Corn-on-Corn Management Guide

Technology Development & Agronomy
by MONSANTO

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1. Agronomics of Corn-on-Corn: The Foundation for Understanding

Agronomy is the Foundation for Understanding

Agronomy is defined as "the science of soil management and the production of field crops"[1]. This principle is evident in Dr. Fred Below and Dr. Laura Gentry's presentation of the 'Seven Wonders of Corn Yield'[2]. They ranked seven factors in terms of their potential influence on corn yield, with the assumption that the fundamentals of drainage, fertility and weed control are managed appropriately (Table 1-1). When considering corn-on-corn rotations, it is important to weigh the benefits and the risks, both economically and agronomically. When trying to maximize yield potential and profitability, agronomic aspects should be evaluated independently as well as for their potential interaction with other agronomic characteristics or environmental conditions.

Reasons People Consider Corn-on-Corn

There are several reasons farming operations might consider corn-on-corn. Some include the following:

1) Commodity prices favor higher profit margins for corn-on-corn that potentially outweigh risks associated with corn-on-corn.
2) Corn-on-corn acres have had good yield potential in recent years, in local geography, or in particular fields.
3) Soybeans, or other alternative crops, may not have had satisfactory performance in local geography or in particular fields.
4) Livestock within the operation might increase the need for corn or silage.

Risks Involved with Corn-on-Corn

Agronomically, rotation can be very beneficial. Corn-on-corn acres are more at risk for several agronomic concerns including lower yield potential, leaf diseases, compaction, insects, residue management, nitrogen immobilization, stalk rots, and ear rots.

"Stress on Stress" is a term commonly used and it summarizes reality. Understanding how and when stresses can interact with each other, and the crop, can help provide a basis for evaluating future management options.

Table 1-1. Seven Wonders of Corn Yield[2].

Rank	Factor
1	Weather
2	Nitrogen
3	Hybrid
4	Previous Crop
5	Plant Population
6	Tillage
7	Growth Regulators

Management Practices to Consider to Help Reduce Risks Associated with Corn-on-Corn

Various management practices can help reduce the risks associated with corn-on-corn. Several are covered throughout this guide. Some of the key tools include the following:

1) Crop rotation, even if it is every 2nd or 3rd year, can help break insect and disease cycles.
2) Selecting a package of hybrids with strong agronomics for corn-on-corn, not planting the same hybrid in the same field annually, and using hybrids with insect protection traits that have dual-modes of action can help manage risks associated with corn-on-corn.
3) Fields should have good drainage, low compaction, and high yield capabilities.
4) Adequate fertilizer should be applied to compensate for immobilized nitrogen.
5) Very good planting conditions, including good seed-to-soil contact, warm soil temperatures, and adequate moisture, can help mitigate corn-on-corn risks.
6) Good scouting techniques can help reduce other risks, such as potentially higher increased disease and insect pressure.

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2. Yield Effects of Long Term Continuous Corn, Second-Year Corn, First-Year Corn, & Rotated Corn

First-year corn or corn grown in an annual rotation with soybeans generally has more yield potential than second-year corn or continuous corn. However, a common belief is that second-year corn generally has less yield potential than continuous corn[7]. Historical data does not support this concept[7,16].

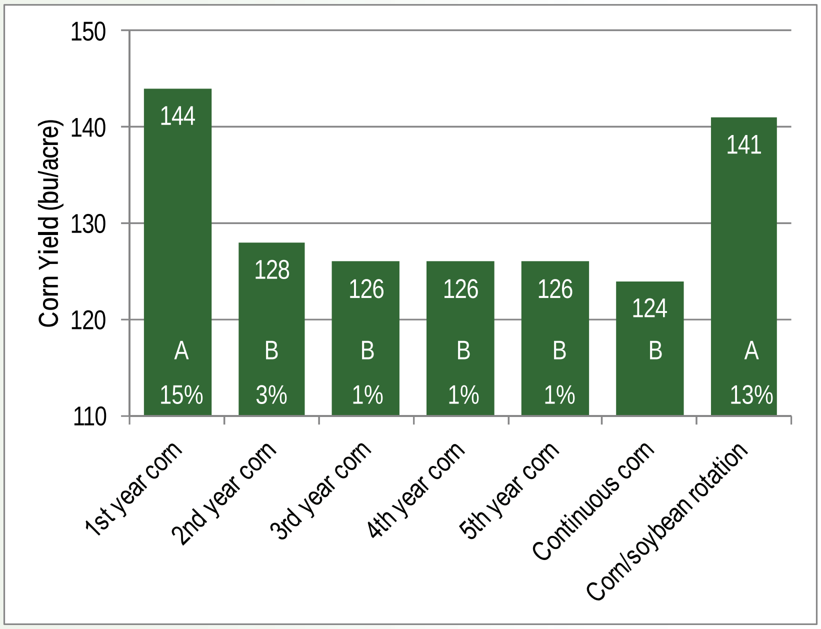

Figure 2-1. Effect of rotation on corn yield across 3 locations representing 29 environments. Treatments assigned different letters are significantly different at the 0.05 probability level. The yield advantage of the treatment versus continuous corn is represented as a percentage[7,17,18].

Trials were conducted from the mid 1980's through the mid-1990's, in three locations in Minnesota and Wisconsin to evaluate the effects of rotation on yield potential (Figure 2-1)[7,17,18]. There was no significant difference between the yield of second-year corn and continuous corn. There was a 13 to 15% yield advantage for rotated corn or first-year corn, respectively. A review of other published data indicates that a similar trend was observed in different locations and years as well (Table 2-1)[16]. It has also been observed that in higher yielding environments, the yield penalty is often less than 15% for continuous corn versus rotated or first-year corn compared to lower yielding environments, when the yield penalty can often be greater than 25%[16].

It is difficult to pinpoint the source of the misconception that second-year corn has less yield potential than continuous corn. There are limited opportunities to truly evaluate the effects of rotation with all other variables eliminated. Therefore, a lot of the support likely came from anecdotal evidence. Some of the concepts below might have contributed to the misconception.

1) Continuous corn generally gets placed on soils with higher yield potential, so some of the yield losses were likely minimized.
2) When trying to expand corn acres in an operation, corn-on-corn might be tried on more marginal ground. Lower yielding environments are more favorable for yield loss due to corn following corn. Hence, second-year corn on this more marginal ground, compared to continuous corn grown on better ground, leaves the impression that continuous corn is better than second-year corn.
3) Some of the corn yield contest winners, have accomplished record yields with continuous corn.
4) In the fields that are very conducive to continuous corn, how many comparisons have been done between continuous corn and rotated corn?

In parts of the Midwest in 2011, many farmers reported that continuous corn was markedly lower yielding than their second-year corn. While there is plenty of historical research that indicates continuous corn tends to yield less than second-

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Table 2-1. A collection of published data comparing yields (bushels/acre) of corn rotated with soybean, second-year of corn after soybean, and continuous corn[16].

Location	Years	Corn Rotated with Soybean	Second-Year Corn after Soybeans	Continuous Corn	Continuous Corn vs. Rotated	Continuous Corn vs. Second-Year Corn
Lamberton & Waseca, MN	1981-1989	138	122	127	-8%	+4%
Aurora, NY	1993-1997	142	121	119	-16%	-2%
Nashua, IA	1979-2004	158	141	139	-11%	-1%
Arlington, WI	1987-1989	141	132	121	-14%	-8%
Arlington, WI	1995-1997	161	146	142	-12%	-3%
Arlington, WI	1998-2001	210	188	183	-13%	-3%
Lamberton, MN	1985-1995	130	116	115	-12%	-1%
Waseca, MN	1986-1995	142	131	129	-9%	-2%
Arlington, WI	1987-1995	151	139	130	-14%	-6%

Notes: For continuous corn, the years of corn prior to yield collection varies among studies.

year corn (contrary to popular belief) there is not a definitive answer for the magnitude of the difference observed in 2011, or the reason for it. A few theories outlining some of the possible contributing factors to continuous corn yielding less than second-year corn in parts of the Midwest in 2011 include:

1) **Residue.** More years of corn results in more corn residue. With increased residue, comes a greater chance for immobilization of N. Additionally, increased residue may lead to an increased risk for issues with autotoxicity. However, given the weather and agronomic conditions, one would have expected the negative effects of nutrient immobilization and autotoxicity to be greater in 2010 than 2011.

2) **Wrong Place at the Wrong Time.** Continuous corn is often placed on heavy, productive (often more poorly drained soils) that can produce high corn yields, but can struggle to produce consistently high soybean yield potential. In 2011, there was a wet spring and early summer followed by a hot, dry period from pollination through grain fill. One might think that the heavy, poorly drained soils should have fared well due to ability to retain moisture for a late season drought. That might have been more true, if the early wet conditions hadn't put such a notable strain on the corn plants growth and root development. The damage caused by excessively wet conditions early was generally worse on heavy, poorly drained soils, setting them up to be even more susceptible to late season drought stress. Therefore, it is possible that the perceived yield penalty for continuous corn versus second-year corn may be a function of placement on certain soils. With limited opportunities for comparison of continuous corn and second-year corn, especially on the heavy, poorly drained soils in a year like 2011, it is difficult to conclude how much this notion contributed to the concept of

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continuous corn yielding less than second-year corn.

