CROP INSIGHTS

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Best Management Practices for Corn-After-Corn Production

by Steve Butzen, Agronomy Information Manager

Summary

- Although the advantages of crop rotation are widely recognized, some growers have opted to increase their acres of corn following corn.
- Hybrid selection is important when growing corn after corn. To aid in this decision, Pioneer rates its hybrids for stress emergence, high residue suitability, resistance to leaf and stalk diseases, and stalk and root strength.
- Other plant and seed technologies can contribute to corn-after-corn success. Pioneer® brand hybrids with Herculex® RW or Herculex Xtra traits, treated with Dynasty® fungicide and Poncho® 250 insecticide, offer the ultimate disease and insect protection for this production system.
- 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.
- More nitrogen will likely be needed when producing corn after corn vs. corn after soybeans. For P, K and lime, test soils and follow local extension guidelines.
- Research has shown that yield reductions for continuous vs. rotated corn are often greater in stress years, probably due to a reduced root system. Growers should be careful to prevent compaction and choose fields with good tilth and water-holding capacity for corn-after-corn production.
- Research studies have shown that tillage system can have a significant impact on the relative yield of corn after corn vs. corn after soybeans. Clearing residue from over the row is often important for best yields under no-till.

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 requirements, decreases disease and insect pressure, allows growers to alternate herbicides, and often improves soil tilth. Most importantly, it usually increases yields.

In recent years, the economic advantages of growing corn have outweighed the benefits of rotation for some growers. High corn yields and prices, as well as challenges with soybean diseases and corn rootworm following soybeans in some areas, have encouraged growers to increase corn acres in their operations. This means growing two or more corn crops before rotating back to soybeans or other crops.

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

Those who take this step may benefit from a review of the issues that will likely be encountered when growing corn crops back to back. This Crop Insights will address best corn-after-corn production practices, with focus on hybrid selection, plant and seed technologies, and high crop residue challenges. These challenges include cool, wet soils at planting, increased disease and insect levels, and tie-up of nitrogen. Other issues are soil compaction, weed management and moisture stress.

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, 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 corn residue.
- Choose the highest-performing genetics with the defensive traits required for this production system. Overall stalk strength can be a hedge against late-season lodging in hybrids with moderate stalk rot tolerance. With more corn acres, stalks may need to stand longer than previously.

Pioneer provides several ratings that can help growers pick the best hybrids for this purpose – stress emergence, high-residue suitability, specific leaf, ear and stalk disease scores, and stalk and root strength.

Stress Emergence: Grower tendencies toward earlier planting and reduced tillage can make the corn-after-corn seedbed an inhospitable environment for stand establishment. Stress emergence refers 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, a trend that is expected to continue. 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, 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).**

Other Leaf, Ear and Stalk Disease Ratings: The incidence and severity of corn diseases has increased in recent years due to build-up in crop residue. In fields with a history of leaf or stalk diseases, growers should choose hybrids with 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. Your Pioneer sales professional can provide these scores to assist you in selecting hybrids for corn on corn.

Plant and Seed Technologies

Pioneer offers several plant and seed technologies for controlling corn insects and diseases that increase in corn-on-corn production systems.

Insects: Insects are harbored in corn residue and previous corn ground, including corn rootworm, corn borer, and a new ear-feeding pest in the midwestern US, western bean cutworm. Other common corn pests must be controlled for successful stand establishment in corn-after-corn production. These include wireworm, white grubs, seedcorn maggot, and others. Growers should choose technologies that defend against these yield-robbing pests.

Corn rootworm (CRW) is the major corn insect pest associated with corn-on-corn production. Many growers who have depended on crop rotation to control CRW in the past will need a new strategy when switching fields to second-year corn. Effective control measures are critical for this pest, as CRW pressure tends to be highest in the second and third years of continuous corn.

Plant and seed technology options include Pioneer® brand hybrids with the Herculex® RW or Herculex Xtra *Insect Protection* traits, or Poncho® 1250 insecticide seed treatment. The appropriate option depends on the level of CRW damage expected in the field.

