Optimizing Conservation Tillage Systems

Plant-to-Plant Uniformity is Essential for Optimum Yield in No-Till Continuous Corn

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Compromises, Consequences, and Perceptions

Corn grown in rotation with another crop usually yields more than corn grown after corn. Yet changing market demand for corn has caused many Indiana and other Midwest corn growers to adopt corn-dominant rotations. Unfortunately, abandoning the corn-soybean rotation common across the central United States comes with a number of compromises and consequences. Possible compromises include increased soil erosion, reduced air and water quality, and greater pest incidence. Potential consequences include grain yield loss, additional tillage, and the need for more nitrogen fertilization (Vyn, 2006).

Figure 1. Higher grain prices have caused many growers to consider corn-dominant rotations.

Although these compromises and consequences are generally inevitable with the adoption of corn-dominant rotations, conservation tillage practices (no-till, strip-till, ridge-till, mulch-till) may partially alleviate some of these negative effects. Grower adoption of conservation tillage practices in corn has been relatively stable for the last decade, but has been consistently lower in continuous corn than in corn grown in rotation with soybeans (Conservation Technology Information Center).

Corn growers have been reluctant to adopt no-till practices, even for corn grown in rotation with soybeans, because of perceptions that no-till systems cause planting delays, lower early-season soil temperatures, reduced plant populations, pest control challenges, delayed plant development and maturity, and lower yield potential.

In corn after corn situations or for corn grown on poorly-drained, fine-textured soils, these negative perceptions or experiences have typically been even more pronounced. However, research throughout the Eastern Corn Belt has shown that yields of no-till corn grown on well-drained soils in a crop rotation are comparable to yields produced using conventional tillage — provided optimum management practices are employed (Kapusta et al., 1996; West et al., 1996; Vyn, 2006).

Corn growers can mitigate some of the compromises associated with corn-dominant rotations and maintain high productivity if they understand the real (not perceived) causes of yield reduction in no-till continuous corn.

This publication discusses some real causes of yield loss in no-till corn after corn related to corn growth and development and provides remedies for alleviating them.

Causes of Lower Yields

Reduced Plant Height

Research documenting reduced plant growth and delayed maturity in no-till continuous corn leads many agronomists and growers to believe that lower yields in such a system are generally associated with reduced plant heights in early vegetative development. A number of factors may result in shorter plants in no-till continuous corn, including greater soil residue cover and cooler, wetter soil environments. These and other factors can delay seedling emergence and slow plant growth and development in the first month or two following the emergence of corn seedlings.

Early-season and mature corn plants are not always shorter in no-till continuous corn since factors such as relative growth rate, moisture availability, soil compaction, and fertilizer application also affect plant height differences among tillage systems. Conflicting research results suggest that mean plant heights (whether during early developmental stages or at physiological maturity) may not be accurate predictors of decreased yield in no-till continuous corn. Instead, plant height variability may be a better predictor of yield reductions, since uniform plant size and grain weight for neighboring plants within a row are associated with greater yields in corn.

Plant-to-Plant Height Variability

Ideally, a field planted to hybrid corn contains plants of equal age and size competing equally for limited resources (soil nutrients, water, sunlight). Yet this is never the case, since all cornfields possess some plant-to-plant variability. Non-uniformity is expressed by differences among neighboring plants in the rate of development (as when a V8 plant is taller than a V6 plant) or in growth (as when multiple plants at the same developmental stage vary in height).

Management practices and environmental conditions both contribute to this variability. Some management-related causes of plant-to-plant variability include deviations in planting depth and seed spacing, uneven nutrient application and crop residue distribution, wheel-track compaction, weed competition, and plant population level. Environment-related causes include variations in insect feeding and disease pressure along with inherent soil spatial variability (Andrade and Abbate, 2005).

No-till continuous corn environments often have a greater number of these potential sources of variability relative to conventional tillage-rotation systems, so plant-to-plant variability is often more pronounced in no-till continuous corn. Since emergence is likely to be more variable in no-till relative to conventional tillage systems (West et al., 1996), the onset of plant-to-plant size variability can occur very early in the growing season. Size variability resulting from variable emergence often results in yield losses since earlier emerging plants out-compete their later-emerging neighbors for limited resources and often grow taller (Carter et al., 1992; Nielsen, 2001; Liu et al., 2004).