3) **Soil Structure.** Both second-year corn and continuous corn would have been exposed to good tillage conditions in the fall of 2010 followed by wet conditions in the spring of 2011. There are good odds that longer term continuous corn would have also been subjected to the challenging fall of 2009 and spring of 2010. The soil tilth and structure of some fields may still be poorer due to damage suffered in previous wet years when the field was in corn. Again, this does not fit all acres, but is another potential contributing factor.

The yield advantage for rotated corn versus corn following corn is fairly consistent, and also more apparent in lower yielding environments. The concept that continuous corn is better than second-year corn is not supported by data. However, reality is that the interactions between crop growth and crop rotation are poorly understood, despite research and years of observation. As discussed in this publication and others, there are several contributing factors about how rotation can affect corn yield potential. Continued research and experience with continuous corn, should help explain some of the differences seen over time.

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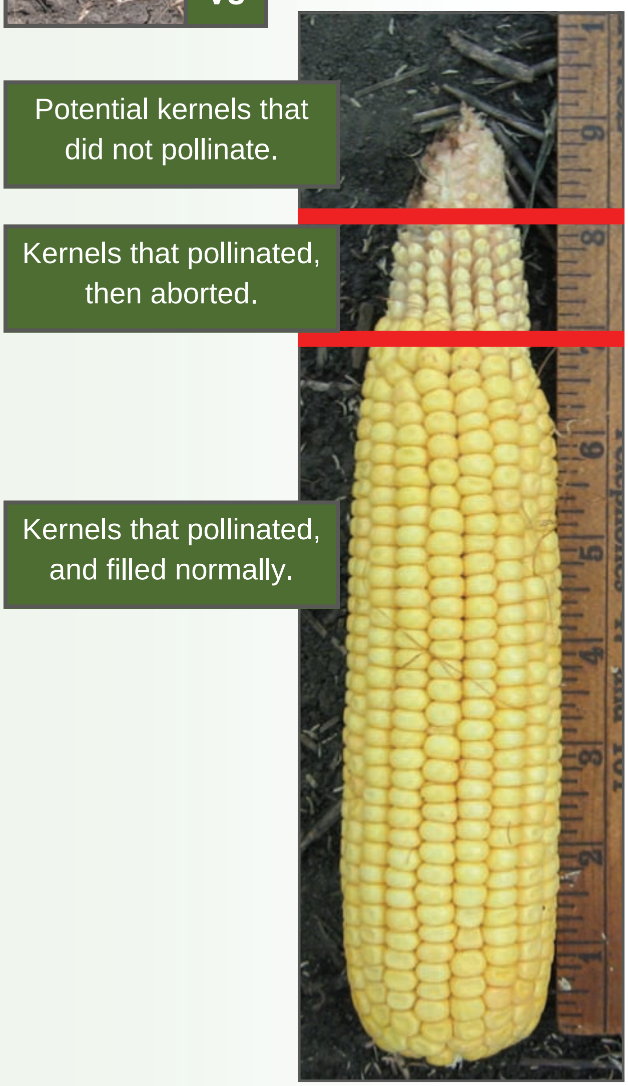
3. Important Growth Stage Milestones

Understanding what is going on within a corn plant at various stages of growth is important to help accurately assess the causes of various situations that can be noticed throughout the growing season. Much of the following is based on information from the Iowa State University Extension publication titled Corn Growth and Development, published in March 2011[3].



V3-V6

Corn plants transition from relying on the endosperm of the kernel to self sustenance via nodal roots and photosynthesis.

V5

The number of potential ear shoots is determined.

V6-V8

The number of potential kernel rows is determined.

V8-V15 (approximate)

The number of potential kernels per row is determined.

VT-R1 (Tassel and Silk)

Corn is highly susceptible to stress, especially moisture stress. Stress at VT or R1 can cause significant pollination problems. The result of the timing of such problems might be evident in ear formation as silks emerge from the base of the ear first and progress upward to the tip.

R2 (Blister)

Stress at R2 can cause significant kernel abortion or tip back.

R3 (Milk)

Little kernel abortion occurs after R3. If stress reduces the resources available to the plant, possible results include reduced kernel depth and stalk cannibalization.

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4. Weather: Not Controllable, Yet Critical

In the 'Seven Wonders of Corn Yield' presentation, weather is shown to have a greater influence on yield potential than the other factors. In that example, weather accounted for 70+ bushels/acre or 27% of total yield potential[2]. Knowledge of how weather conditions at different stages of corn growth can affect yield potential can help explain what management practices may or may not be able to be improved.

Some might challenge the notion that "weather" should be considered a main factor contributing to the potential yield differences between corn-on-corn and rotated acres. For example, if the two cropping systems are in close proximity to each other, and all other variables are equal, including the weather, there can still be considerable differences in yield potential. However, while the weather may have been the same, the amount of stress factors the crop endured may not have been the same. Effects of weather can be amplified if the corn plants are already suffering from multiple stress factors, which can be greater in corn-on-corn situations. This again reinforces the concept of stress on stress.

Weather can directly or indirectly influence several aspects of agronomics that can differ between corn-on-corn and rotated acres:

- A wet fall can lead to less fall tillage, increasing the amount of residue left on the surface and decreasing the ability for that residue to be broken down. Residue is a greater concern in corn-on-corn as it is present in greater quantities, can potentially decrease seed to soil contact at planting, and can inhibit nutrient availability.
- Corn-on-corn often has more tillage compared to rotated corn. Damp conditions during the ideal time for tillage operations can result in poor seed bed preparation and/or soil compaction.
- More residue in corn-on-corn fields can result in more time needed for the fields to get fit in the spring. Damp and/or cool conditions near planting can amplify that situation.
- Foggy mornings and damp conditions in the middle of the growing season are favorable for diseases such as gray leaf spot (GLS), which overwinters on residue. Since corn-on-corn has more residue, there is potentially a higher inoculum load which may result in a greater incidence of GLS on corn-on-corn ground.
- In dry situations, corn-on-corn may be more challenged due to restricted root growth from potential compaction from the additional tillage passes that are often used to manage residue.

There are several other ways weather can interact with the agronomics of corn-on-corn production. Combining weather information with the fundamental agronomics of corn-on-corn can help explain various results at the end of a growing season (Figure 4-1).

Precipitation (% of mean)	Departure from Mean Average Temp. (° F)

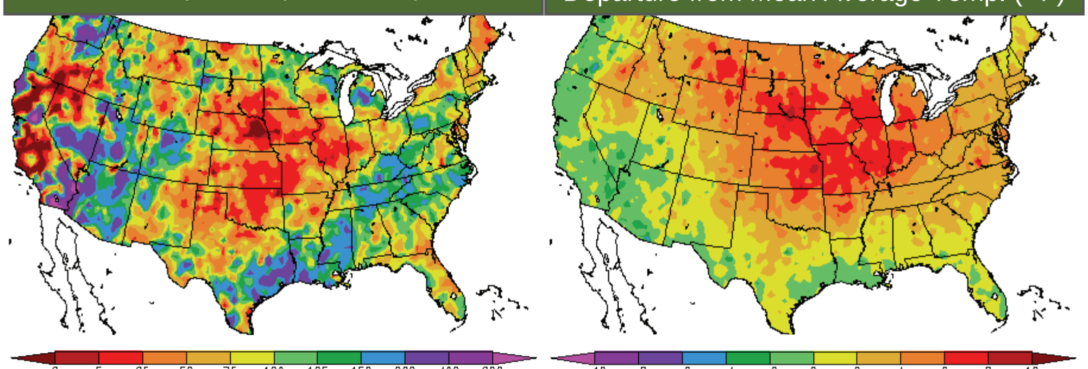

Figure 4-1. Precipitation (% of mean) and departure from the mean average temperature (º F) for July 2012 is represented in these maps. Mean period is 1981-2010.

The Current Climate Summary Maps are produced daily using data from the Applied Climate Information System (ACIS). Stations used are from the National Weather Service Cooperative Observer Network (COOP) and the Automated Weather Data Network (AWDN). All near-real-time data are considered preliminary and should be used responsibly. For more information, please see the High Plains Regional Climate Center web page: http://www.hprcc.unl.edu.

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5. Soil Structure and Compaction

Corn needs water, nutrients, and sunlight to grow. Water and nutrients are provided to the plant through the root system belowground. Soil and root structure can often be overlooked due to it being more difficult to observe than plant tissue aboveground. Even if water and nutrients are ample in the soil, poor roots or soil conditions can prevent the corn plant from obtaining what is needed for desired plant growth. Without the ability to obtain adequate water and nutrients, corn is more likely to express nutrient deficiency symptoms, as well as susceptibility to heat and drought stress, and diseases such as stalk rots. Continuous corn has the potential to be more prone to challenges with soil structure, such as compaction, due to it generally receiving more tillage and traffic than rotated ground, as well as it retaining soil moisture longer than rotated ground largely due to higher amounts of residue (Figure 5-1). The visual and physiological effects of restricted root growth may be hidden by favorable environmental conditions or amplified with additional stress.

