneer 25R26) tolerated a skipped area of up to 15% without a yield loss.

This study was continued for three more growing seasons (2001 through 2003). Based on results from the initial study (1999-2000), skip length was not varied (all skips were 12 inches in length). However, the area containing skips was increased to 20%. Two varieties that differed in tillering potential were again used. A reduced seeding rate (25 seeds/ft^2) was also used in the field with the largest skipped area (20%).

Average wheat yield results over the three seasons for this study (Table 7) were very similar to those obtained in the initial study (1999-2000). The less prolific tillering variety (Pioneer 2552) again tolerated skipped areas up to 10% of the total area without yield loss; however, yield again tended to be less when 15% or more of the area contained skips. Yield was also greatly reduced with this less-prolific tillering variety when the seeding rate was reduced to 25 seeds/ft^2 for the field with the largest skipped area (20%). The more prolific tillering variety (Pioneer 25R26 or 25R37) again tolerated a skipped area of up to 15% of the total area without a significant yield loss. In two of the three years, yield was not reduced even when 20% of the area contained skips. The more prolific tillering variety also seemed to better tolerate a reduced seeding rate when 20% of the area contained skips. In fact, yield of this variety was not significantly reduced at the reduced seeding rate in two of the three years.

In order for yield to remain the same when irregular stands occur due to skips, the yield of individual plants surrounding the skip must increase. Due to increased tillering, the number of heads for plants in the rows that surrounded the skipped areas increased by 35 to 50%. The yield compensation could have also occurred from more grains per head or more weight per grain (data not taken).

Conclusion—No-till wheat fields with irregular stands should be able to maintain yield potential unless a substantial portion of the field contains no plants (skips). Research data indicates that when the area containing skips was 10% or less, there was no yield loss, regardless of variety (tillering potential). When the area containing skips was as large as 15 to 20%, varieties with high tillering potential had no or minimal yield reduction. However, yield is likely to be reduced at lower (less-than-optimum) seeding rates if the percentage of area with skips is 20% or larger, particularly for varieties with less tillering potential.

Crop Residue Management

Another aspect of no-till wheat stand establishment is crop residue management. Most wheat in Kentucky is planted following corn, which results in a large amount of residue that can hinder no-till wheat seed placement. No-till wheat stand establishment is more successful following soybean due to a lesser amount of residue if the residue is uniformly spread during harvest.

Producers debate the best method for managing corn residue for no-till wheat planting. Many producers seed directly into the corn residue as it exists following corn harvest. Other producers prefer to mechanically shred corn stalks, which results in a more uniform distribution of smaller pieces of residue. Non-shredded corn residue is not uniformly distributed and also has larger stalk pieces that the no-till drill must cut through before placing the seed in the soil.

A study conducted for two years (1998-99 and 1999-2000) indicates there may be no best method for managing corn residue for no-till wheat planting. Two mechanical shredding methods (rotary-mowed and flail-mowed) were compared with two direct seeding methods (stalks were not shredded). The two direct seeding methods consisted of planting parallel to the corn stalk rows and planting at an angle to the rows. Additional treatments consisted of no residue (corn residue above the soil surface removed) and an increased seeding rate for direct seeding. The wheat seed-

Table 7. Effect of Irregular Stands (Skips within the Row) on Wheat Yield over 3 Years (2001-2003)

Area Skipped (%)	Length of Skip (inches)	Seeding Rate (Seeds/ft^2)	Variety: Pioneer 25R26[a]	Variety: Pioneer 2552[b]
			Yield (bu/ac)	
0	0	35	99	96
5	12	35	97	96
10	12	35	98	95
15	12	35	97	93
20	12	35	93	92
20	12	25	91	84

a Pioneer 25R26 = prolific tillering potential (25R27 in 2003).
b Pioneer 2552 = average tillering potential.

Table 8. Effect of Corn Residue Management on No-Till Wheat Stand and Yield over 2 Years (1998-2000)

Corn Residue Treatment	Stand (plants/ft^2)	Yield (bu/ac)
Corn residue removed	34	107
Flail-mowed residue	31	106
Rotary-mowed residue	31	103
Non-shredded (parallel planted)	32	104
Non-shredded (diagonally planted)	31	113
Non-shredded (15% seed increase)	37	108

ing rate was 35 seeds/ft^2 except for the increased seeding rate treatment of 40 seeds/ft^2.