Management-related variability can magnify the negative effects of no-till environments. No-till continuous corn systems maintain greater residue coverage than other tillage-rotation systems, resulting in slower rates of soil warming and drying in the spring. Cooler, wetter soils delay plant germination, emergence, and initial seedling development. Delayed stand establishment lengthens the time when seedlings can be exposed to seedling blights and insect pressure. This can lead to a higher proportion of weakened plants that have to tolerate later-season stresses as well as compete with their healthier neighbors for limited resources throughout the remainder of the growing season (Nielsen et al, 2006). Variable germination, emergence, and seedling development increase individual plant size and yield variability, thus reducing overall yield and grower profitability (Nielsen, 2001).

Results of a Long-term Rotation and Tillage Experiment

From 1981 to 1994, the ongoing, long-term rotation and tillage experiment at Purdue University's Agronomy Center for Research and Education used a single corn hybrid (Becks 65X) planted near the rows from the preceding year. Full weed control was achieved by applying residual herbicides and hand weeding as necessary. The experiment measured corn plant height and yield for two crop rotations (corn-soybean and continuous corn) and two tillage systems (moldboard plow and no-till).

Figure 2. *This photo shows a pre-planting comparison of the continuous corn, plow (left) and continuous corn, no-till systems in the Purdue University long-term rotation and tillage experiment.*

Table 1. Grain Yields, Plant Heights, and Plant Height Variability
This table shows the relative and actual plant population and grain yield, and relative plant height and plant height variability for each crop rotation and tillage system from 1981 to 1994 for a single hybrid in West Lafayette, Indiana (Chalmers silty clay loam). The desired plant population was 25,000 plants/acre. Relative data is expressed as a percentage of the corn-soybean plow system. The results were calculated by averaging the annual relative values for each individual treatment combination.

Crop Rotation	Tillage System	Relative Plant Population (%)	Actual Plant Population (plants/ acre)	Relative Grain Yield (%)	Actual Grain Yield (bu./acre)	Relative Plant Height Mean at Week 4 (%)	Relative Plant Height Variability at Week 4 (%)[1]
Corn-Soybean	Plow[2]	100.0	24,700	100.0	184.5	100.0	100.0
Corn-Soybean	No-till[3]	99.4	24,550	96.8	178.4	98.5	127.4
Continuous Corn	Plow	99.8	24,650	94.4	174.5	101.2	122.7
Continuous Corn	No-till	92.9	22,850	77.7	143.3	76.9	130.1

[1] Actual variability was calculated as the standard deviation of plant heights and is expressed on a relative basis. The standard deviation is a common statistical calculation used to describe variability within a set of values, and in this case is used to represent plant height variability at four weeks after planting.
[2] Fall moldboard plowing to an 8- or 9-inch depth, with a single disking and field cultivation to a 4-inch depth in the spring prior to planting.
[3] No-till planting with a single fluted or bubble coulter to cut through crop residue and loosen soil ahead of standard planter units.

***Figure 3.** This figure shows corn plant height variability in different rotation-tillage systems. (From top) Corn-soybean, plow; corn-soybean, no-till; continuous corn, plow; and continuous corn, no-till.*

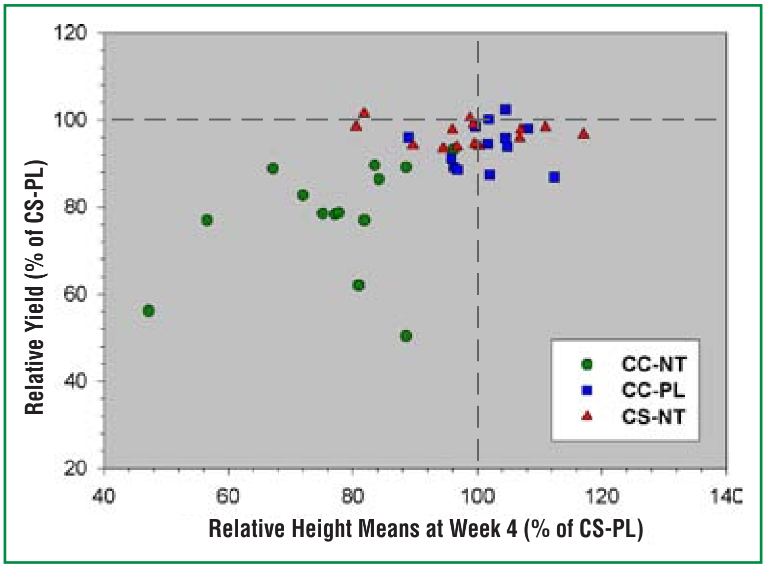

***Figure 4.** This graph shows the relationship between relative grain yield and plant height mean four weeks after planting for continuous corn, no-till (CC-NT); continuous corn, plow (CC-PL); and corn-soybean, no-till (CS-NT) systems. Each system is shown as a percentage of corn-soybean, plow values. Each data point represents a particular rotation-tillage treatment in a single year. The relationship between relative grain yield and relative height mean at week four was not statistically significant for any of the rotation-tillage systems at P = 0.05.*

Table 1 and Figures 4 and 5 present the results of this experiment on a percent basis relative to the plow system for corn-soybean. The results in Table 1 were calculated by averaging the annual relative values for each individual treatment combination.