Basics of Compaction

Soil compaction occurs when mechanical loads are applied to susceptible soils which are at or near field capacity with moisture. Field capacity is the point where the pore space surrounding soil particles is completely occupied with soil water, displacing the air portion which is present in drier soils. Water in the soil acts as a lubricant between soil aggregates, allowing them to become tightly packed together.

Coarse textured soils, and those with high levels of organic matter are less prone to compaction. Medium and fine textured soils typically have a greater moisture holding capacity, are slower to dry down, and are more likely to suffer compaction. The degree of compaction is determined by the weight of the equipment transferred to the soil, and the amount of moisture present at the time of the field operation.

Two main types of compaction are sidewall compaction and compaction caused by traffic and tillage. Both types of compaction can be caused by similar soil conditions and can put the corn plant under similar stresses. However, the visual symptomology of the root structure and some of the tools to reduce each type of compaction can vary.

Figure 5-1. Corn on corn has greater potential for compaction in the fall due to traffic required to remove more bushels from the field compared soybeans.

Also, more residue can result in corn on corn fields staying wetter for a longer period of time in the spring. If tillage is done too soon, before the field is fit, then a cloddy seedbed and uneven emergence may result.

Restriction of Roots

Root growth can be reduced not only because of compaction but also because of low soil oxygen availability[4]. Above average rainfall resulting in low soil oxygen availability can be especially challenging when corn is focused on vegetative growth, prior to tassel. Deficiencies of nutrients such as nitrogen (N) and potassium (K) may occur due to slow root growth and poor root exploration. Restricted root development can also increase lodging and have a negative effect on yield potential, especially if the latter half of the growing season is hot and dry. Restricted root growth in the first half of the growing season can result in smaller than normal root masses later in the season when water deficiencies reach the most critical point.

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Monmouth Demonstration. Continuous corn and a corn and soybean rotation, were compared in conventional tillage and strip-till scenarios at the Monsanto Learning Center at Monmouth, IL in 2011. Root pits were dug late in the summer to illustrate the effect of the treatments on root growth and ear development (Figure 5-2). Roots in the continuous corn conventional tillage treatment were shallower than those in the other treatments. A density layer from tillage and traffic compaction was likely the cause. Ear size was smaller in the continuous corn with the conventional tillage treatment as well.

Roots in the continuous corn with the conventional tillage treatment were more shallow than those in the other treatments. A density layer from tillage and traffic compaction was likely the cause. Ear size was smaller in the continuous corn with the conventional tillage treatment as well.

Continuous corn
Conventional tillage

Rotated
Conventional tillage

Continuous corn
Strip-tillage

Rotated
Strip-tillage

Figure 5-2. Effect of crop rotation and tillage system on root growth and ear development in corn. Monmouth, IL, 2011.

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Potential Effects of Sidewall Compaction

Sidewall compaction can cause poor seed-to-soil contact. Often a too-shallow placement of the seed is an outcome of sidewall compaction. Consequences can include reduced germination and poor stands, uneven emergence and growth, restricted root growth, and stunted seedlings. Roots will often proliferate within the area opened by the disc openers, but not the surrounding soil. The result is a 'tomahawk' root system (Figure 5-3). Plants with restricted root growth often show symptoms of nutrient deficiencies, even in soils with adequate soil test values, as the roots are not able to intercept enough nutrients. Often the seed furrow is not completely closed when sidewall compaction occurs. If dry conditions develop after planting, the germinating seedling and its early roots may suffer from inadequate amounts of moisture, and the seed slot may open wider (Figure 5-3). Floppy corn or rootless corn syndromes can often result from sidewall compaction, shallow planting and/or open seed furrows (Figure 5-3).

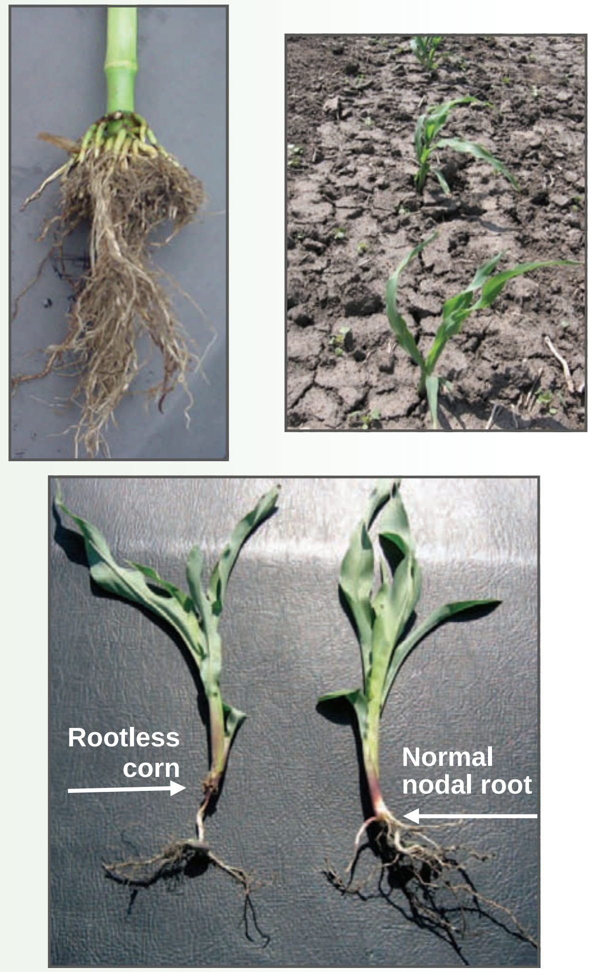

Figure 5-3. Effects of sidewall compaction can include tomahawk root structure (top left), seed furrows that reopen (top right), and/or rootless or floppy corn (bottom).

Effect on Yield Potential

During years when adequate water and nutrients are available, compaction is much less likely to affect grain yield potential. When the crop is water or nutrient stressed, compaction can reduce yield potential by up to 50 percent[5]. While it is impossible to conduct field operations without affecting the soil, the goal should be to have the smallest negative effect possible. In some years, such as 2011 in central Illinois, even a "normal" amount of soil compaction can unfortunately have a negative effect on root growth, nutrient uptake, and yield potential.

Repairing Damage

Altering tillage depth may be a useful method to minimize the development of compaction zones. During wet years, tillage should be kept shallow to help prevent formation of a deep tillage pan. If a shallow pan forms, it can be easily fractured when the soil is dry. In dry years, tillage can be deeper for more soil shattering[6]. Tillage depth should be determined based on proper use of the tool and what is needed to accomplish the goals at hand: compaction reduction, residue management, or seed bed preparation.

If the fields are classified as highly erodible land (HEL), permission from the USDA Natural Resources Conservation Service may be required to perform tillage operations. Consult with your local NRCS state conservationist regarding appropriate actions that may be taken on HEL fields.

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6. Residue Management from Harvest to Harvest

The greater amount of crop residue in corn-on-corn systems requires different management techniques compared to rotated ground. It is important to manage residue at harvest and manage the effects of it through the following growing season.

The Effects of Crop Residue

Three agronomic risks that can lead to potential yield loss if crop residue is not adequately managed are (Figure 6-1):

1. **Immobilization of Nutrients.** If most of the residue decomposition is occurring during the growing season, the N required for decomposition can limit the N available for corn growth.
2. **Uneven Emergence and Vigor.** Poor emergence and vigor can result from excessive residue at planting contributing to the following: a) poor seed to soil contact, b) a cool, damp microclimate around the seedling, and c) additional seedling physical challenges as it tries to emerge through the residue.
3. **Diseases.** Gray leaf spot (GLS), northern leaf blight (NLB), diplodia, and anthracnose overwinter in corn residue (which will be covered in more detail in a later section).

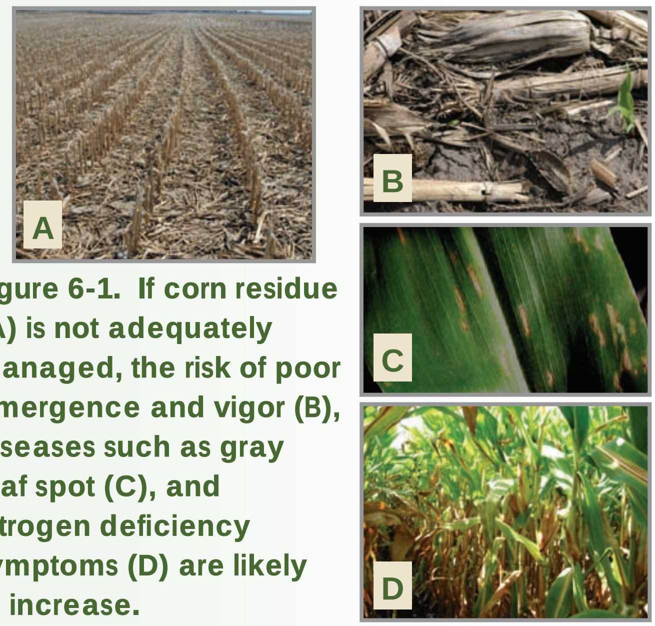
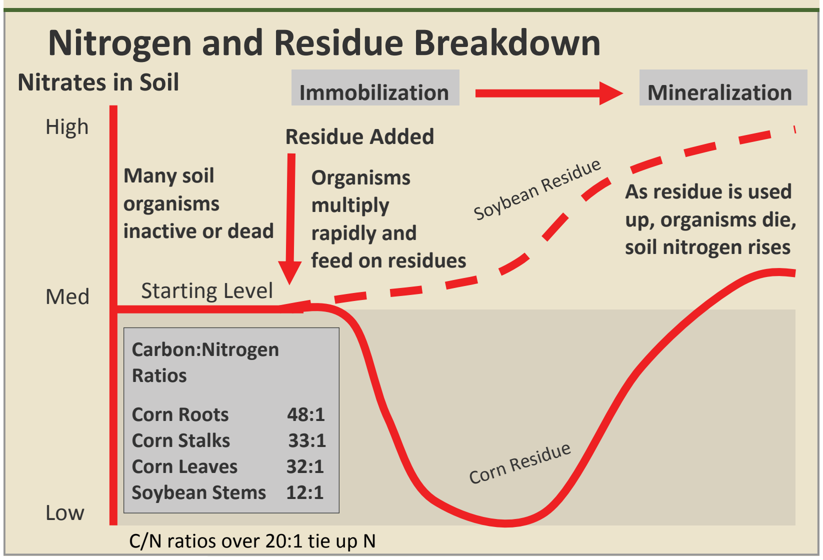