Results from this study indicated there is no consistently best method for managing corn residue (Table 8). Except for residue removal or an increased seeding rate, none of the other corn residue management methods resulted in better wheat stand establishment. All of the corn residue management methods achieved a wheat stand above 30 plants/ft^2, high enough for maximum yield potential. No consistent yield differences occurred among the corn residue management treatments, although there was a trend for lower yields with the rotary-mowed and non-shredded, parallel-planted treatments. Based on measurements of soil cover, flail-mowed corn residue was more evenly distributed than rotary-mowed corn residue.

Although not indicated by the wheat stand results in this study, planting diagonally to the corn stalk rows in non-shredded residue might have an advantage over planting parallel to the corn stalk rows. This advantage would occur because individual wheat drill-row units would not be consistently traversing the heavy residue in the corn stalk row, which would hinder seed placement.

Another approach to residue management tried by some wheat producers has been the use of aeration or tillage with a rotary tine harrow prior to otherwise no-till wheat planting. These tillage practices can break up and incorporate a bit of corn residue while "scratching" the soil surface. A three-year study to examine the benefit of these tillage practices, conducted at two locations, found no positive yield impact on no-till wheat after corn (Table 9).

Careful management during the planting process is critical for achieving successful wheat stands, regardless of the residue management method. These studies were conducted under good conditions for wheat stand establishment and generally favorable growing seasons. Under unfavorable weather, corn residue management could influence wheat stand and/or yield. A cool fall and spring would deter wheat growth and development (tillering). Irregular residue distribution would also result in irregular seed placement. Shallow seed placement would subject plants to more winter injury and also decrease their ability to survive cold temperatures.

Profitability of No-Till Wheat

Most experiments comparing tilled and no-tilled wheat have not included economics as a part of the data. An experiment was conducted comparing data from 11 on-farm field trials over three growing seasons (1997-2000). The average yield for tilled wheat was 4.2 bu/ac greater than for no-till wheat. The yield differential was multiplied by a reasonable market price for each year, which resulted in an average advantage in gross income of $11.80/acre for tilled wheat. The average additional costs (residue management and tillage) was $25.10/acre for the tilled wheat, while the average additional costs (seed, herbicide, and nitrogen) was $15.50 for the no-till wheat. On the average, these 11 tests showed, by this partial budget analysis, a slight advantage of $2.20/acre for tilled wheat. These on-farm field trials had the greatest yield disadvantage for no-till wheat. All other studies showed little or no yield disadvantage for no-till wheat compared to tilled wheat.

The recent economic impact of higher costs for machinery, labor, and fuel favor no-till wheat and have provided the incentive for more growers to switch to it. Additional incentives that favor no-till wheat include an economic credit for topsoil conservation and potential benefits to rotated corn and soybean crops.

No-Till Wheat Planting Date

Wheat planting dates have tended to become earlier in recent years. That trend has coincided with some producers' belief that no-till wheat needs to be planted earlier than tilled wheat, especially when following corn. When evaluated in a three-year study (1997-99 harvests), no-till wheat after corn did not benefit from earlier planting (Table 10), though yields of both tilled and no-till wheat were reduced with a late November planting date. In keeping with these research observations, current recommendations do not call for earlier planting of no-till wheat compared to tilled wheat.

Table 9. Effect of Aeration and Rotary Tine Harrow Tillage on Wheat Yield over 3 Years (2005-2007) at Two Locations

Location Number	Tillage	Grain Yield (bu/ac)			
		2005	2006	2007	Average
1	No-Till	66.4	70.2	46.4	61.0
	Aeration	61.8	74.0	47.5	61.1
2	No-Till	69.4	90.3	56.0	71.9
	Aeration	75.2	89.0	56.0	73.4
	Aeration + Harrow	71.1	90.1	56.9	72.7

Table 10. Effect of Tillage and Planting Date on Wheat Yield in 1997, 1998, and 1999

Planting Date	Tillage	Grain Yield (bu/ac)			
		1997	1998	1999	Average
Middle October	No-Till	43	74	74	63
	Tilled	44	81	81	68
Early November	No-Till	55	77	67	66
	Tilled	50	82	69	67
Late November	No-Till	50	77	48	58
	Tilled	49	80	48	59

Wheat Varieties

There continues to be a question as to whether or not certain varieties should be targeted for no-till wheat. Seventeen wheat varieties were compared in no-till and tillage each season for three growing seasons at two locations. Varieties that have performed well in no-till conditions also performed well in tilled conditions (correlation coefficient of 0.85). The conclusion, after three years of wheat variety-tillage trials, was that varieties which performed well with tillage will very likely perform well with no-tillage. Varieties with above-average tillering potential would be advantageous if irregular or reduced stands occurred.

