CROP INSIGHTS

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Best Management Practices for Corn-After-Corn Production

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Summary

- Choose fields with good tilth and water-holding capacity for corn after corn. The yield penalty for this production system is much lower in high-yield environments.
- Hybrid selection is critical when growing corn after corn. To aid in this decision, Pioneer rates its hybrids for stress emergence, high residue suitability, disease resistance, drought tolerance and stalk and root strength.
- Proficient management of corn residue is another key to successful corn-after-corn production. High corn residues can result in cooler, wetter soils at planting, higher disease and insect levels, nitrogen tie-up and planting challenges.
- Foliar fungicides can effectively reduce leaf diseases and their detrimental effects on corn yields, especially under high-residue conditions associated with corn following corn.
- Research has shown that yield reductions for continuous vs. rotated corn are often greater in stress years, probably due to a reduced root system. Managing rootworms and preventing compaction can help diminish this problem.
- More nitrogen will likely be needed when producing corn after corn vs. corn after soybeans. Corn residues tie up nitrogen during the decomposition process.
- Consider planting corn-after-soybean fields first to allow wetter corn ground time to dry. This can reduce sidewall compaction that limits root growth and leads to uneven stands.
- Studies show that tillage system can have a significant impact on the relative yield of continuous vs. rotated corn.

Rotating corn with other crops, particularly soybeans, has long been the overwhelming choice of farmers in the U.S. and Canada. Rotation with soybeans reduces nitrogen fertilizer requirements, decreases disease and insect pressure, allows growers to alternate herbicides, and usually increases corn yields. In recent years, however, the economic advantages of growing corn have prompted many growers to increase the proportion of corn acres in their operations. This means growing two or more corn crops before rotating back to soybeans or other crops. Those who use this practice may benefit from a review of the issues likely to be encountered when growing corn crops back to back. This *Crop Insights* will address best corn-after-corn production practices to maximize stand establishment and yield, and minimize disease and insect challenges in high-residue fields.

Corn-on-corn acres are increasing on many farms.

Yield Reductions with Corn after Corn

Numerous studies have documented corn yield reductions when corn follows corn rather than soybeans, even when all limiting factors appear to have been adequately supplied in the continuous corn system. Yield losses average about 5 to 15 percent, but are much greater some years. Yield reductions are usually greatest when yield potential is low (Table 1).

Table 1. Yield decrease in corn following corn vs. corn following soybeans at different yield levels*.

Corn-after-corn yield	Corn yield decrease when following corn vs. soybeans	
110 bu/acre	32 bu/acre	29%
120 bu/acre	17 bu/acre	14%
140 bu/acre	24 bu/acre	17%
155 bu/acre	25 bu/acre	16%
165 bu/acre	12 bu/acre	7%
180 bu/acre	5 bu/acre	3%
200 bu/acre	5 bu/acre	2.5%

*Nitrogen was supplied at 200 lb/acre. Source: Four-year study at the University of Minnesota Southern Research and Outreach Center at Waseca.

These results indicate that rotated corn is generally better able to tolerate yield-limiting stresses than continuous corn. Other studies as well as grower experience also confirm that major yield losses for corn following corn are often associated with stresses from moisture extremes. This implicates the root

system as the most likely source of the problem. In corn-after-corn production, the plant's root system may be limited due to increased populations of corn rootworms, or in some cases, compaction. Less extensive root systems under continuous corn may cause increased plant stress and yield losses in years when demand for soil moisture is high. Lack of soil moisture in July and August, during the pollination and early grain-fill stages of corn development, may be most detrimental to continuous corn yields.

To minimize losses in corn-after-corn production systems, growers should select appropriate hybrids, manage corn residue, and adjust soil fertility, weed management and tillage practices to accommodate the change in cropping patterns.

Hybrid Selection

Hybrid selection is an important component of successful corn-on-corn production. Growers should always be sure to:

- Select hybrids with proven performance under the diverse environments and stresses their field may encounter.
- Select hybrids with above average drought tolerance. Root mass may be reduced in this production system, hence limiting water uptake the same as during drought conditions.
- Select appropriate hybrid maturities that match corn planting date and seasonal growing degree units, accounting for cooler soils and slower emergence under high residue conditions associated with corn following corn.
- Choose the highest-performing genetics with defensive traits such as standability and disease and insect resistance required for this production system.