Figure 6-1. If corn residue (A) is not adequately managed, the risk of poor emergence and vigor (B), diseases such as gray leaf spot (C), and nitrogen deficiency symptoms (D) are likely to increase.

Figure 6-2. The interaction between available nitrogen and microbial activity aids in decay of crop residue[7].



Basics of Residue Decomposition

In terms of the N cycle, the process of residue decomposition includes immobilization and mineralization which both involve soil microbes (Figure 6-2). Immobilization is when N is tied up by soil microbes. Mineralization is the release of N which generally happens upon death of the soil microbes. The soil microbes feed on the carbon (C) in crop residues and require N to do so. Soil microbes try to maintain a carbon to nitrogen (C:N) ratio between 8:1 and 12:1[7]. To grow, they need to take in C and N at a ratio of about 20:1[8]. C:N ratios of crop residues vary greatly. Alfalfa, soybean, and other legumes generally have lower C:N ratios (less than 20:1) and mineralization often occurs quickly. Crop residues that have higher C:N ratios generally take more time to decay and

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result in higher amounts of N being tied up by soil microbes. When the microbes break down residues with high C:N ratios, such as corn (60:1) or wheat (80:1), they can outcompete growing corn for available N in order to maintain their own preferred C:N ratio of 8:1 to 12:1[9]. This immobilization of available N can result in N deficiency symptoms until the majority of the decomposition is complete and mineralization occurs as the microbes die and release the N back into the soil (Figure 6-2 and 6-3). Some of the conditions that favor decomposition of residue include time, warm moist weather, smaller pieces of residue, and maximizing the contact between residue and the soil[10].

Figure 6-3. Field had 45-60 lbs UAN applied preplant in the spring to help combat immobilization of N. Nitrate tests (taken the same day as photo) confirm immobilization occurring in the block where corn is pale and more yellow in appearance.

Uneven Emergence and Vigor Due to Excessive Residue at Planting

Poor Seed to Soil Contact. Managing residue to minimize trash getting wedged into the seed trench can help improve seed to soil contact and help minimize differences in soil moisture within the seed trench (Figure 6-4). Soil moisture variability in the seed zone is a leading cause for uneven corn stands. A corn kernel imbibes approximately one third of its weight in water during germination[14]. When kernels within a row are exposed to different amounts of soil moisture, the rate of germination and emergence can vary from plant to plant, resulting in uneven emergence and early growth, or possibly stand loss. Small differences in soil moisture within a row can lead to considerable differences in germination and emergence.

Cool and Damp Conditions. It takes approximately 120 growing degree units (GDU) for corn to emerge. It can take several days to accumulate 120 GDU with cool temperatures. Once a seed germinates, it can survive for approximately 14 days if it only has access to energy via the endosperm[3]. Ideally the kernel should develop a root system and emerge within much less than 14 days, reducing the dependency on the endosperm. Minor differences in the microenvironment directly around the seeds, can magnify the effect of cool temperatures on small seedlings, resulting in uneven early corn growth. In middle photograph in Figure 6-4, the residue was gently moved off of the row by hand to expose the spiking seedling that was one or two stages behind

Figure 6-4. Corn seedlings struggling to emerge due to residue being wedged in seed trench (left), cool and damp conditions courtesy of residue (middle), and physical resistance from residue (right).

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the plants on either side of it due to cool damp conditions from the residue.

Physical Resistance. Even if the cool and damp conditions caused by heavy residue are overcome, the seedling is still likely to be challenged due to physically having to grow through the residue. Additionally, the amount of sunlight that seedlings have access to can be limited due to the physical barrier of the residue (Figure 6-4).

Effect of Uneven Emergence and Vigor on Yield Potential. Emergence delays of 10 days or more usually translate to growth stage differences of two leaves or more[19]. Yield potential will be affected where larger plants are competing with smaller plants for sunlight, water, and nutrients. A 1.5 week delay between corn plants within a row may result in a 5 to 8% decrease in yield[19]. Examined from a leaf stage perspective, a 4-leaf difference in corn plant stage could result in yield losses of 8 to 10%[19]. While uneven emergence in corn is detrimental to yield potential, generally it does not justify replanting in most situations[20]. When two plants differ by two leaves or more, the younger, smaller plant is more likely to be barren or produce small ears (Figure 6-5).

Management Considerations for Fields with Uneven Emergence. Most uneven stands do not justify replanting[20]. When dealing with uneven stands throughout the growing season, it is important to use recommended herbicide application rates to avoid injuring corn. Apply herbicide based on the most advanced leaf stage in the field.

Figure 6-5. Later emerging plants often have small ears and incomplete pollination.

What about Allelopathy or Autotoxicity?

With some people noticing a difference between second-year corn and long term continuous corn, questions have been raised about allelopathy and/or autotoxicity. Allelopathy is the ability of a plant to produce chemicals that can affect the growth, survival, or reproduction of another plant[11]. Autotoxicity is a form of allelopathy in which allelopathic chemicals from a species can inhibit the growth of other plants of the same species[11].

Field research on the effects of autotoxicity in corn is limited and the effects of autotoxicity in corn are difficult to measure. However, there have been some laboratory studies that have identified autotoxic chemicals released from decaying corn residue[12,13]. The effects of these chemicals are often overshadowed by other effects of the residue in the field, such as keeping soils more cool and damp in the spring. Basically, autotoxicity may play a part in the challenges of continuous corn, but it is more likely that there are other, much larger contributing factors.

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Learning Center Demonstration Report: Impact of Residue Removal in Continuous Corn

A long term demonstration trial was conducted at the Monsanto Learning Center at Monmouth, IL to assess the effects of removing crop residue from a continuous corn system. The third year of yield data was collected in 2010. Four different percentages of residue were removed annually from the trial: 0%, 50%, 75%, and 100% removal. A chisel plow and a soil finisher were run in the fall and spring, respectively.

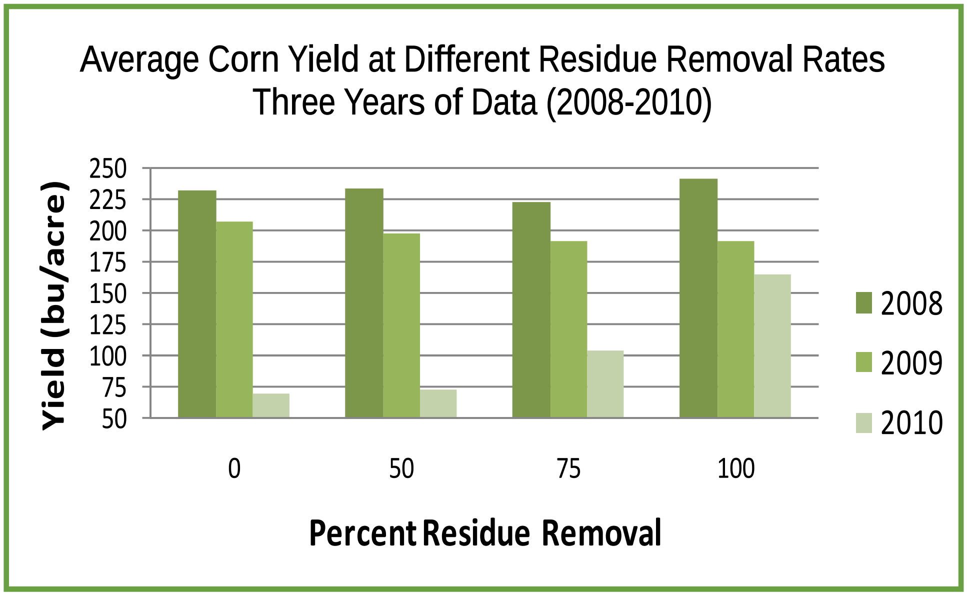

Figure 6-6. Average corn yield at 0%, 50%, 75%, and 100% residue removed at the Monsanto Learning Center at Monmouth, IL in 2008, 2009, and 2010.