Nitrogen Fertility

Recommended nitrogen (N) rates on most no-tilled crops are greater than those for tilled crops. Research studies indicate that an additional 20 to 30 lb N/acre is needed to maximize no-till crop yields. Present University of Kentucky recommendations reflect these research results. A nitrogen study was conducted on no-till wheat to determine if the extra nitrogen could always be justified (Table 11). The N in this study was managed for maximum wheat production, with one-third applied at the Feekes 3 growth stage (February) and the remainder at Feekes 5 (mid-March). The recommended N rate for no-till wheat is 120 lbs N/acre and for tilled wheat is 90 lbs N/acre.

The no-till wheat sometimes appeared to be slightly N deficient before the second application, but in most years this had little effect on yield. Table 11 shows that increasing the N rate from 90 to 120 lb N/acre had only a small effect on yield. Over the 16 years of the study, the extra 30 lb N/acre increased both no-till and tilled wheat yields by an average of 4 bu/acre. Although 120 lb N/acre is recommended for no-till wheat, it is not always justified. The years that this rate of N resulted in higher yield were those in which late winter freezes resulted in wheat damage or when excessive amounts of rain fell after the first application of N. The 120 lb N/acre rate yielded significantly more than the 90 lb N/acre rate in seven of the 16 years. The economic return to the extra 30 lb N/acre for no-till wheat would only be slightly greater than breakeven when considered over the 16 years.

The increased N rate needed on no-till wheat is due to the increased amount of crop residue on the soil surface. Under no-till conditions, reduced soil N mineralization and greater fertilizer N immobilization occurs when fertilizer N is surface applied and crop residues are present.

Nitrogen Sources—Choice of fertilizer N source for no-till wheat should be guided largely by the cost of N from each source, especially for fields with generally well-drained soils. A two-year study, summarized below (Table 12), found little difference in no-till wheat yield response to rates of N from ammonium nitrate (34-0-0), urea (46-0-0), or urea-ammonium nitrate (UAN) solution (28 to 32-0-0), the latter applied both broadcast and via stream jets. The optimal rate was close to 90 lb N/acre when no-till wheat followed corn. There was less response to fertilizer N when soybean was the previous crop, and only 30 lb N/acre was required in these two years.

Cold Injury

No-till wheat has been more susceptible to cold injury than tilled wheat, and this is probably the main reason that no-till wheat yields are lower than tilled wheat yields in some seasons. Cold injury is experienced mainly in March or April as temperatures are warming and the wheat plants become more susceptible to this injury. Temperature measurements indicate that the soil warms more slowly in no-till wheat fields, with lower night temperatures both at the soil surface and 2 inches above the surface. The lower temperatures at and just

Table 11. Effect of Nitrogen Rates on Tilled and No-Till Wheat over 16 Years (1993-2008)

Tillage	Total Nitrogen Rate (lb/ac)	Average Yield (bu/ac)
No-Till	90	95
No-Till	120	99
Tilled	90	96
Tilled	120	100

Table 12. Effect of Previous Crop, N Source, and N Rate on 2-Year (1999-2000) Average No-Till Wheat Yield

		2-Year Average Grain Yield (bu/ac)			
Previous Crop	N Rate (lb N/ac)	Broadcast Ammonium Nitrate	Broadcast Urea	Broadcast UAN Solution	Stream-jet UAN Solution
Corn	0	59	59	59	59
	30	61	69	70	66
	60	71	79	73	75
	90	81	81	78	78
	120	77	80	78	80
	150	79	76	76	78
Soybean	0	77	77	77	77
	30	80	84	84	83
	60	76	83	84	84
	90	77	83	87	83
	120	80	82	78	82
	150	76	77	73	80

above the soil surface in no-till wheat can be attributed to the layer of previous crop residues that impedes radiation of heat from the soil.

On one occasion of freeze damage, the temperatures were 5° F lower at the no-till soil surface than at the tilled soil surface. Since the temperature that night was close to the critical temperature for damage, no-till wheat experienced about 25% more stem damage than tilled wheat.

Fortunately, critically cold temperatures do not occur often, so the overall yields of the two wheat tillage systems are similar when compared over years.