To assist in selecting hybrids for corn-on-corn fields, Pioneer sales professionals can provide hybrid ratings for stress emergence, high residue suitability, disease resistance and stalk and root strength. They can also recommend products with appropriate insect resistance traits and refuge options, as well as the best seed treatment choices for growers' fields.

Stress Emergence: Early planting and reduced tillage can make the corn-after-corn seedbed an inhospitable environment for stand establishment. Stress Emergence ratings refer to the genetic potential of hybrids to emerge under these stressful conditions (including cold, wet soils or short periods of severe low temperatures) relative to other Pioneer® brand hybrids. Ratings of 6 to 9 indicate above average potential, 5 indicates average potential, and 1 to 4 indicate below average potential to establish normal stands under stress conditions.

High Residue Suitability: Farmers have steadily increased acres managed under high residue cropping systems including no-till, strip till and other conservation tillage practices, as well as corn-after-corn production. To assist growers in selecting hybrids under high residue systems, Pioneer researchers have assigned a High Residue Suitability rating for all Pioneer® brand corn hybrids. The rating is based on a formula using five key defensive traits – stress emergence, and resistance to northern leaf blight, gray leaf spot, anthracnose stalk rot and Diplodia ear rot. Based on these criteria, Pioneer hybrids are rated as Highly Suitable (HS), Suitable (S), or Poorly Suited (X).

Leaf, Ear and Stalk Disease Ratings: The incidence and severity of corn diseases has increased in recent years due to build-up of corn residue. In fields with a history of leaf or stalk diseases, growers should choose hybrids with adequate resistance to those specific diseases. Pioneer rates its hybrids for resistance to common corn leaf diseases, including northern and southern leaf blight, gray leaf spot, common and southern rust and eyespot. Ear disease scores include Fusarium, Gibberella and Diplodia. Other disease ratings include anthracnose stalk rot, head smut, Stewart's and Goss's wilt, corn lethal necrosis and maize dwarf mosaic virus complex. Stalk and root strength ratings are also available for all hybrids.

Insect Traits: Insects are harbored in corn residue and previous corn ground, including corn rootworm, corn borer, and western bean cutworm. Growers should choose technologies that defend against these yield-robbing pests. Corn rootworm is the major corn insect pest associated with corn-on-corn production. Effective control measures are critical for this pest, as corn rootworm pressure tends to be highest in the second and third years of continuous corn.

Pioneer offers several technology options to combat northern, western and Mexican corn rootworm, including single-bag options that do not require a separate refuge. Numerous studies have proven the effectiveness of these corn rootworm traits, with efficacy surpassing that of soil-applied insecticides. Pioneer also offers many technology options for above-ground insect control, including single-bag products and those with stacked traits for above- and below-ground insect protection in the same hybrid.

Pioneer Premium Seed Treatment (PPST 250):
Soils are cooler and wetter under corn residue, which slows corn emergence and increases the vulnerability of seeds and seedlings to disease and insect pests. Seed treatments are especially important in this kind of seedbed environment to protect seedlings and help ensure that stands are sufficient for highest yields.

Standard on all Pioneer® brand corn hybrids, PPST 250 seed treatment includes fungicide, insecticide and biological components. The fungicide component is a combination of four active ingredients, including a new active for corn disease control. According to the manufacturer, the four-way formulation provides increased broad-spectrum protection from corn seed and seedling diseases, including Fusarium and Pythium. The insecticide component of the PPST 250 treatment, applied at the rate of 0.25 milligrams a.i./kernel, offers proven insect protection to enhance early season plant health. A new biological component of this seed treatment has consistently demonstrated improved overall plant performance and enhanced crop yields in Pioneer research trials.

Poncho® 1250 + VOTiVO® Seed Treatment: Pioneer customers can also choose Poncho 1250 + VOTiVO seed treatment on selected Pioneer hybrids where nematode or enhanced insect protection is needed. According to the manufacturer, this product protects corn seed from planting through the critical stages of early season development against many soilborne and seedling pests that often reduce stands and yields. Insects controlled include wireworm, white grub, seedcorn maggot, grape colaspis, black cutworm, flea beetle, chinch bug and billbug, according to the product label. Control of over 10 species of nematodes is provided through a biological mode of action that protects corn seedlings and roots.

