# Agronomic Impacts of Strip Tillage and New Reduced Tillage Systems in Corn Production

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## Research Application Summary

### (a) Problem description

Many farmers in the Corn Belt states are still reluctant to adopt no-till systems for corn in rotation with soybean. Their concerns range from possible delays in completing planting in the optimum time period, to concern for poor plant establishment and lower yields than those with conventional tillage. Many of these same farmers are intrigued about the adoption of more recent high residue tillage systems that are being encouraged by tillage manufacturers. These include:(a) fall strip tillage (with various shanks and berm-formation attachments), (b) very shallow full-width tillage operations with rotary harrows or roller harrows in spring (e.g. To The Max™, Turbo-Till™, McFarland™, Phoenix™, Phillips™), and, (c) very deep tillage with rippers involving full-width disturbance (e.g. disk rippers) or loosening in narrow slots with minimum surface soil disruption. There is, therefore, a need for more investigations of alternate single-pass systems.

**(b) Objectives:**

1. To compare the relative effectiveness of three relatively new tillage approaches (very shallow, strip tillage, and deep loosening) for corn following soybean on multiple soils types.
2. To determine possible interactions of corn response to strip tillage treatments with alternate planting dates.

### (c) Study description

Tillage experiments comparing multiple tillage systems for corn after soybean were established at three Purdue University Research Farm locations from 2003 to 2005. Some field studies were conducted for the full 3-year period, but resource constraints forced some of the experiments to be conducted for only 2 years. These 3 separate experiments are going to be considered under the two themes below.

<u>Fall Strip Tillage versus Disk Ripper and Traditional Tillage Alternatives:</u>

The largest tillage experiment (8 to 10 treatments with 4-6 replications) investigated strip tillage (8-10") with multiple planting dates relative to disk ripping (12-14"), chisel plow (8-10") and no-till systems for 2 years (2003-2004) at 2 locations. One location was near West Lafayette in North Central IN (Drummer silty clay loam prairie soil) and the other location was near Wanatah in North Western IN (Sebawa loam soil). The same strip tillage tool (Remlinger™) and disk-ripper-disk (Case-IH MRX 690™) as used at both locations.

The corn hybrid for these two experiments was Pion. 34M94. The early planting dates for strip-till and no-till were April 15, 2003 and April 7, 2004 at West Lafayette and April 15, 2003 and April14, 2004 at Wanatah. Most treatments (including the "normal planting dates" for no-till and strip-till) were planted on April 24, 2003 and April 20-26, 2004 at West Lafayette, and on April 28 in both 2003 and 2004 at Wanatah. All experiments included starter N band-applied at planting, the in-row application of Force as a soil insecticide, and side-dress UAN application at rates exceeding 200 pounds of N per acre.

Tillage treatment abbreviations include DRD (disk ripper disk), VE3BDR and VC3BDR (Vibra-Edge™ or Vibra-Chisel™ shanks, respectively, with a 3-bar double rolling harrow attachment for a Case-IH 4400 combo mulch finisher.

<u>Rotary Harrow Tools versus Traditional Tillage Alternatives:</u>

This tillage experiment was conducted near Columbia City (at Purdue University's North-East research farm) from 2003 to 2005. The field sites alternated between 2 soil types (the Blount/Pewamo soil in 2003 and 2005, and the Glynwood or Morley loam soils in 2004). Each year, we compared single-pass tillage tools (the standard field cultivator versus "To The Max" harrow or Great Plains "Turbo-Till" rotary harrow) in spring with the conventional chisel plow and no-till systems. These 30' or 32' wide rotary harrows were provided (together with a tractor) courtesy of the Allen County Soil and Water Conservation District. The single-pass tools were always used on the day before or the day of planting corn. Strip tillage was added to the trial in 2004, although as a spring strip-till operation some 10 days before planting in that first year. There were 4-6 replications.

The corn hybrid at this study was Pioneer 34D72, and it was generally planted in mid- to late April (although the test needed to replanted after excessive rain and stand loss in the first year on May 27, 2003). Corn always followed no-till soybean. All experiments included starter N band-applied at planting, the in-row application of Force or Aztec as a soil insecticide, and side-dress UAN application at rates exceeding 180 pounds of N per acre.