Herculex RW: The Herculex RW (HXRW) trait, new in 2005, is a highly effective option for CRW control, providing protection against western, northern, and Mexican CRW. In studies conducted from 2004 to 2006, hybrids with the HXRW trait demonstrated the lowest feeding of any CRW management option, including Yieldgard® Rootworm and Yieldgard Plus, soil insecticides and seed-applied insecticides. Results of studies conducted in 2006 are shown in Figures 1and 2.

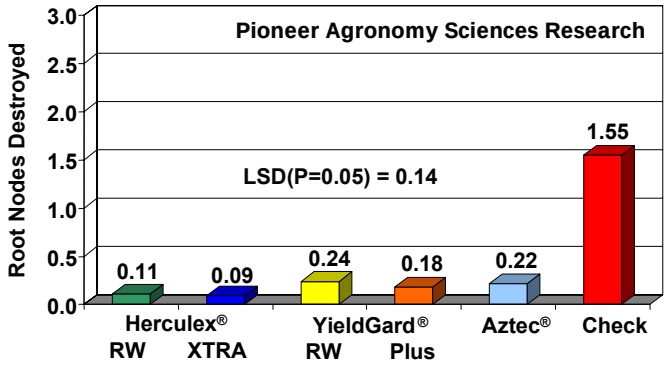

Figure 1. Performance of CRW management options at 6 locations with high CRW pressure -- IA (2), IL, MN, IN, and WI, 2006; 2 hybrids/treatment. Source: Pioneer Hi-Bred.

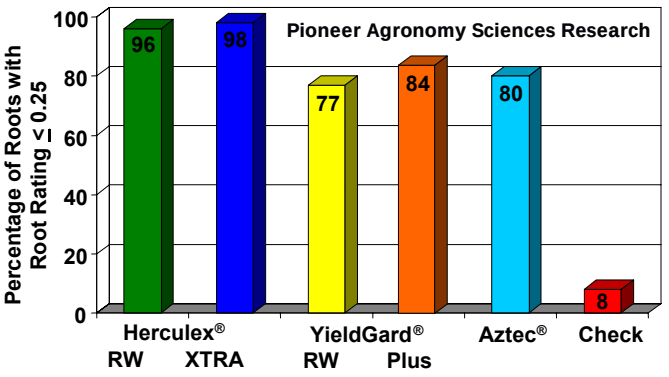

Figure 2. CRW consistency ratings at 6 locations with high CRW pressure -- IA (2), IL, MN, IN, and WI, 2006; 2 hybrids/treatment. Source: Pioneer Hi-Bred.

In locations with heavy CRW pressure, Pioneer hybrids with the Herculex RW trait provided better root protection and proved to be more consistent than the Yieldgard Rootworm and Yieldgard Plus hybrids. Herculex RW hybrids are treated with Poncho 250 seed-applied insecticide to help control wireworm, white grub, seedcorn maggot, flea beetle, grape colaspis, chinch bug and black cutworm, according to the

manufacturer's label. This seed is also treated with Dynasty® fungicide for control of seedling diseases (see more on Dynasty fungicide below).

Herculex XTRA: Herculex® XTRA (HXX) is a stack of the Herculex I and Herculex RW traits. Pioneer hybrids with the HXX trait protect against a broad array of destructive plant and ear-feeding insects in addition to corn rootworm, including European and southwestern corn borer, black cutworm, western bean cutworm, fall armyworm, lesser and southern cornstalk borer, sugarcane borer, and suppression of corn earworm. This spectrum of insect protection provided by hybrids with the Herculex XTRA trait is unmatched by any other in-plant technology available today. In fact, while several Bt options control corn borer, only hybrids with the Herculex I or Herculex Xtra traits control western bean cutworm and black cutworm.

Like HXRW hybrids, HXX hybrid seed includes Poncho 250 and Dynasty seed treatments. These transgenic CRW-resistant hybrids require planting a 20% in-field refuge.