Weed Control

Weed control is one of the most important management practices for successful no-till wheat production (Table 13). In research trials, yield reductions that resulted from lack of weed control varied by year and were almost 40% in some years. On average, yield was reduced by 15 to 20% when no weed control occurred. Without herbicide applications in the fall or spring, weed competition was mainly from henbit, some common chickweed, annual bluegrass, and field pansy. Good weed control in no-till wheat was obtained with three treatments:

- Harmony Extra® (DuPont) applied in the fall about 30 to 45 days after planting
- A contact herbicide at planting plus Harmony Extra in the spring at the Feekes 5 to 6 growth stage
- Harmony Extra in the spring at the Feekes 5 to 6 growth stage

Table 13. Effect of Weed Control Methods on No-Till Wheat over 11 Years (1993-2003)

Weed Control	Yield (bu/ac)
Gramoxone at Planting, Harmony Extra in Spring	95
Harmony Extra 30-45 days after Planting	95
Harmony Extra in Spring	93
None	80

The recommended method to assure good control of emerged weeds is to apply a burndown herbicide such as paraquat or glyphosate at planting followed by a herbicide such as Harmony Extra in the spring at Feekes 5 to 6. For special problem weeds, such as annual ryegrass, additional herbicide treatments may be needed.

Insects

Using scouting and traps, insects were monitored for 11 years of the long-term trial comparing tilled and no-tilled wheat at Princeton. Barley Yellow Dwarf (a viral disease vectored by aphids) was present in both the tilled and no-till wheat the first year of the 11-year trial but was more prevalent in the no-till wheat. Conversely, the incidence of the disease did not appear to be necessarily linked to the tillage system used. Thus, after the first year, insecticides were applied each fall and the disease was never present to any extent during the remaining 10 years. This insecticide cover treatment effectively removed aphids, the most important risk factor, from the experiment. In the spring, a few aphids, true armyworms, and cereal beetles would be present but never approached the economic threshold. There was no difference between tilled and no-tilled wheat. No insect problems specific to no-till have been reported by farmers. An insecticide applied in the fall to control aphids (and the transmission of Barley Yellow Dwarf) is common in both tilled and no-tilled wheat. The greatest risk of insect damage that might be more important in no-till would be the possible presence of a "green bridge" between the grass weeds remaining in the previous crop and the newly emerged wheat. In a traditional tillage system these weeds would be plowed under, destroying the green bridge. When no-tillage is employed, destruction of the green bridge would largely be accomplished by herbicidal means or by mechanical means such as flail mowing.

Diseases

Diseases were monitored for 11 years in the long-term trial comparing tilled and no-tilled wheat. Barley Yellow Dwarf was somewhat more prevalent in the no-till wheat but was found on wheat in both soil management systems. Other diseases that survive in deteriorating wheat stubble, such as tan spots, speckled leaf blotch, and leaf and glume blotch, are apparently not worse in no-till wheat. This is because planting wheat after wheat is uncommon in Kentucky and infested residue deteriorates quickly in Kentucky soils. In other words, no-till wheat fields are not at greater risk to these diseases than tilled fields. The wind-borne diseases—leaf rust, stripe rust, and stem rust—were not expected to be more common or severe, which has turned out to be the case.

Fusarium head blight (FHB), also called Head Scab, is caused by a *Fusarium graminearum*, a fungal organism that is common in soil, on decaying corn stalks, and on wheat and soybean residue. Corn residue is the main fungal survival substrate of concern because it is the bulkiest substrate and may persist in fields for two or more years under typical Kentucky climatic conditions. Many plant pathologists and wheat experts in the United States believe that no-till wheat planted after corn will result in significant fusarium infection when the conditions are right for the expression of the disease in wheat, due to the large inoculum base (high spore levels of the causal fungus).

Plant pathologists in Kentucky believe the rate of infection is high and about equal with the two different tillage systems. Spores of the FHB fungus are known to be windblown long distances. So, as long as conditions favor spore production and dispersal , the inoculum levels in the environment would generally be high everywhere(in all fields), largely negating any impact of somewhat higher spore levels (inoculums) in the field where no-till wheat is planted following corn.