Managing Corn Residue

A corn crop produces more than twice the residue of a soybean crop. This has advantages in reducing soil erosion, but also presents some challenges. Growers should be prepared to manage corn residue to reduce its negative impact on their corn-on-corn crop.

Effects of Corn Residue on Stand Establishment: Excessive corn residue can result in cooler soil temperatures and higher soil moistures at planting time. Residue positioned directly over the row can lower temperatures in the seed zone, delay germination and early growth, and reduce stands and yields (Table 2).

Table 2. Influence of previous crop and tillage on residue cover, soil temperature, and corn grain yield (Lund, et al. 1993).

	Residue Cover (%)*		Soil Temperature (°F)**		Grain Yield (bu/acre)	
Previous Crop	**Plow**	**No-Till**	**Plow**	**No-Till**	**Plow**	**No-till**
Soybean	2%	31%	65°F	63°F	173	176
Corn	5%	69%	65°F	58°F	162	149

* At planting.

** Mid-day, in-row temperature at seed depth, averaged for seven days after planting.

Effects of Corn Residue on Corn Diseases: Corn disease issues generally increase in corn-after-corn production systems, as pathogens survive in corn residue and disease inoculum builds up over time. Leaf diseases such as gray leaf spot, northern corn leaf blight, anthracnose, and eyespot are all known to increase in long-term, high-residue crop production systems. Stalk rot and ear rot fungi such as *Fusarium*, *Gibberella*, *Diplodia* and *Aspergillus* also survive in crop residue and increase in high-residue systems. Goss's wilt has spread from western states to central Corn Belt states as farming practices have left more corn residue on fields. Seedling disease pathogens also survive in corn residue as well as in the soil, and may increase in corn-after-corn production.

Gray leaf spot lesions on corn in high-residue field.

Tips for Managing Corn Residue

Managing corn residue effectively at harvest, with tillage implements and at planting can contribute to successful corn-after-corn production.

- At harvest, knife rolls can replace normal stalk rolls to more aggressively shred stalks at the corn head. Even distribution of residue behind the combine is equally important.
- In areas with cellulosic ethanol plants or feedlots, stover harvest is another option to reduce excess residue, often improving stand establishment and yield (Heggenstaller, 2012).
- Burying corn residue using various tillage operations is another way to manage the additional residue in corn-following-corn production.
- Strip or "zone" tillage is a residue management option that allows growers to retain the benefits of no-till between the rows while gaining the advantages of clean till over the rows.
- Row cleaners, coulters or other residue-management devices on the planter can move residue off the row area to create a suitable environment in the seed zone for more rapid germination and emergence of corn.

Foliar Fungicide Application

Foliar fungicides can effectively reduce leaf diseases and their detrimental effects on corn yields. In 475 Pioneer on-farm trials, foliar fungicides increased yields by an average of 7.0 bu/acre (Jeschke, 2012). However, yield increases were greater in high-residue fields resulting from reduced tillage or corn on corn (Figure 1).

Yield increases due to foliar fungicides also depend on hybrid susceptibility to predominant leaf diseases in a field. In a Pioneer/University of Tennessee study with gray leaf spot pressure, foliar fungicide application increased yields of susceptible hybrids by 24 bu/acre compared to 12 bu/acre for moderately resistant hybrids and 7 bu/acre for resistant hybrids (Jeschke, 2012).

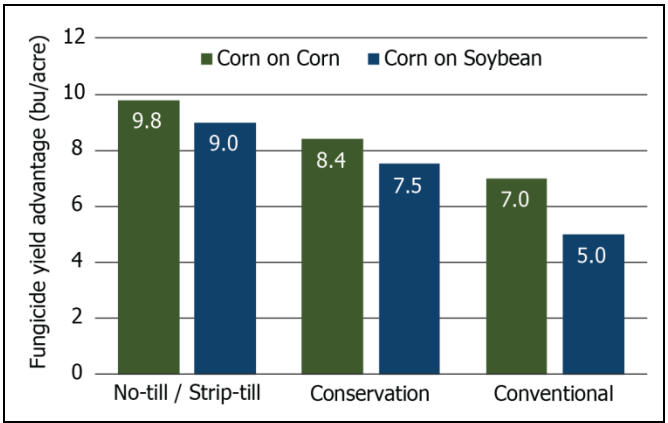

Figure 1. Average yield response to foliar fungicide application as influenced by tillage and previous crop in Pioneer on-farm trials (289 trials, 2007 to 2011).