Poncho 1250: Poncho® 1250 is a high-rate insecticide seed treatment, applied at a rate of 1.25 mg/kernel. The primary pest target for Poncho 1250 is corn rootworm (CRW), but in addition, it offers the broadest insect protection available in a seed-applied insecticide for a number of other problematic insects. Secondary soil insects on the Poncho 1250 label include wireworm, white grub, grape colaspis, and seedcorn maggot. Above-ground insects are billbug, chinch bug, flea beetle and black cutworm.

Poncho 1250 has proven effective in low and moderate corn rootworm infestations, but is not recommended under high infestations. However, when combined with adult beetle control programs, Poncho 1250 can provide an alternative to planter-applied granular insecticides. This option eliminates the cost and time required to install soil-applied insecticide equipment, calibrate equipment and load products during planting, and handle and return insecticide containers.

These insect management technologies have different roles in protecting corn-on-corn production. In many areas, agronomists recommend monitoring adult CRW populations to determine potential control options for the following year. A crop consultant or scout can provide weekly beetle numbers allowing you to determine level of risk next season. Your Pioneer sales professional can help you interpret these numbers and choose the right option for your geography, field history, and probable insect spectrum and infestation level.

Seedling Diseases: Seedling disease problems caused by *Pythium*, *Fusarium*, *Rhizoctonia* and other pathogens have increased throughout the US and Canada in recent years, reducing stands and yields in corn-after-corn production. For this reason, Pioneer has introduced a new seed fungicide for corn hybrids called **Dynasty** as part of a seed-treatment combination with Poncho 250 or Poncho 1250 insecticide seed treatments (ISTs). This treatment will also include the standard Maxim® XL fungicide and a new seed treatment polymer. Dynasty has activity against soil fungi that cause corn seedling diseases, including the most common damping-off organism, Pythium.

Poncho 250 and Poncho 1250 ISTs have proven to be very effective at protecting stands in stressful environments. Although these are insecticides, they also protect against seedling disease by reducing insect feeding and depriving pathogens of points of entry. Both products provide effective control of secondary insects such as wireworms, seedcorn maggots and white grubs. These insects tend to be active in the early season and can cause significant stand reductions, especially if emergence is slow due to stress.

Crop 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 crop.

Excessive corn residue can result in **cooler soil temperatures and higher soil moistures** at planting time. Residue directly over the row can lower temperatures in the seed zone, delay germination and early growth, and reduce stands and yields (Table 1).

Table 1. Influence of previous crop and tillage on residue cover, soil temperature, and corn grain yield. Source: University of Wisconsin three-year study.

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

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

When planting, ensure that soils conditions are dry enough to prevent sidewall compaction of the seed furrow. Sidewall compaction can limit early root growth and cause uneven stand establishment. Cool, wet soils beneath corn residue may also result in later planting than when following a soybean crop. To counter this problem, growers should plan to manage corn residue effectively – at harvest, with tillage implements, and at planting.

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. Strip-tillage (zone-tillage) systems allow 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 also help to create a suitable environment in the seed zone for more rapid germination and emergence. Various tillage operations can also effectively manage the additional residue in corn-following-corn production.

Diseases: In tillage systems that leave significant amounts of residue on the soil surface, corn diseases may become an issue. Pathogens survive in corn residue and disease inoculum builds up over time.

When planting early into a high-residue seedbed, corn seedling diseases may increase. Strip (zone) tillage or otherwise removing residue from over the row, and delaying planting until soils are 50 to 55°F (and likely to remain there) are possible management practices to help reduce seedling diseases. (Also see sections on *Hybrid Selection* and *Plant and Seed Technologies* in this article for additional options.)


Northern leaf blight.

Leaf diseases such as gray leaf spot, northern leaf blight, anthracnose, and eyespot are all known to increase in long-term, high-residue farming 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. Burying corn residue by tillage may be an option for some growers, but all growers should select hybrids with good disease resistance and standability (See section on *Hybrid Selection* in this article). Stalk rots often accompany leaf diseases, so monitoring stalk quality and timely harvest are helpful when leaf diseases occur.