## (d) Applied Questions

1. *Are there any advantages to single-pass systems based on fall strip tillage, fall disk-ripping, or spring cultivation versus traditional tillage for corn after soybean?*

*(a) Silty clay loam soil:*

If maintaining surface residue to reduce soil erosion is a goal, then all 2-pass tillage systems would leave less than the 30% cover needed (Table 1). Strip-till systems left less residue cover than no-till, but considerably more than the best single-pass, full-width system (field cultivator at 36%). Plant populations were lowest in the no-till treatments (whether planted early or at the normal time). Plant populations were significantly higher in strip-till treatments than in no-till, and strip-till treatments had essentially the same final plant populations as all full-width tillage treatments. Although there were significant plant stand differences, the population range from the highest to the lowest treatment were only 6% different (1800 plants/acre), and this difference was not sufficient to have a major effect on yield.

Fall strip tillage resulted in taller plants (and a faster rate of plant growth) at 8 weeks, though not at 4 weeks after planting (Table 1). Full-width tillage systems tended to have even taller plants than strip tillage treatments in both measurement periods. Significant plant height differences were expected between planting dates since the soil temperatures were so much cooler after the first planting date than after the second planting date.

Table 1. Agronomic performance of corn following soybeans, W. Lafayette, 2002-2004.

| Tillage Treatment † | Residue cover | Week 4 stand | Height Week 4 | Height Week 8 | Grain moisture |
|---|---|---|---|---|---|
| | % | Plants/a. | Inches | Inches | % |
| 1. Fall chisel, spring fd. cultivate | 21 e ‡ | 29600ab | 14.3 b | 63.5 bc | 16.6 ab |
| 2. Spring field cultivate | 36 d | 29300bc | 14.3 b | 64.0 ab | 16.7 a |
| 3. Fall DRD, stale seedbed | 18 ef | 29600ab | 15.1 a | 65.7 a | 16.5 ab |
| 4. Fall DRD, spring field cultivate | 14 f | 29900a | 14.3 b | 64.0 ab | 16.6 ab |
| 5. Fall strip-till, early planting | 59 c | 29400abc | 5.4 d | 32.3 e | 16.3 c |
| 6. Fall strip-till, normal planting | 59 c | 29500ab | 12.8 c | 61.6 c | 16.6 ab |
| 7. No-till, early planting | 72 b | 28900c | 5.1 d | 29.8 f | 16.4 bc |
| 8. No-till, normal planting | 80a | 28100d | 12.4 c | 59.2 d | 16.7 a |

‡ Means with the same letter are not significantly different at P=0.05.

Table 2. Tillage effects on lodging in corn following soybeans West Lafayette,2003-04.

| Tillage Treatment (Ranked by percent lodged for the two year average) | Plant Lodging July, 2003 | Plant Lodging July, 2004 | Plant Lodging 2003-2004 |
|---|---|---|---|
| | % | % | % |
| 4. Fall DRD, spring cultivate | 28 a‡ | 61 a | 45 a |
| 3. Fall DRD, stale seedbed | 25 ab | 53 ab | 39 a |
| 1. Fall chisel, spring cultivate | 16 abc | 60 a | 38 a |
| 2. Spring field cultivate 1 pass | 28 a | 39 abc | 34 ab |
| 6. Fall strip-till, normal planting | 9 bc | 23 bcd | 16 bc |
| 5. Fall strip-till, early planting | 10 bc | 17 cd | 13 c |
| 7. No-till, early planting date | 3 c | 0 d | 2 c |
| 8. No-till, normal planting date | 1 c | 1 d | 1 c |

‡ Means with the same letter are not significantly different at P=0.05.

In July of both 2003 and 2004 we noted extensive plant lodging in all tilled plots, but practically no lodging in the strip-till and no-till plots. The lodging most likely occurred as a result of high winds when soils were near saturation and the corn was approaching tassel extrusion. We counted lodged plants in all treatments in both years (See Table 2).