Soil Fertility

Soil fertility in corn-after-corn production should be based on thorough soil testing and local extension recommendations. Soil tests are needed to determine soil pH and existing levels of phosphorous (P) and potassium (K). The soil pH should be at 6.2 or above for growing corn. A 200 bu/acre corn crop removes about 74 lbs of P_2O_5 and 54 lbs K_2O from the soil in the grain; a 60 bu/acre soybean crop removes about 48 lbs of P_2O_5 and 84 lbs of K_2O. Growing more corn crops relative to soybeans in the rotation will deplete P more quickly and K more slowly. This would have a negligible short-term effect, but bears watching long-term. Banding P and K can improve nutrient uptake efficiencies particularly on soils with pH above 7.2. Starter fertilizers are most beneficial on soils with low soil fertility and may provide more uniform seedling growth during extended cold periods in the spring. The N and P components of starter provide the early growth enhancement.

Determining nitrogen (N) rates for corn after corn involves compensating factors - yields are likely to be lower, so overall N use by the crop will be reduced; but because N is immobilized by corn residue, additional N must be added. For example, if using yield-based calculations of N requirements, scientists recommend that growers adjust their yield goals to approximately 10% less (5 to 15% less) for corn following corn vs. soybeans. Once N needs are determined by this or other methods, producers should increase their N fertilizer by 30 to 50 lbs/acre to compensate for N immobilized by the decomposition of corn residue in the soil. Nitrogen rate recommendations vary from state to state and may have changed with higher N prices in recent years. Growers are encouraged to follow their local extension recommendations regarding N fertilization.

Nitrogen rate has been a component of numerous rotation studies over many years. These studies generally show that increased N alone does not compensate for the reduction in corn yield when following corn vs. soybeans (Table 3).

Table 3. Effect of crop rotation and nitrogen rate on average corn yields. Mallarino and Pecinovsky. 1999*.

Rotation	Crop	Nitrogen lbs/acre (spring-applied)			
		0	80	160	240
		- - - - Corn grain yield (bu/acre) - - - -			
C-C	Corn	55	106	128	135
C-S	Corn	100	141	148	151
C-C-S	Corn1	101	137	148	150
	Corn2	56	106	129	135
C-C-C-S	Corn1	100	135	147	147
	Corn2	58	108	131	136
	Corn3	57	103	127	134

Corn1, Corn2 and Corn3 = 1st, 2nd and 3rd year of corn after soybeans, respectively. *20-year study - Iowa State University.

In this study, corn following corn yields never equaled those of corn following soybeans, regardless of the nitrogen rate applied. At 160 lbs N/acre, this difference averaged 19 bu/acre, or 13% lower yields following corn. At 240 lbs/acre of N, the difference was 14 bu/acre, or 10% less yield following corn vs. soybeans. However, a recent study showed that additional N may, in some cases, overcome much of the yield reduction associated with corn after corn (Mallarino and Rueber, 2011).

Weed Management

Weed management is an important issue when changing from corn following soybeans to corn on corn, as certain weeds may be more problematic. Growers should monitor fields for any increase in specific weed pressure and employ appropriate management solutions.

Volunteer corn is much harder to manage in a corn crop than in a soybean crop. Therefore, growers should strive to prevent volunteer corn by minimizing stalk breakage, ear droppage and harvest losses. This begins with regular scouting of fields in the fall and harvesting fields early if they are at risk of lodging or dropping ears. Adjusting and maintaining the combine helps to minimize kernel loss during harvesting.

When rotating corn with soybeans, an obvious opportunity exists to rotate herbicides as well. Rotating herbicide modes of action helps ensure long-term weed management success by preventing weed shifts and/or weed resistance. When switching to corn-after-corn production, growers should continue alternating herbicide modes of action and using

mixtures or sequential applications of herbicides with different modes of action.