Over the 14 years of this trial, grain yield and plant height at four weeks after planting averaged lower in no-till continuous corn than in the other rotation-tillage systems (Table 1). Plant height variability at four weeks was greater in no-till systems than in plow systems regardless of crop rotation. Plant height variability also was greater in the continuous corn rotation than in the corn-soybean rotation regardless of tillage system.

Table 1 makes it clear that no-till continuous corn had the greatest early-season height variability. In fact, the relative increase in plant height variability associated with no-till continuous corn was greater than the relative decrease in average plant height. Although plant populations also were somewhat lower in no-till continuous corn in this 14-year experiment, they were not low enough to account for the substantial yield reductions.

Figure 4 shows the relationship between relative grain yield and relative plant height mean at week four in the continuous corn, no-till; continuous corn, plow; and corn-soybean, no-till systems. For all three rotation-tillage combinations, the relative plant height mean had no significant relationship with relative yield. Incidentally, relative mean plant heights greater than 100 percent were not associated with higher relative yields in the corn-soybean, no-till system or the continuous corn, plow system.

Figure 5 shows the relationship between relative grain yield and relative plant height variability at week four in the continuous corn, no-till; continuous corn, plow; and corn-soybean, no-till systems. An increase in plant height variability did not significantly affect relative yield in the continuous corn, plow or corn-soybean, no-till systems. However, as relative height variability in no-till continuous corn increased, yield decreased significantly.

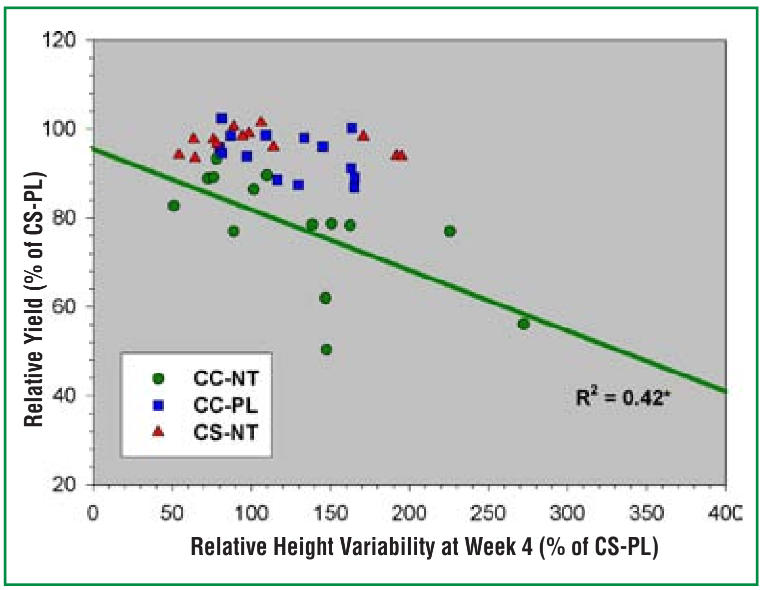

Figure 5. *This graph shows the relationship between the relative grain yield and plant height variability four weeks after planting for continuous corn, no-till (CC-NT); continuous corn, plow (CC-PL); and corn-soybean, no-till (CS-NT) systems. Each system is shown as a percentage of corn-soybean, plow values. Each data point represents a particular rotation-tillage treatment in a single year. The relationship between relative grain yield and relative height variability at week four was statistically significant only for the continuous corn, no-till system at P = 0.05. In statistics, R^2 values indicate the strength of a relationship between two variables. Values for R^2 range from 0 to 1, with values near 0 showing no relationship and values near 1 showing a very strong relationship between two variables.*

Even when relative height variability was similar among the rotation-tillage systems, relative yield was consistently lower in no-till continuous corn. An increase in plant height variability therefore leads to greater yield reductions in no-till continuous corn than in plowed continuous corn or no-till corn grown in rotation with soybeans.