In 2008, average corn yields were similar across each of the corn residue removal rates (Figure 6-6). In 2009 average corn yields were also similar across the different corn residue removal rates, even though the yields were consistently lower in 2009 compared to 2008.

In 2010, major differences in average corn yields were observed across the different crop residue rates. The plots with 100% of the residue removed had the highest yields. Corn yields decreased as the amount of residue left in the field increased. The lowest average corn yields were found in the plot where 0% residue had been removed. There was no significant differences found in the 2011 data.

In conclusion, the 2008 and 2009 trials showed little differences in average yield across the four different rates of corn residue removal. In 2010 a major difference in yield was observed, most likely due to weather conditions that occurred during the season. The 2010 yield results at the Monmouth site mirror the lower than average yields seen in 2010 on much of the continuous corn in Northern Illinois. The right conditions do not always exist for residue to affect yield potential to a great extent; however, when they do, residue can significantly reduce yield potential.

The information discussed in the Learning Center Demonstration Report "Impact of Residue Removal in Continuous Corn" is from a single site, non-replicated, three-year demonstration. This informational piece is designed to report the results of this demonstration and is not intended to infer any confirmed trends. Please use this information accordingly.

Management Practices to Assist in Decomposing Residue and/or Improve the Ability of the Corn Crop to Overcome Challenges of Heavy Residue

- **Harvest corn-on-corn fields first** to help maximize the amount of time for residue decomposition prior to cold winter temperatures which limit soil microbial activity.
- **Combine heads** can be set to cut about a foot (or more) above the ground. Additionally, some are available that chop the residue as it is fed through the head.

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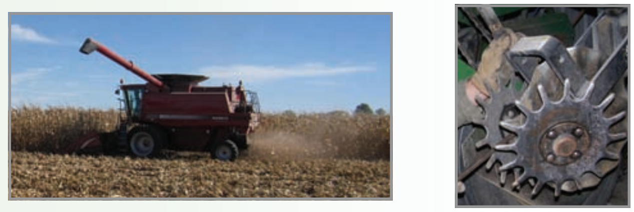
- **Combine spreaders** can help distribute residue evenly.
- **Chopping stalks** into smaller pieces can aid in residue break down, but having a mat of residue may make planting more difficult.
- **“Vertical” tillage,** not subsoiling, but rather a tool comprised of discs with notches that runs parallel with the tractor can be used to ‘mulch’ residue.
- **Aggressive tillage** can help maximize contact of residue and soil. Tilling, aggressive or “vertical”, as soon as possible after harvest can help take advantage of warmer weather and increased microbial activity. Often tillage can be done in the fall and the spring. To prevent plugging or clogging, the implement should be set properly and the soil should not be too wet.
- **Fall N applications** to aid in decomposition are greatly debated. The concept is that applying N in the fall can help speed up the degradation of corn residue since N is the energy source for the soil microbes. However, research has not consistently shown a benefit to fall N applications intended to assist in decomposition[10]. Some believe this lack of response is real, because N is not generally the limiting factor for decomposition in the fall. However, cooler temperatures and/or dry weather may play a larger role in impeding microbial activity[10]. Another theory is the lack of response indicated in research is not reflective of what occurs in a field setting. The environmental conditions and variability that make N research difficult may mask the benefits of fall N applications intended to break down residue. An additional challenge for fall applied N for residue decomposition is the risk of the N being deleterious to the environment. If planning this type of fall N application, consider leaving a check strip for comparison purposes.

Vertical tillage tools can be helpful to manage residue.



Spreaders on combines and residue managers on planters are only a couple examples of tools available to help mitigate the negative effects of excessive residue in continuous corn.

- **Higher N rates** may be an option since much of the N normally applied may be immobilized by microbes for residue degradation during most of the growing season. The amount of additional N needed depends on the other conditions that influence microbial degradation. For example, a corn crop following a late harvest, cold winter, and early planting season may benefit from more additional N compared to a corn crop following an early harvest, warm winter, and normal planting season. However, additional N generally does not overcome all of the residue issues. It can help reduce, but likely not eliminate, their effect.
- **Planters** can be equipped with row cleaners to move residue and enhance seed to soil contact.

Continued on next page

7. Nutrient Management: Applied vs. Available

Supplying corn with adequate nutrients, and having them available at the optimum time, can be quite challenging. While all major nutrients are important for proper growth, nitrogen (N), is often one of the most difficult to manage. Environmental conditions can greatly limit the N available for plant growth. Also, high levels of decomposing residue can outcompete corn for N well into the growing season. Available amounts of other nutrients, such as potassium (K), can interact with other stresses commonly found with continuous corn, such as drought stress and stalk integrity.

What Can Cause Nutrient Deficiency Symptoms in Corn?

When nutrient deficiency symptoms are observed, multiple questions should be considered:

1) Was adequate fertilizer applied?
2) Did an adequate amount remain in the intended area?
3) Did the plant have adequate root growth and soil conditions to access nutrients applied?
4) Did something else outcompete the crop for the nutrients intended for the crop (i.e. did something such as immobilization occur)?

Was Adequate Fertilizer Applied?

Ample fertilizer is applied to most fields. For most nutrients, especially N and K, plant availability is significantly affected by soil moisture. When conditions for uptake are not as good, fertilizer use efficiency goes down and it takes more nutrients in the soil to maintain an adequate amount in the plant.

Did Adequate Nutrients Stay In the Intended Area?

Nitrogen is the nutrient that is most pertinent to this conversation as it is mobile in the soil. While plenty may have been applied, heavy rainfall events can lead to considerable N loss through leaching, especially in sandier fields, and denitrification (Figure 7-1).

Did the Plant Have Adequate Root Growth and Soil Conditions to Access Nutrients Applied?

This is one of the most important questions. Compared to rotated fields, many corn-on-corn fields, can have increased compaction due to more water retention and pressures associated with delayed planting. Additionally, the roots in corn-on-corn fields are more susceptible to diseases and reduced growth due to wet conditions.

Roots that are restricted in the vegetative stage by compaction and excessive moisture which limit oxygen availability, generally lack health and often have a decreased ability to absorb nutrients and moisture. This can be especially evident when the weather turns dry in July and August[4].

Did Something Outcompete the Corn Crop for Nutrients?

Soil microbes, that help decompose crop residue, and weeds can outcompete the crop for nutrients. Several acres across the Midwest in 2010 likely suffered from N deficiencies due to immobilization of N with residue decomposition.

Figure 7-1. N loss in wet soils due to denitrification and/or leaching.

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7. Nutrient Management: Applied vs. Available

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Consequences of Inadequate Potassium.

Plants deficient in K can have leaves on the lower portions of the plant (due to K being mobile in the plant) that are necrotic on the outside margins (Figure 7-2). Corn plants deficient in K have been shown to lose more water through transpiration than plants with ample K as plants require sufficient K for effective stomatal closure[14]. In addition, low K levels, especially in conjunction with adequate or high N levels, have been shown to increase the risk for stalk rots, lodging, and *Helminthosporium* leaf blight.

Uptake of K is rapid after the nodal root system begins to get established around V6. Corn will absorb about 90% of its K by R2[3]. If roots are restricted early on, during the window for K uptake, the corn plant might not have sufficient K for the duration of the season. The lack of K in the plant could compound some of the issues that are possible with corn-on-corn when it turns hot and dry following pollination.

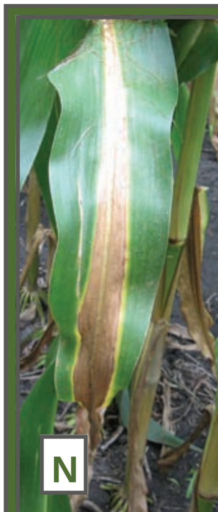

Figure 7-2. N deficiency can cause necrosis in the middle of the bottom leaves, near the midrib.

K deficiency can cause chlorosis and necrosis on the outside margins of the bottom leaves.

Management Options

To help nutrient availability, one should first evaluate and possibly employ the management recommendations from the ‘Soil Structure and Compaction’ and ‘Residue Management from Harvest to Harvest’ sections of this document. Additionally, proper soil tests and fertilizer applications are needed to provide nutrients for crop growth.

Continued on next page

8. Diseases: Introduction and Management

Corn disease management is reliant on four key management tools: crop rotation, genetic resistance in host plants, tillage, and fungicides (foliar or seed treatments). Continuous corn puts increased pressure on resistance, tillage, and fungicides. For the purpose of this summary, corn diseases are separated into four groups: seedling diseases, foliar diseases, ear rots, and stalk rots.

Disease Triangle

The disease triangle illustrates that the amount of disease that occurs in a particular field depends on the quantity of the pathogen present, the resistance or susceptibility of the host, and the extent to which the environment is favorable for that disease (Figure 8-1).

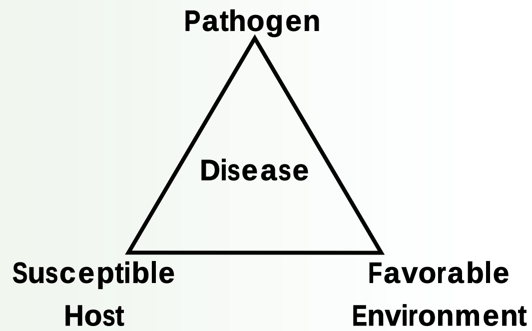

Figure 8-1. The disease triangle illustrates that the amount of disease that occurs in a particular field depends on the quantity of the pathogen present, the resistance or susceptibility of the host, and the extent to which the environment is favorable for that disease.