We concluded that due to looser soils and a hybrid with a weaker or late-developing root system (based on comments from Pioneer agronomists), plant roots in the tilled plots were not physically able to support the weight of the tall plants. Soils in the strip-till and no-till plots, though just as saturated, provided firmer rooting and, therefore, very few lodged plants. One of the key advantages of no-till and strip-till appears to be the likelihood of substantially less lodging with lodging-sensitive hybrids in susceptible (high wind plus high rainfall) environments.

When averaged for 2003 and 2004, corn yields were highest with early planting of either strip-till or no-till (Table 3). Neither strip-till nor no-till resulted in higher yields than the traditional practices of chisel plowing or disk ripping followed by secondary tillage, but both no-till and strip-till systems were superior to the more traditional tillage systems in terms of residue cover (Table 1) and input cost reduction. A single pass with a field cultivator was not beneficial to yield, relative to the no-till system, and also left far less residue cover than no-till (though more than that after the other systems with primary tillage). Yields were highest with early planting in both years (Table 3), though this might not always be the case. This same experiment had been initiated in 2002, and yields were lower with the early planting date in that year (data not shown).

The data from 2003 and 2004 for this soil confirm the corn yield competitiveness of no-till and all single-pass tillage systems (including fall strip tillage and spring cultivation alone) but not the single pass of a fall disk ripper without subsequent secondary tillage. No-till and strip-till systems resulted in the least mid-season lodging risk.

Table 3. Tillage treatment effects on grain yields of corn following soybeans on dark prairie soil at West Lafayette, IN, 2003-2004.

| Tillage Treatment (Ranked by 2-year average yield) | Grain yield at 15.5% | | |
|---|---|---|---|
| | 2003 | 2004 | 03-04 Avg. |
| 5. Fall strip-till, early planting | 225.8 a‡ | 243.1 a | 234.4 a |
| 7. No-till, early planting date | 220.0 ab | 242.5 a | 231.3 a |
| 8. No-till, normal planting date | 213.6 bc | 224.8 b | 219.2 b |
| 6. Fall strip-till, normal date | 213.8 bc | 221.3 b | 217.5 b |
| 4. Fall DRD, spring cultivate | 212.9 bc | 218.5 bc | 215.7 b |
| 2. Spring field cultivate | 215.1 bc | 215.2 bc | 215.2 b |
| 1. Fall chisel, spring cultivate | 211.5 c | 213.0 bc | 212.2 b |
| 3. Fall DRD, stale seedbed | 208.2 c | 207.7 c | 208.0 c |

‡ Means with the same letter are not significantly different at P=0.05.

*(b) Loam Soil:*

Surface residue cover was lowest for the 2 treatments involving full-width tillage with either a chisel plow or disk-ripper-disk in fall followed by full-width cultivation in spring (Table 4). Surface residue cover was highest in no-till (65 to 77 %) as expected, but it is noteworthy that strip tillage treatments tended to keep residue cover higher than other single-pass tillage systems. Corn plant populations were very close to the intended populations (about 31,000 plants/acre), and were not significantly between no-till and strip-till treatments. Lowest plant populations were in the stale seedbed system (Fall disk-ripper-disk with no secondary tillage in spring). Corn plant heights at 4 and 8 weeks after planting were fairly similar between no-till and strip-till treatments in both planting periods. Full-width primary tillage in fall resulted in no advantage for plant heights relative to any of the single-pass treatments (strip tillage or mulch finishing in spring).

Table 4. Agronomic performance of corn following soybean, Wanatah, IN, 2002-2004.†