If ear rots are found, late-season scouting can help growers make informed decisions about harvest timing, postharvest grain handling, storage and utilization. Grain with significant ear rot symptoms from the field should be dried at high temperature as quickly as possible to 15% moisture or less. The lower the moisture content in storage the lower the risk of mycotoxin development.

Soil Compaction: Because heavy corn residue keeps soils wetter, fall or spring tillage may be performed under wetter soil conditions than in the past. Corn harvest also requires more combine and grain cart loads than does soybean harvest. This contributes to increased likelihood of soil compaction, which can restrict root growth and limit water uptake and yield during drought conditions. Soil compaction also limits drainage during periods when rainfall is excessive, which can damage crops and decrease yields.

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.

P and K requirements are fairly similar for corn after corn vs. corn after soybeans, but corn grain removes more P and less K from the soil than soybeans. 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.

Nitrogen: Corn residues tie up much more nitrogen than soybean residues as they decompose in the soil. Therefore, soil scientists suggest that producers increase their N fertilizer by 30 to 50 lbs/acre above their previous rates when changing from corn after soybeans to corn after corn. If using yield-based calculations of nitrogen requirements, growers should adjust their yield goals to approximately 10% less (5 to 15%) for corn following corn. Nitrogen rate recommendations vary from state to state and many have changed with higher N prices in recent years. Growers are encouraged to follow their local extension recommendations regarding nitrogen 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 2).

Table 2. Effect of crop rotation and nitrogen rate on average corn yields. Northeast Research and Demonstration Farm, Nashua, Iowa. 1979-1998. Source: Iowa State University.

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=1st year of corn after soybeans. Corn2=2nd year of corn after soybeans. Corn3=3rd year of corn after soybeans.

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. Other studies have shown even greater yield reductions for corn following corn, in spite of high rates of nitrogen fertilizer.

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.

Growers may also need to manage volunteer corn. In conventional tillage, cultivation can be used to control volunteers in row middles. In reduced till and no-till fields, growers should strive to reduce stalk lodging and ear droppage that lead to volunteer corn. Use of Bt hybrids that control corn borer is a primary way to reduce both stalk breakage and ear drop. Monitoring fields for stalk quality during the fall allows growers to harvest fields at risk of stalk breakage first. Adjusting and maintaining the combine help to minimize kernel loss during harvesting. Also, no-tilling or delaying tillage allows wildlife to forage the seed during the winter.

Many growers in a corn-soybean cropping system have been applying glyphosate to soybeans, and other herbicides to corn. This program exemplifies good weed management stewardship by rotating herbicide modes of action to help ensure long-term weed management success and prevent weed shifts and/or weed resistance. When switching to corn-after-corn production, continue alternating herbicide modes of action and using mixtures or sequential applications of herbicides with different modes of action.

Tillage Systems

Research studies have shown that tillage system can have a significant impact on the relative yield of corn after corn vs. corn after soybeans, usually lowering yields (Table 3).

Table 3. Corn yield response to tillage and rotation, 1975-2004. Chalmers silty clay loam. West Lafayette, IN*.

	1975 - 2003		2004		Yield gain for rotation (%)	
Tillage System	**Corn/ Soy**	**Cont. Corn**	**Corn/ Soy**	**Cont. Corn**	**1975-2003**	**2004**
	Yield (bu/acre)				%	
Moldboard	176	168	213	201	5	6
Chisel Plow	177	164	209	198	8	5
No-till	172	146	207	179	18	16

*Yield data from a cooperative project involving T.D.West, T.J.Vyn and G. Steinhardt. Agronomy Dept., Purdue Univ.

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.
- Full-width tillage systems should focus on sizing residue with stalk choppers or disks so residue can be incorporated to speed decomposition.
- Check for soil hard pans and use appropriate tillage to break up compacted soil layers. More trips across the field with grain carts and combines during corn harvest increase risk of soil compaction.
- In northern corn-producing 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.
- Use of auto-steer guided equipment when strip or zone tilling can enable the planter to stay on top of the tilled area the following season.
- 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.