Disease Management in Continuous Corn

Hybrid Selection. Planting hybrids with 1) good tolerance and/or resistance to the diseases of concern in your area, 2) good standability and stalk strength, and 3) good emergence and seedling vigor can help mitigate the potential effects of diseases that are common in continuous corn.

Residue Management. Tillage that buries as much corn residue as possible can reduce pathogen inoculum levels from season to season. If conservation tillage is practiced, strip tillage or row cleaners on the planter are recommended to reduce the direct contact of the residue with the plants. Stalk choppers and knife rolls on corn heads are recommended to spread residue uniformly during harvest. No-till systems are not recommended for continuous corn systems if disease pressure was high in the previous years' corn crop.

Fertility and Moisture Management. Soil tests should be used to help balance fertility. Good fertility can help reduce stress, which may otherwise predispose the plant to stalk rots and other diseases. Continuous corn should be placed on the most fertile and well drained soils possible, to help reduce the risk of additional stress. Corn should be planted when soil temperatures are above 55° F. Cooler soils can slow germination and emergence, which may lead to greater seed rot and seedling diseases.

Insect Pest Management. Planting hybrids with insect resistance, such as Genuity® SmartStax® Corn, can help reduce insect feeding that can lead to root, stalk, and ear rots. Soil insecticides are recommended if transgenic hybrids are not planted. Please see the insect portion of this guide for more information.

Fungicide Application. Fungicides should only be applied if disease pressure warrants an application; using fungicides in a prophylactic manner is not recommended. A fungicide application is more likely to be advantageous when susceptible hybrids are planted and weather conditions are favorable for disease development. Seed treatments that contain fungicides are highly recommended.

Scouting. Scouting near the VT growth stage is important to determine if a fungicide application is needed. Scouting is essential each year, not only to determine management needs for the current year's crop, but also to identify potential disease risks in the following year's crop.

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8a. Diseases: Seedling Diseases

Cool soil conditions (< 50° F) can delay germination and emergence, as well as predispose corn seedlings to diseases. Seedlings become more susceptible to infection when experiencing stress and slow development during germination and emergence. It is important to scout for seedling diseases so that replanting can occur as soon as feasible if stands are weak.

Survival of corn seedlings depends on healthy kernels, roots and mesocotyls. The seedling is dependent upon the mesocotyl to transport energy from the endosperm to the leaves until around V3. The mesocotyl is also responsible for transporting water and nutrients from the seminal root system until around V6, when the nodal root system becomes the primary root system.

Disease Symptoms

Corn infected with seedling diseases such as Pythium or Fusarium often appear wilted, stunted, and/or purple. These symptoms are similar to environmental stresses, insect feeding, and herbicide damage, so it is important to consider the complete history of the field when determining the cause of the symptoms. If the aboveground symptoms are due to seedling diseases, mesocotyls and/or roots will also be symptomatic.

Wet soils in the spring are particularly favorable for Pythium infection. Rotten mesocotyl tissue can be caused by Pythium (Figure 8a-1). Symptoms are often worse in areas that are wet, compacted, or have heavier soil. Symptoms may occur on scattered plants or in small-to-large patches. The growth stage of the corn plant and the severity of the infection can influence whether that seedling will survive.

Disease Protection from Seed Treatments

Seed treatments can provide a level of protection against seedling diseases but may not eliminate all threats under severe conditions that promote infection. All seed treatments have a limited period of activity, which is usually three to four weeks.

Figure 8a-1. A rotting mesocotyl infected with a seedling disease such as Pythium.

Management

During the Growing Season. If reduced stands are observed, evaluate if replanting is the best option. Replanting decisions should be based on stand uniformity, remaining population, target replanting date, and the costs and risks associated with replanting. If needed, there are often herbicide options for controlling the existing stand if soil insecticide and/or tillage limitations reduce the options to remove the stand.

Future Years. Several fungi that can cause seedling diseases (Pythium, Fusarium, Penicillium, Rhizoctonia, Trichoderma, Aspergillus, and Stenocarpella (Diplodia)) in corn are more likely to infect and rot the mesocotyl the longer seedlings are in the ground without good growing conditions. Additionally, although these fungi are wide spread, many of them are more abundant when corn follows corn and in no-till situations. The occurrence of seedling diseases in certain field areas is an indication of abundant soil-borne fungal populations that could cause similar problems next year if environmental conditions are similar. Therefore, rotation or later planting into warmer soils in suspect fields should be considered as management options.

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8b. Diseases: Foliar Diseases

In continuous corn systems, foliar diseases caused by pathogens that survive on corn residue are of the most concern, including the following: gray leaf spot (GLS) (*Cercospora zeae-maydis*), northern leaf blight (NLB) (*Exserohilum turcicum*), southern leaf blight (SLB) (*Bipolaris maydis*), anthracnose leaf blight (ALB) (*Colletotrichum graminicola*), and Goss's wilt (*Clavibacter michiganense* subsp. *nebraskensis)*. Conversely, the fungi that cause common rust (*Puccinia sorghi*) and southern rust (*P. polysora*) do not overwinter on residue but are blown in from the southern United States during the growing season, so there is less likely to be a difference of severity of rust infection based on prior crop. Similarly, the bacterium that causes Stewart's wilt (*Panteoa stewartii*) survives the winter in its insect vector, the corn flea beetle, so crop residue has little or no effect on the occurrence of this disease.

Gray Leaf Spot (GLS)

Corn-on-corn and reduced tillage are favorable for development of GLS because the pathogen overwinters on corn residue. Weather conditions significantly influence the development of GLS. The disease develops readily during prolonged periods of warm (75 to 85° F), humid weather[21]. Infection is favored by relative humidity above 90% in the crop canopy for 11 hours or longer[22, 41]. Spores for GLS have the ability to stop development if conditions are not favorable and resume development when humidity and other environmental factors are acceptable[21]. Typically, there is a two to three week latent period between the time infection occurs and symptoms appear[21]. Severity often worsens after pollination, partly because early infections are beginning to pass through their latent period.

GLS lesions on susceptible corn are gray to tan linear, rectangular lesions along the veins of the corn leaf. The lesions are limited by the leaf veins, giving the lesions a blocky appearance (Figure 8b-1). A yellow halo usually surrounds young lesions before they elongate into the rectangular grayish brown streak. Mature lesions can be 1/2 to 2 1/2 inches long and 1/8 to 1/4 inch wide.

Figure 8b-1. GLS has blocky lesions.

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8b. Diseases: Foliar Diseases

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Northern Leaf Blight (NLB)

This disease can be found nearly anywhere corn is grown. NLB can be particularly severe in areas with humid climates and it may cause significant yield losses when moderate temperatures (65 to 80° F) and extended periods of dew prevail[23]. In addition to effects on grain yield, NLB infection may reduce forage value and predispose plants to stalk rots.

Initially, NLB lesions are typically gray-green in color and elliptical or cigar-shaped (Figure 8b-2). As lesions mature, they turn tan and develop distinct dark areas of fungal sporulation. Lesions first appear on lower leaves and move upwards as the disease progresses. Lesions can be as large as 3/4 inch wide and 6 inches long. Symptoms can progress rapidly after anthesis. Yield losses of 30% have been documented if lesions are present in the upper canopy at silking[23]. If infection is delayed until dent, loss of yield potential is likely much less[23]. On severely infected plants, almost all leaves are infected. Lesions often occur in a band across leaves. As lesions grow into one another in these bands, entire leaves may become necrotic causing plants to look like they have been killed by an early frost.

Two types of resistance to NLB exist in corn. Polygenic (multiple gene) resistance is expressed as a reduction in lesion size, lesion number, and sporulation. There also may be a longer incubation period between the time of infection and conidia production. Monogenic (single gene) resistance is controlled by several different single, dominant genes, e.g. *Ht1, Ht2, Ht3*, *HtN* and *Htm1*. Resistance conferred by *Ht1, Ht2,* and *Ht3* is expressed as chlorotic lesions with decreased size and sporulation[25]. Resistance conferred by *HtN* and *Htm1* is expressed as fewer, smaller lesions with an extended period of time between initial infection and symptom occurrence and spore production. Polygenic and monogenic resistance can act together to reduce the severity of NLB.