| Tillage Treatment (Ranked by treatment number) | Residue cover | Week 4 stand | Week 4 height | Week 8 height | Grain moisture |
|---|---|---|---|---|---|
| | % | Plants/a. | Inches | Inches | % |
| 1. Fall chisel, spring VE3BDR | 9 f | 30800 bc | 13.7 ab | 55.6 ab | 18.0 abc |
| 2. No-till, normal planting | 77 a | 31200 abc | 13.6 ab | 53.6 b | 18.7 a |
| 3. Spring VE3BDR | 34 cd | 31300 abc | 13.7 ab | 54.6 ab | 18.4 ab |
| 4. Fall VC3BDR, stale seedbed | 32 d | 31900 a | 13.9 a | 55.1 ab | 18.0 abc |
| 5. Fall VC3BDR, spr. VE3BDR | 19 e | 31000 abc | 13.3 abc | 55.7 a | 18.5 a |
| 6. Fall DRD, stale seedbed | 14 ef | 30500 c | 13.3 bc | 55.0 ab | 18.6 a |
| 7. Fall DRD, spring VE3BDR | 9 f | 30700 bc | 12.8 c | 55.2 ab | 18.4 ab |
| 8. Fall strip-till, early planting | 33 d | 31200 abc | 6.5 d | 24.0 c | 17.3 c |
| 9. Fall strip-till, normal planting | 42 c | 31400 ab | 12.7 c | 54.0 ab | 18.4 ab |
| 10. No-till, early planting | 65 b | 30600 bc | 6.3 d | 23.9c | 17.6 bc |

‡ Means with the same letter are not significantly different at P=0.05.

Table 5. Tillage effects on corn yields following soybean on loam soil Wanatah (2003-04)

| Tillage Treatment (Ranked by 2-yr average yield) | Grain yield at 15.5% | | |
|---|---|---|---|
| | 2003 | 2004 | Average |
| 10. No-till, early planting | 198.4 a | 215.8 | 207.1 |
| 4. Fall VC3BDR, stale seedbed | 190.2 bc | 223.8 | 207.0 |
| 5. Fall VC3BDR, spring cultivate | 186.6 c | 222.5 | 204.6 |
| 3. Spring cultivate VE3BDR | 188.6 bc | 219.7 | 204.2 |
| 8. Fall strip-till, early planting | 193.6 ab | 214.7 | 204.2 |
| 7. Fall DRD, spring VE3BDR | 184.6 c | 223.6 | 204.1 |
| 6. Fall DRD, stale seedbed | 185.6 c | 221.9 | 203.8 |
| 9. Fall strip-till, normal planting | 188.9 bc | 216.7 | 202.8 |
| 1. Fall chisel, spring VE3BDR | 188.3 bc | 217 | 202.7 |
| 2. No-till, normal planting | 187.9 bc | 213.8 | 200.9 |

‡ Means with the same letter are not significantly different at P=0.05.

There were no yield benefits associated with doing anything other than no-till on this soil after soybean harvest because neither chisel plowing, disk-ripping, strip tillage or single-pass cultivation increased yields in either year (Table 5). Corn yields were significantly increased by planting earlier in 2003, but even in that situation there were no yield differences between strip-till and no-till treatments. However, it is important to mention that a killing frost after corn emergence did not occur in either 2003 or 2004. In 2002 at this same location, corn yields were negatively affected by planting earlier because of the stand loss associated with a late April killing frost after the early planting treatment had emerged (data not shown).

Table 6. Agronomic performance of corn as affected by tillage following soybean on Sebewa loam, Wanatah, IN, (2005 plus yield mean for 2001-2005).

| Tillage Treatment | Residue cover | Plant stand 4 weeks | Height 4 week | Height 8 weeks | Yield in 2005 @15.5% | Yield Mean 2001-05 |
|---|---|---|---|---|---|---|
| | % | Plants/a | in | in | Bu/a. | Bu/a. |
| Chisel/disk/fd. cultivator | 21 d | 29700 | 8.0 b | 54.6 a | 194.8 | 199.3 |
| Chisel/field cultivator | 24 d | 30400 | 8.0 b | 54.5 a | 187.2 | 197.3 |
| Fall Disk/field cultivator | 41 c | 31200 | 8.3 a | 54.3 a | 205.7 | 203.6 |
| Fall strip-till | 64 b | 30400 | 7.9 b | 53.6 a | 191.6 | 202.1 |
| No-till | 92 a | 30000 | 7.0 c | 43.5 b | 186.6 | 197.1 |

‡ Data followed by same letter are not significantly different with Student-Newman-Keuls Test (P =0.05).