Tillage Systems

In studies conducted at Purdue University, tillage system affected the penalty for growing corn after corn rather than in rotation with soybean. No-till systems suffered the greatest penalty followed by conservation till and then moldboard plowing. However, in some high-yield environments, the penalty under no-till systems was no different than that of the other tillage systems. Effective residue management under no-till systems may help to minimize the yield losses associated with switching from corn after soybean to corn after corn. Strip or "zone" tillage or row cleaners can be used to remove crop residue from over the row while retaining residue between the rows. Some tillage and seedbed tips are listed below:

Tillage and Seedbed Tips

- Plan for tillage that builds a good seedbed for next year, including adequate labor and equipment to complete tillage in the fall. Spring tillage operations are often delayed due to cooler and wetter conditions in continuous corn.
- Check for soil hard pans and use appropriate tillage to break up compacted soil layers.
- Full-width tillage systems should focus on sizing and incorporating residue to speed decomposition.
- In northern areas and on poorly drained soils, strip or zone tillage systems can create a warmer seedbed versus no-till while requiring less fuel than full tillage systems.
- Equip planters with row cleaners to move residue off the row and achieve more consistent soil warm up and seedling emergence in the spring.
- Closely monitor the wear on planter double disc openers to ensure they cut clean and form a good seed furrow.

Conclusions

Though some yield decrease is expected when switching from rotation to corn after corn, yield reductions can be minimized by selecting appropriate hybrids, dealing effectively with corn residue, and adjusting key production practices. In addition to the management considerations described above, the following list can help mitigate yield-reducing issues in corn-after-corn production systems.

- Choose fields with good drainage, medium-textured soils with ample water-holding capacity, and adequate P and K levels.
- Consider planting corn-after-soybean fields first, to allow wetter corn ground the opportunity to dry. Delaying planting until soils are above 50°F (and likely to remain there) can help reduce seedling diseases and improve stands.
- When planting, ensure that soil conditions are dry enough to prevent sidewall compaction of the seed furrow, which limits early root growth and may cause uneven stand establishment.
- Routinely scout and monitor fields to identify any problems early. Look for stand establishment issues, nitrogen shortages, insect buildups, disease outbreaks, weed problems and moisture stress effects.
- Be diligent to prevent soil compaction on corn-after-corn fields. Avoid excess traffic with combines, grain wagons and trucks in the fall and fertilizer and manure applicators in the fall or spring, especially if fields are wet.

Sources

Heggenstaller, A., 2012. Residue management: partial stover harvest increases no-till continuous corn yield. Crop Insights Vol. 22, no. 4. Pioneer Hi-Bred, Johnston, IA. Online: https://www.pioneer.com/home/site/us/agronomy/library/template.CONTENT/guid.49421C06-3AB8-A634-AED7-A8DCCFBE7D28

Jeschke, M., 2012. Maximizing the value of foliar fungicides in corn. Crop Insights Vol. 22, no. 3. Pioneer Hi-Bred, Johnston, IA. Online: https://www.pioneer.com/home/site/us/agronomy/library/template.CONTENT/guid.8899F662-572B-84BD-5F5F-96F177FDBA0D

Lund, M.G., P.R. Carter and E.S. Oplinger, 1993. Tillage and crop rotation affect corn, soybean and winter wheat yields. J. Prod. Agric., 6:207-213. Online: http://corn.agronomy.wisc.edu/Pubs/PC_JournalArticles/006-02-0207.pdf

Mallarino, A.P., and D. Rueber. 2011. Iowa State University publication, RFR-A01107, as reported in Ag Decision Maker, Vol. 16, no. 2, Dec., 2011. Online: http://www.extension.iastate.edu/agdm/newsletters/nl2011/nldec11.pdf

Mallarino, A.P. and K. Pecinovsky. 1999. Effect of crop rotation and nitrogen fertilization on crop production over a 20-year period. p. 13–16. In Annual progress reports: 1998 - Northeast research and demonstration farm ISRF98-13. Iowa State University, Ames.

Vyn, T.J. 2010. Managing residue and tillage on "saturated soils" for optimum production in the short-term and long-term. Illinois Tillage Seminar presentation. Purdue University, West Lafayette, IN. Online: http://www.agry.purdue.edu/staffbio/Illinois%20Tillage%20Seminar%20Presentation%201-26-2010.pdf