This may result from the unique growth environment of no-till continuous corn. It is an environment characterized by variable soil temperatures, non-uniform soil compaction, and late-season foliar disease pressure. Such conditions restrict improvements in uniformity later in the season through the compensatory growth or “catching-up” of weaker plants. These conditions also introduce additional sources of variability during late-vegetative and reproductive growth and development.

Overall, our results strongly suggest that yield reductions in no-till continuous corn are not so much related to overall growth and development delays (as reflected in reduced early-season mean plant heights), but to greater plant-to-plant height variability early in the growing season.

Remedies

Maximizing yield in no-till continuous corn systems requires improving plant-to-plant uniformity. Improving uniformity begins with minimizing the negative effects of management and environmental factors that contribute to plant-to-plant variability in this system — uneven residue distribution, inconsistent seed spacing and depth, inadequate starter nitrogen fertilization, and greater disease and insect pressure (Steinhardt et al., 2002).

Management Factors

No-till continuous corn generates a large amount of residue that must be distributed evenly for the subsequent crop to germinate and emerge uniformly. Even residue distribution promotes early plant uniformity by making soil moisture and temperature relatively consistent in the root zone of neighboring plants. Spreading residue evenly at harvest is one way to improve residue uniformity (Steinhardt et al., 2002; Nielsen et al., 2006).

Use seed firmers in high-residue seedbeds to ensure consistent seed spacing and depth — which in turn, improves plant-to-plant uniformity (Nielsen, 2001). Uniform seed spacing and depth are also promoted by avoiding no-till planting directly into old cornrows, and by properly managing surface residue to prevent it from interfering with the planter's furrow opening and closing operations (Steinhardt et al., 2002). Tined row cleaners are helpful in achieving a residue-free area. The optimal placement for new no-till cornrows is about 6 to 7 inches to the side of the old cornrow.

Figure 6. *In no-till continuous corn, plant new rows next to the previous year's rows to avoid variable germination, emergence, and early seedling growth. Early-season variability can lead to variations in plant size, which can reduce grain yield.*

Adequate nitrogen availability also is necessary to maintain plant-to-plant uniformity throughout the growing season (Boomsma and Vyn, 2006). Continuous corn requires roughly 30 to 50 more pounds of nitrogen per acre than corn grown in rotation (Nielsen et al., 2006). Since soil nitrogen mineralization rates are often lower in no-till than conventional tillage systems, starter nitrogen is very important in no-till continuous corn to ensure adequate nitrogen availability for early corn growth and development (Stecker, 1993; Steinhardt et al., 2002). We recommend starter nitrogen rates of at least 30 pounds per acre for no-till corn after corn.

Field selection is important, since no-till continuous corn performs best on better-drained soils. Cooler, wetter soils in no-till continuous corn frequently lead to delayed germination, emergence, and initial seedling development. Delays in full stand establishment increase the risk of exposing plants to damaging soil-borne diseases and insects, both of which contribute to plant-to-plant variability. Select hybrids with superior emergence, seedling vigor, and disease resistance to improve plant-to-plant growth and developmental uniformity (Steinhardt et al., 2002; Nielsen et al., 2006). Also, use the best available fungicide seed treatments. To reduce early- and late-season insect risk (both of which can cause plant-to-plant variability), use soil-applied insecticides, insecticide seed treatments, or select varieties with transgenic resistance to Western corn rootworm (*Diabrotica virgifera virgifera*) or European corn borer (*Ostrinia nubilalis*) (Nielsen et al., 2006).

Soil compaction increases the susceptibility to stress of no-till corn plants, so it is important to minimize compaction in all field operations in no-till cornfields. Minimize wheel traffic, particularly when soils are moist and axle loads are high (like at harvest). Consider maintaining consistent traffic lanes in the same zones from year to year, and reduce compaction as much as possible in future cornrow areas.

Conclusions

Plant growth and development is frequently delayed and, more importantly, less uniform on a plant-to-plant basis in no-till continuous corn than in conventionally-tilled continuous corn and conventionally-tilled corn grown in rotation with soybeans. This variability leads to significant yield reductions.

Factors that can cause plant-to-plant variability in no-till continuous corn include non-uniform residue distribution, variable soil compaction, inconsistent seed spacing and depth, inadequate nitrogen fertilization, and greater disease and insect pressure. Growers should properly manage these factors to maximize yield. Overall, no-till continuous corn producers should be more concerned about plant-to-plant uniformity than small delays (on a field-average basis) in plant growth and development.

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