To put the relative strip-tillage results of this main tillage trial at Wanatah into perspective, we have achieved similar responses in a smaller ongoing experiment on the same soil (Table 6). In the latter trial, we have investigated fall strip tillage versus no-till, fall chisel and fall disk alternatives for corn following soybean since 2001 (current hybrid is Pioneer 34A16). Strip tillage has resulted in much higher residue cover and early corn height advantages than no-till (note the 2005 results in Table 6), but final yields have been similar for all tillage systems. Strip tillage is a reliable alternative to the more traditional intensive primary tillage systems based on chisel and disk systems, but it won't necessarily yield significantly more than a well managed no-till program on coarse to medium-textured soils. Strip tillage does, however, provide opportunities for earlier planting of corn than an undisturbed no-till situation.

2. *Are there any advantages to shallow rotary harrow operations just before planting in spring versus no-till and traditional tillage systems for corn after soybean?*

Table 7. Tillage effects on corn following soybean, Columbia City, IN, 2003.

| Tillage Treatment (Ranked by yield) | Residue cover | Grain moisture | Grain yield at 15.5% |
|---|---|---|---|
| | % | % | Bu/a. |
| 5. Chisel plus field cultivate | 22 c | 19.9 b | 131.5 a |
| 3. To The Max 2 passes | 54 ab | 20.0 b | 124.2 ab |
| 4. Field cultivate once | 32 bc | 20.4 ab | 123.2 ab |
| 1. No-till | 63 a | 21.0 a | 115.0 b |
| 2. To The Max 1 pass | 57 a | 20.5 ab | 113.8 b |

‡ Means with the same letter are not significantly different at P=0.05.

In 2003, the To-the-Max rotary harrow did not result in any loss in residue cover relative to no-till, but it also did not improve overall yields (Table 7). Corn yields (although lower than expected) were highest this year for the traditional chisel-plow system. However, corn yields with either 2 passes of the rotary harrow or a single pass with the field cultivator were intermediate between those after chisel and no-till treatments. Although 2 passes of the rotary harrow appeared to result in somewhat better yields than a single pass of the same tool, it is important to acknowledge that this year is essentially an aberration of the normal situation. The corn treatments had to be replanted in 2003; it is possible that the additional soil loosening from the second pass of the To-the-Max harrow operation provided some residual benefits that were not possible a full month after the implement operation (and the first planting date). Grain moisture levels were quite dry at harvest, but were significantly higher after no-till compared to the 2-pass system with the rotary harrow. Overall, it seems that 2 passes of the rotary harrow resulted in yields at least as good as those after a field cultivator, but with the additional advantage of much more residue cover retention. The conventional chisel plow operation proved superior for yield, but not for residue cover in 2003. However, it is impossible to make recommendations based on such a one-year and single-location result, particularly when such replanting situations are unlikely.

Table 8. Tillage effects on corn following soybean, Columbia City, (mean 2004-2005).

| Tillage Treatment (Ranked by yield) | Residue Cover # | Plant stand | Grain moisture | Grain yield at 15.5% |
|---|---|---|---|---|
| | % | Plants/a. | % | Bu/a. |
| Great Plains Turbo-till (single pass) | 32 b | 29900 | 16.9 | 178.4 a |
| Field cultivator (single pass) | 20 b | 31100 | 16.9 | 172.2 ab |
| No-till | 51 a | 30400 | 16.8 | 171.3 ab |
| Fall chisel plow plus field cultivator | 14 b | 29500 | 16.8 | 170.1 ab |
| Great Plains Turbo-till (double pass) | 29 b | 30000 | 16.9 | 166.2 ab |
| Strip-till (spring 2004, Fall 2005) | 16 b | 29900 | 16.9 | 162.6 b |

‡ Means with the same letter are not significantly different. # Residue cover only for 2005.

For 2004 and 2005, mean corn yields were highest for the single pass of the Turbo-Till rotary harrow unit and lowest for strip tillage (Table 8). The large difference in mean yields (12 bu/acre) between one versus two passes of the of the Turbo-Till was primarily the result of a 22 bu/acre yield loss with the two-pass system (versus the one-pass) in 2004; the latter yield reduction may have been related to the additional compaction and surface soil crusting associated with the second pass in that year. Mean plant populations were not significantly affected by tillage treatments, though populations were lowest with the chisel plow system in 2004 (data not shown).