To test the above hypothesis, a three-year survey (249 fields total) was conducted from 1997-2000. FHB was moderate to light during the years of the survey. Results confirmed the hypothesis that FHB was no more severe in no-till than tilled wheat when conditions favored moderate-to-light FHB. The survey also confirmed that high corn residue levels (percent surface cover) are frequently associated with tilled Kentucky wheat fields. Residue levels were higher in no-till fields, but the assumption that corn residue is eliminated, or even greatly reduced, by tillage before seeding wheat in Kentucky is erroneous. In addition, a three-year, on-farm trial confirmed that there seems to be little difference in FHB between tilled or no-till wheat in moderate-to-severe FHB years (Table 14). In this trial, large fields were split for side-by-side comparisons of no-till and tilled wheat planted behind corn. Each treatment had a minimum of 20 acres, so the data should somewhat represent a field situation. The disease was significant in 2002 and 2003 and was a severe problem in 2004. The data collected showed no trends to indicate that no-till wheat fosters conditions that result in a greater amount of FHB. There was a slight trend towards increased levels of the grain toxin deoxynivalenol (DON) in no-till wheat (data not presented), but this tendency is outweighed by the significant benefits associated with no-till.

Long-Term Rotational Effects

No-till wheat, as a part of a continuous no-tillage cropping system rotation that included no-till double-crop soybean and no-till corn, resulted in soil structural change and a subsequent increase in soybean and corn yields as compared to the same crop rotation with tilled wheat.

Long-Term Study—A 16-year, small plot trial established to compare tilled and no-tilled wheat indicates that both no-till double-cropped soybean and no-till corn tend to yield more when planted behind no-till wheat as compared to tilled wheat (Table 15). The yield increase observed was 5% for soybean and 4% for corn. These yield differences indicate that soil property changes between the two wheat tillage systems have taken place with time and that these changes favor the system with continuous no-tillage establishment. Soil investigations indicate that the reasons for the difference are due to residue cover, soil moisture, and physical property changes in the soil. The most important soil factor probably was a change in pore size distribution. There were more medium-sized pores in the upper 6 inches of soil that was continuously no-tilled, which enabled the soil to hold more plant-available water—a very important characteristic in Kentucky soils that are not noted for being extremely deep.

On-Farm Study—An on-farm research trial that involved six farms over six seasons (2001-2006) looked at tilled and no-till wheat in the context of a rotation of wheat, no-till double-crop soybean, and no-till corn. Farmer fields and management practices on large, field-size plots of 20+ acres were used. In the first two years of the trial, there were no significant differences in yields of any of the three crops and no significant differences in any of the soil physical parameters that were measured. As the trial continued, the soil properties and some of the yields began to change.

Wheat Yields—The average wheat yields for the fields over the six wheat crops grown from the beginning of the project are reported in Table 2 (Test B). The wheat yields with the two different tillage practices were the same.

Soybean Yields—When the yields of the six fields were averaged over the six years that double-crop soybean was grown, the yields were very similar and there were no statistical differences (Table 16). Based on previous research, we would expect the yields of soybean in the continuous no-tillage system to increase during some years due to soil structural changes that are expected to take place with time. However, soybean yields for the final two seasons of the project were not significantly different between tillage systems (data not shown). Even though soil structure was changing in the no-till fields compared to the tilled fields, soybean yields were not affected. It is felt that the weather conditions were not right for the soil changes to cause a difference in yield during these two years. Past research indicates that a yield increase is found about one-third of the time.

Corn Yields—Corn yields over the six seasons for tilled and no-tilled were almost identical (Table 16). By the final two seasons, corn yields were greater for the no-tilled conditions (Table 17), which indicates that soil structural changes were taking place and weather conditions were favorable for these changes to be expressed in terms of an increased corn yield.

Soil Measurements—Soil measurements were taken at least once each year. There were no changes or small changes between the no-till and tilled wheat areas the first two years. Soil measurements for the fields that had been in the program for three consecutive years indicated that significant soil changes had taken place. By the third season, the aggregate size and bulk

Table 14. Effect of Tillage on the Incidence and Severity of Head Scab in Large Acreage Comparisons in 2002, 2003, and 2004

Year	Tillage	Incidence[a] (% of heads)	Severity[b] (% of head)	Severity Index[c] (%)	VSK[d] (%)
2002	No-Till	18.5	33.9	6.6	-
	Tilled	19.4	27.5	5.7	-
2003	No-Till	24.0	10.6	2.4	-
	Tilled	39.7	24.4	7.4	-
2004	No-Till	61.5	35.5	21.5	41.1
	Tilled	68.2	41.5	27.9	48.3
Average	No-Till	34.7	26.7	10.2	41.1
	Tilled	42.4	31.1	13.7	48.3

a Incidence = percent of heads in field with head scab.
b Severity = percent of infected head area showing symptoms.
c Severity Index = combined rating of incidence and severity/100.
d VSK = percent visually shriveled kernels.