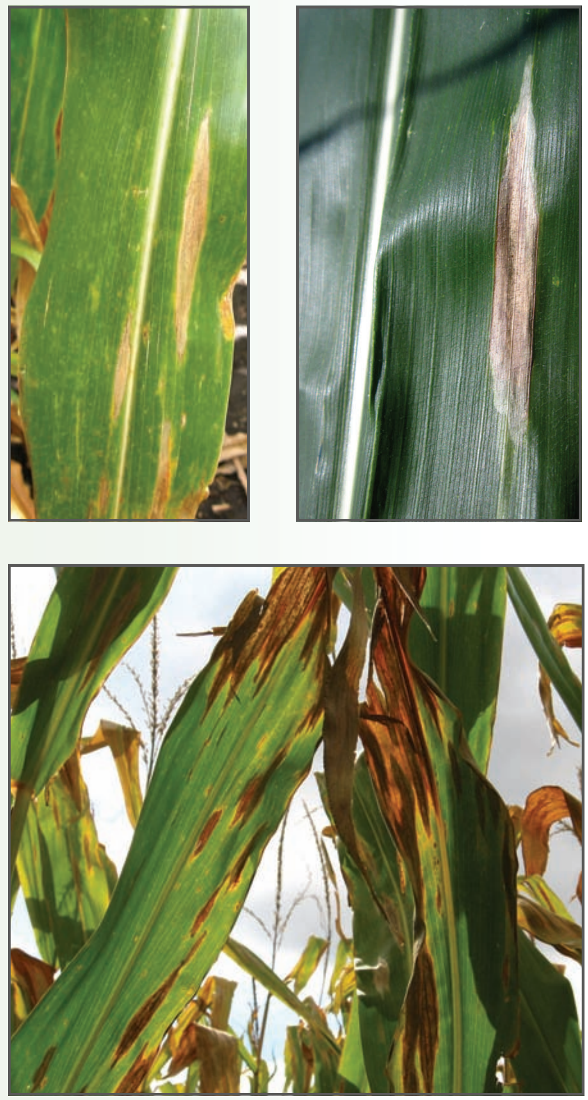

Figure 8b-2. Elliptical or cigar-shaped lesions typical of NLB.

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8b. Diseases: Foliar Diseases

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Southern Leaf Blight (SLB)

This disease, caused by the fungus *Bipolaris (Helminthosporium) maydis,* can be found in corn growing areas worldwide. *B. maydis* overwinters on infected corn debris and is spread by wind and splashing water. Lesions produced on the leaves are the source of conidia that cause secondary infection. This disease cycle can take as little as 60 -72 hours under ideal conditions. SLB is most severe in regions with a warm (68 to 90° F), damp climate[26]. Extended periods of dry, sunny weather between rains are unfavorable for disease development. Reduced yield potential is primarily due to significant leaf tissue loss during grain fill which leads to reduced kernel weight. Severe SLB can also predispose plants to stalk rots.

Symptoms of SLB may vary due to differences in the genetic background of hybrids and with different isolates of the fungus. The most common isolate, named race O, produces small, elongated, parallel-sided lesions that are tan with brownish borders (Figure 8b-3). Race O attacks only the leaves. Race T is less common and is most often a problem on corn containing Texas-cytoplasmic male sterility (cms-T). The lesions produced by race T are larger, spindle-shaped, and tan with yellow-green halos. Race T lesions have dark brown borders and may occur on all aboveground parts of the plant. Race T is a less fit pathogen than race O and generally does not cause major problems because cms-T corn is no longer widely used.

Two types of resistance to SLB exist in corn. Polygenic (multiple gene) resistance is expressed as a reduction in lesion size and length in young plants and as a reduction in disease development and severity in adult plants. Monogenic (single gene) resistance is controlled by a single recessive gene, *rhm*. Resistance conferred by *rhm* is expressed in seedlings and young plants as chlorotic flecks. This resistance may not be as effective in older plants.

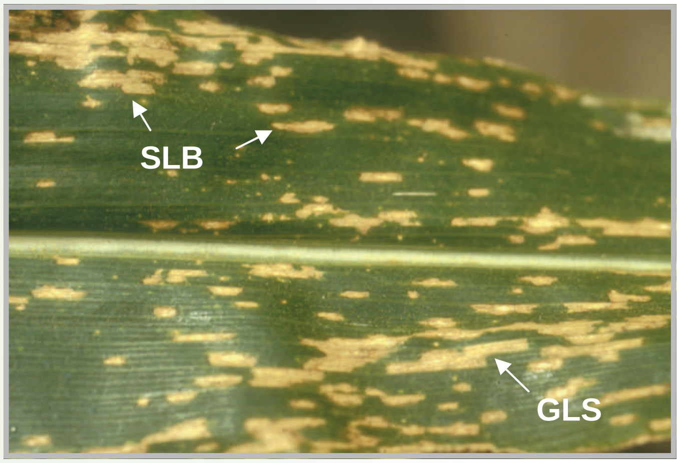

Figure 8b-3. Small, tan, parallel-sided lesions with brownish borders typical of SLB race O. It is not uncommon for SLB lesions and gray leaf spot (GLS) lesions to be interspersed on the same leaf. GLS lesions are limited by the leaf vein while SLB lesions can expand across veins.

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8b. Diseases: Foliar Diseases

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Anthracnose Leaf Blight (ALB)

Anthracnose in corn has a leaf blight phase and a stalk rot phase. The leaf blight phase is an indicator that the pathogen is present in the field, but does not confirm that the stalk rot phase will be an issue. The stalk rot phase is of greater concern than the leaf blight phase in terms of potential yield loss.

The fungus that causes anthracnose overwinters on corn residue. Spores spread to growing plants by windblown rain and splashing. Anthracnose is favored by warm, moist weather. Disease severity can increase during extended periods of low light intensity (e.g. overcast conditions) and high humidity.

Lesions of the leaf blight phase vary depending on the host variety, age of the leaf and environment. Lesions can be oval- to spindle-shaped and appear water-soaked (Figure 8b-4). As lesions coalesce, larger non-descript, irregular-shaped areas of leaves can become necrotic. Lesions are often found on the bottom leaves first and can progress to the upper leaves. They are tan to brown with yellow to reddish-brown borders. Heavily infected leaves wither and die. Long, black hair-like structures called setae occur in ALB lesions. Setae can be seen with the aid of a hand lens (Figure 8b-4).

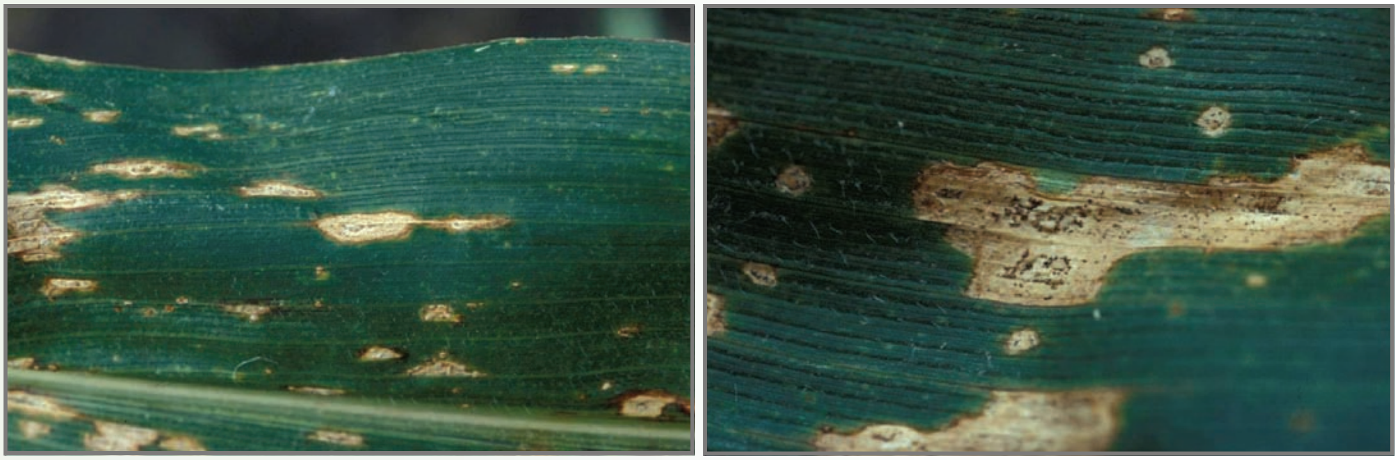

Figure 8b-4. Symptomology of the leaf blight phase of anthracnose leaf blight. Setae, the long, black hair-like structures that occur in ALB lesions can be seen in the photo on the right.

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8b. Diseases: Foliar Diseases

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Goss's Wilt

Goss's wilt is a bacterial disease that occurs as either a vascular wilt at vegetative growth stages or leaf blight during reproductive stages (Figure 8b-5). Infection commonly occurs following severe weather that creates wounds to leaves through which the bacteria enter the plant. While Goss's wilt has been prevalent in the western portion of the Corn Belt for three decades, the disease has spread eastward and become more firmly established and potentially threatening over a larger area of US corn acreage in the last five years in association with the increased popularity of minimum tillage and corn-on-corn production.

Systemic infection and vascular wilt may occur early in the season, when corn is 5 to 24 inches in height, causing severe wilting and plant death on less resistant hybrids. In this "systemic phase" random plants can often be found that are stunted, wilting, and in the process of dying. Plants wilt because the plumbing of the corn plant (xylem and phloem that help move water and nutrients) becomes plugged with bacteria and exudates, preventing water and nutrients from being effectively transported to the leaves. Bacterial ooze or the shellac-like spots on leaves often associated with Goss's wilt may or may not be evident in this phase (Figure 8b-6B). A laboratory analysis may be needed to confirm the presence of Goss's wilt. Some Goss's wilt tolerant hybrids can show significant stand loss in the systemic phase. These same hybrids often tolerate the leaf infection stage. Increasing the planting rate can help minimize the risk of having a harvest population that is not adequate for maximum yield potential.