The 20% loss in residue cover with the operation of the Turbo-till (i.e. relative to no-till after soybean) is more substantial than 6-9% loss in residue cover occurring with the less aggressive To-the-Max implement in 2003 (Table 6). Strip tillage performed poorly at this site, but this is primarily a function of strip tilling 10 days before planting in the spring of 2004 (when the loosened strip-tilled berms dried out and corn yields were 25 bu/acre less than after a single pass of the Turbo-Till).

Neither the single pass with the Turbo-Till (Table 8) or the field cultivator (Tables 7 and 8) resulted in any higher corn yields than after no-till alone, but they may have provided some advantages in terms of earlier planting opportunities had the spring soil situations been wetter than they were in this location. The no-till planter used at this location is also better equipped for zone-till planting ("Rawson" 3-coulter unit in front of each seed-disk opener) than most no-till planters. Corn growth advantages associated with either strip-till or shallow rotary harrow operations may be more apparent when no-till planters have minimal accessory equipment for in-row soil loosening.

3. *Based on our admittedly limited research, which of these systems would we recommend for corn after soybean in the Eastern Corn Belt?*

*(a)* *Strip tillage.* Although strip tillage won't necessarily increase corn yields compared to well-managed no-till corn planted on the same day, strip-till provides the distinct advantages of retention of most surface residue cover plus earlier soil drying and

warmer soil temperatures in the intended seed zone - which results in an expanded window for spring planting during the optimum period and the possibility of more vigorous early corn growth in cool, wet seasons. Ideally, strip tillage should be done in the fall, and the implement should be adjusted so as to retain loosened and raised berms in spring. Precision steering (e.g. RTK automatic guidance) for both strip tillage and corn planting operations may enhance the system's success even more than what we were able to achieve with visual guidance. Strip tillage is also the only system among those we tested that allows for simultaneous nutrient banding.

*(b)* *Rotary Harrows.* Shallow tillage tools like rotary harrows operated at high speeds on previously undisturbed soybean stubble just before planting corn in this "modified" no-till system are potentially helpful in advancing the planting date and improving seed-furrow closing where there is uneven, matted surface crop residue on medium- and fine-textured soils. Rotary harrows are superior to the one-pass field cultivator system because they generally leave more residue cover, are less likely to result in excessively cloddy seedbeds, and still result in similar corn yields. It is important to realize that some of these tools can be operated too deep, or in soil conditions which are too wet. The no-till planters which follow these tools should still employ tined row cleaners. Furthermore, farmers must always be concerned about tractor compaction effects associated with pulling these implements, and are discouraged from making two passes since that could be detrimental to corn establishment. However, we need more research results with the growing array of these implements to provide more definitive recommendations.

*(c)* *Field Cultivators.* On well-drained, friable soils without serious compaction problems that might benefit from deeper primary tillage (e.g. with a disk ripper or similar tool), single-pass field cultivator systems in spring are a superior alternative to the typical 2-pass or 3-pass tillage systems. They tend to result in slightly more residue cover than the combination of fall chisel or disk plus secondary tillage, and involve less cost with no apparent reduction in corn yield. They typically allow for more time in applying weed control products than no-till, strip-till or rotary-harrow alternatives. However, both fall strip-till and certain rotary harrow systems may allow for earlier corn planting opportunities with substantially more residue protection, less risk of cloddy seedbeds, and comparable corn yield potential to the field cultivator option.

*(d)* *Disk Rippers.* These may be helpful as a fall operation for additional soil loosening if soil compaction is sufficient to warrant their use, and soil conditions are suitable. They result in similar or less residue cover than chisel plows because of their increased soil mixing intensity and disk-incorporation. The disk-ripper-disk we used was successful as a one-pass system (i.e. no corn yield benefit from secondary tillage) on loam soil, but not on our silty clay loam soil. These tools could have one-pass potential if sufficient soil leveling could be accomplished on that first pass in fall. However, they did not improve corn yields relative to strip-till or no-till.

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