Table 15. Effect of Wheat Tillage Systems on the Average Yield of Succeeding Double-Crop Soybean and Corn Crops after 14 and 13 Years, Respectively.

Succeeding Rotational Crop	Tilled	No-Till
	Yield (bu/ac)	
Double-Crop Soybean[a]	39	41
Corn[b]	182	189

a Three of 14 years no-till was significantly higher.
b Four of 13 years no-till was significantly higher.

density were significantly greater in the no-till wheat fields. The plant-available water-holding capacity in the surface 6 inches was greater in no-till but not significantly different relative to tilled wheat. Soil changes were taking place in the no-till wheat fields but did not result in greater corn or soybean yields during the third year due to either soil changes not being great enough at that time or rainfall amount and distribution not favoring conditions that would result in an increased yield even with the soil changes.

By the fourth season, significantly greater aggregate size and bulk density was measured in the no-tilled areas. The plant-available water-holding capacity was greater in the no-till wheat treatment on some of the fields. The soil structure change that occurred in some of the no-till wheat fields appeared to be great enough to result in a yield difference in the succeeding crop. On some of the other fields, aggregate size, bulk density, and plant-available water-holding capacity were only marginally different, and the succeeding crop yields on these fields did not favor the no-tillage wheat system.

Four seasons of continuous no-tillage appeared to be long enough to cause significant changes in soil properties in some fields but was associated with only marginal changes in other fields. Either more time is required to make soil structure changes in some of the fields, or these fields were "structurally behind" other fields at the beginning of the study, requiring more time for observable change.

Lessons Learned

Based on several years of University of Kentucky research, most of the concerns and problems anticipated with no-till wheat did not materialize. The best management for no-till wheat is as follows:

- Increase the seeding rate about 10%.
- Increase N fertilizer rates about 20 lb N/acre.
- Apply fall and spring herbicides for good weed control.
- Distribute the corn or soybean residue evenly.
- Check planting to assure good seed placement in the soil.

All other practices are similar to those for tilled wheat.

Table 16. Effect of Wheat Tillage on the Succeeding Yields of Double-Crop Soybean and Corn for Six Fields over Six Years, 2001-2006

Tillage	Yield (bu/ac)	
	Soybean	Corn
No-Till	42	174
Till	43	173

Table 17. Effect of Wheat Tillage on the Succeeding Corn Yields the Last Two Years of the Six-Year Trial, 2001-2006

Tillage	Yield (bu/ac)
No-Till	184
Till	179

Table 18. No-Till Wheat Adoption in Kentucky (1980-2008)

Year	Harvested Acres (% No-Till)
1980	<1%
1990	22%
1994	29%
1997	37%
2000	39%
2004	42%
2008	50%
2009	69%

NOTE: Data for 1990, 1994,1997, 2000, and 2004 from National Crop Residue Management Survey coordinated by the Conservation Tillage Information Center (CTIC). No CTIC information available for 1980, 2008, or 2009. Numbers for those years based on farmer survey.

Farmer Practices

Since the first questions about no-till wheat occurred in the 1980s, harvested wheat acres in Kentucky under no-till management have increased to about 70% of the current crop (Table 18). The increased adoption of no-till wheat is the result of farmers and University of Kentucky personnel working together to ask smart questions and attempt to find good answers. Research has shown that a yield reduction of about 3 bu/acre may occur as a farmer moves from tillage to no-tillage wheat establishment, but many farmers have not experienced an initial yield reduction. In most cases, there is no difference in yields as farmers gain experience and the soil structure changes. Depending on input costs and commodity prices, anything less than a 4 bu/acre reduction should result in a net positive return to no-tillage. Also, a continuous no-tillage cropping system with a rotation of wheat, double-crop soybean, and corn may sometimes result in a slight yield increase (4% to 5%) for both the soybean and corn in the rotation, as opposed to soybean and corn yield when the wheat is planted into tilled soils. Continuous no-till systems tend to improve soil structure over time, increasing water-holding capacity.

No-till wheat production is not a perfect system and does have challenges distinct from those for tilled wheat production. However, in Kentucky the positive attributes of no-till wheat appear to outweigh the negatives for more and more farmers. Farmers have used tillage since the dawn of agriculture and throughout the ages, new questions have constantly arisen. No-tillage wheat production is still in its infancy, and no doubt new questions will arise here as well.

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