Yields were reduced by 5 to 8% when switching from a corn-soybean rotation to continuous corn under a moldboard or chisel plow tillage system. But under no-till, yields were reduced by 18%. Even under the very high yield conditions of 2004, the percentage difference between plowing and no-till systems was almost identical. These yield reductions may be due in part to cooler soil temperatures and other negative effects of corn residue in continuous corn production. Another study with different tillage systems shows less drastic results (Table 4).

Table 4. Corn yield response to tillage and rotation, 1997-2004. Sebewa loam. Wanatah, IN*.

	1997 - 2003		2004		Yield gain for rotation (%)	
Tillage System	**Corn/ Soy**	**Cont. Corn**	**Corn/ Soy**	**Cont. Corn**	**1975-2003**	**2004**
	Yield (bu/acre)				%	
Fall Chisel	188	174	230	210	8	9
Fall Disk	189	170	234	211	11	11
No-till	185	161	224	206	14	9

*Yield data from a cooperative project involving T.D.West, T.J.Vyn and G. Steinhardt. Agronomy Dept., Purdue Univ.

In this study, corn yields under fall chisel plowing and fall disking were similar, and were reduced by 8 to 11% in

continuous corn production vs. the corn-soybean rotation. But yields under no-till were reduced by 14% in continuous corn vs. rotation (1997-2003 results). However, in the very high-yield year of 2004, yield reductions for continuous corn were no greater in no-till than in fall disk or fall chisel.

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.

Rotation Effect and Stress Environments

The so-called crop "rotation effect" is an unexplained benefit that results in yield increases with rotations, even though all limiting factors appear to have been controlled or adequately supplied in continuous cropping. This yield increase averages about 5 to 15 percent, but is much greater some years. Yield reductions for continuous vs. rotated corn are usually greatest when yield potential is low (Table 5).

Table 5. Yield advantage of corn following soybeans over corn following corn at different yield levels*. Four-year study at Waseca, MN. Source: University of Minnesota.

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

*Nitrogen levels were 200 lb/acre.

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 corn-following-corn yield losses often accompany 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. In seasons with excessive soil moisture in spring and early summer, yield differences between corn after corn vs. corn after soybeans have been magnified in some cases. If N is lost under wet conditions, less extensive root systems could limit nitrogen uptake in corn-following-corn production.

Management Suggestions for Corn After Corn

- Choose fields for corn-after-corn production that are best-suited to this cropping system. Fields selected should have good drainage, medium-textured soils with ample water-holding capacity, and adequate P and K levels.
- 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.
- Manage residue effectively at the combine corn head and stalk chopper, and with tillage implements and planter attachments. Keeping residue distributed evenly at harvest and cleared from the row area at planting are key goals.
- Consider planting corn-after-soybean fields first, to allow wetter corn ground the opportunity to dry. Planting later combined with cooler soils may slow crop development, so select hybrids of appropriate maturity (CRM).
- Manage nitrogen carefully. Combination pre-plant and sidedress N applications may help limit effects of N losses due to leaching or denitrification in wet years.
- Routinely scout and monitor corn-after-corn fields to identify any problems early. Look for stand establishment issues, nitrogen shortages, insect buildups, disease outbreaks, weed problems, and moisture stress effects.
- Corn-after-corn production will require management of corn rootworm in the vast majority of cases. Growers have choices of hybrids with Herculex® RW or Herculex XTRA traits, Poncho® 1250 seed-applied insecticide, or granular soil insecticides. Your local Pioneer sales professional can help you weigh these options.
- Monitor fields for corn diseases, primarily leaf diseases and stalk and ear rots. Diseases may be best controlled by managing residue levels and selecting resistant or tolerant hybrids. Gray leaf spot, northern leaf blight and anthracnose stalk rot are some diseases that should be monitored in corn following corn.