The leaf blight phase is the typical time when Goss's wilt is noticed. Symptoms usually appear near flowering as long, gray-green to black, water-soaked streaks extending along leaf veins (Figure 8b-6A). Small, dark, water-soaked flecks, referred

Figure 8b-5. Symptoms of Goss's wilt systemic infection (left) and leaf blight (right). In the leaf blight photo, the hybrid on the left exhibits more tolerance to Goss's wilt than the hybrid on the right.

Effective Disease Management Includes:

1) Scouting
2) Proper Identification
3) Hybrid Selection
4) Possibly Fungicide Applications
5) Cultural Practices

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8b. Diseases: Foliar Diseases

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to as "freckles", often occur inside larger lesions and at edges of lesions where symptoms are advancing (Figure 8b-6A). Leaf freckles are luminous when lighted from behind, such as when the sun is used as backlighting (Figure 8b-7). Bacterial cells may ooze from infected leaves and dry on leaf surfaces forming a shellac-like sheen (Figure 8b-6B). As lesions mature, large areas of tan to brown dead leaf tissues are apparent.

Goss's wilt can "blow up" quickly, going from green, healthy appearing corn to fully brown leaves in four to ten days in susceptible hybrids. This rapid development of symptoms is associated with secondary infection following weather events that create wounds in leaves and with the increase and movement of bacteria in vascular and leaf tissues of susceptible hybrids. Fields showing rapid development of Goss's wilt may be candidates for silage harvest. Chopping these fields reduces the inoculum available to infect the following corn crop. Corn grain yield and test weight will be reduced whether the corn is taken for silage or mature grain. The amount of yield loss depends on the ability of the hybrid to delay the onset of infection and slow disease progress. Late season infection on an early maturing hybrid likely will not show as much yield loss as a full season hybrid that has more time to be affected by the disease.

Figure 8b-6. Identifying characteristics for Goss's wilt.

Figure 8b-7. These photos show how different lighting sources available in the field can change appearance of the exact the same leaf. The photo on the left was taken in the canopy. The photo on the right, with the sun behind the leaf, shows how the freckles can be illuminated when held up to the sun. Comparatively, the middle photo shows how the freckles appear dark with the sun behind the person holding up the leaf.

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8c. Diseases: Ear Rots

Pathogens that cause ear rot diseases survive on corn residue and are of greater concern in continuous corn. These include Diplodia ear rot (*Stenocarpella maydis*), Gibberella ear rot (*Gibberella zeae*), and Fusarium ear rot (*Fusarium moniliforme*). Applied field research on pathogens causing ear rots in corn is limited. Control measures such as genetic resistance and tillage are less effective in general for ear rots compared to foliar diseases. Genetic resistance to ear rots is fairly limited. Hybrids with tight husks and/or ears that remain upright are thought to be more susceptible to ear rots.

Diplodia

Diplodia ear rot occurs most frequently in reduced tillage fields where corn follows corn. Diplodia was the primary ear rot of corn during the first half of the 20th century but this disease was relatively unimportant for much of the second half of the 20th century when production practices routinely included moldboard plowing. Diplodia has reemerged as a major ear rot of corn as reduced tillage and continuous corn have become more popular.

Diplodia is recognized by a white to gray mold that usually begins at the base of the ear and develops toward the tip, growing between kernels (Figure 8c-1). With severe infection, the entire ear turns gray-brown and completely rots, a symptom known as mummification. *Diplodia* is favored by wet weather within the first 21 days after silking[31]. Hybrids vary in the level of susceptibility to *Diplodia*, but because of the erratic nature of the disease most hybrids are not well-characterized and any hybrid can be infected given the proper environmental conditions.

Concerns: Although *Diplodia* is not known to produce mycotoxins that can harm humans or livestock, it is important to dry and store infected grain properly as kernel damage can continue to spread if grain moisture is over 20%.

Gibberella

Gibberella causes an ear mold that usually begins at the ear tip and progresses down toward the base (Figure 8c-1). The color of the mold varies from red to white, but is often bright red-pink. Infection is favored by cool and wet weather after silking, through late summer[31]. Infection also frequently follows damage from insect feeding.

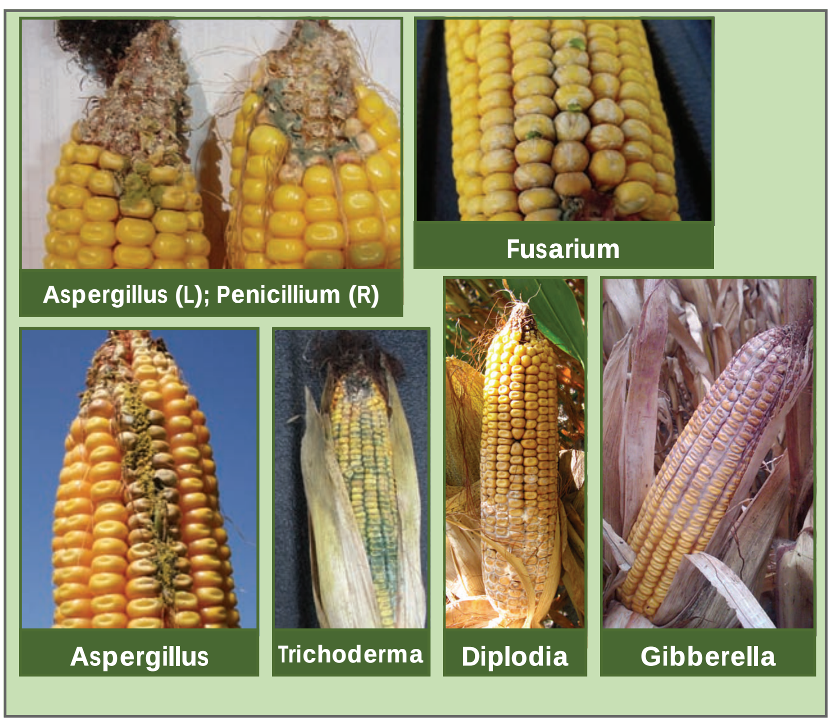

Figure 8c-1. Examples of different ear molds.

Concerns: *Gibberella* can produce vomitoxin and zearalenone, which are mycotxins that are harmful to livestock, especially hogs.

Penicillium

This blue-green mold grows on and between kernels (Figure 8c-1). Infection is more likely on ears damaged by earworms, corn borers, or from mechanical injury[31].

Concerns: High moisture stored corn may develop "blue eye" as a result of this mold.

Trichoderma

Trichoderma produces an ear mold that is dark green and grows on and between husks and kernels (Figure 8c-1). *Trichoderma* usually enters the plant through bird or insect damage to the ear[31].

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8c. Diseases: Ear Rots

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Concerns: The effect of *Trichoderma* is generally minor. The fungus does not typically produce mycotoxins. Being able to differentiate *Trichoderma* from other green-colored ear rots that produce mycotoxins, such as *Aspergillus*, is beneficial.

Fusarium

Kernels infected with *Fusarium* typically occur in a scattered pattern over the ear sometimes with white streaks in a starburst pattern radiating from the top of the kernel (Figure 8c-1). The mold is white to pink. A common method of infection is via silks although other infection sites include kernel growth cracks and ear damage from insects such as earworm or corn borer. Hot, humid weather favors development[31].

Concerns: *Fusarium* can produce a mycotoxin, fumonisin, that is toxic to livestock, particularly horses[32].

Aspergillus

Aspergillus ear rot appears as a gray-green or olive, powdery mold, starting at the tip of the ear and following damage from insects such as Japanese beetle, corn rootworm adults, and corn earworm (Figure 8c-1). The fungus infects through silks or kernels damaged by insects, hail, or birds. Infection can occur from the time of silking through harvest. Aspergillus is common in drought years and the fungus can grow on ears at grain moistures down to 15%[31].

Figure 8c-2. Various views of ears and kernels infected with *Cladosporium*.

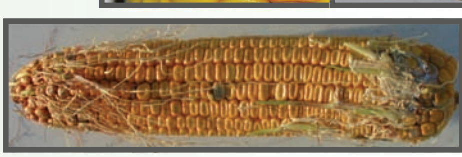

Figure 8c-3. Sprouted kernels

Table 8c-1 FDA guidelines for acceptable aflatoxin levels in corn based on intended use[1].

Use	Aflatoxin level (ppb)
Corn of unknown destination	< 20
Corn for Young Animals	< 20
Corn for Dairy Cattle	< 20
Corn for Breeding Beef, Cattle, Swine, and Mature Poultry	< 100
Corn for Finishing Swine	< 200
Corn for Finishing Cattle	< 300

Concerns: *Aspergillus* produces mycotoxins known as aflatoxins, which are toxic to humans and livestock. Grain elevators can reject loads of corn with aflatoxin levels above the limits set by the FDA (Table 8c-1).

Cladosporium

Cladosporium often infects kernels damaged by insects, hail, or frost (Figure 8c-2). When grain with high moisture content is frosted, micro-fractures can occur in the pericarp. Starch from these openings serves as the nutrient source for *Cladosporium*. The colors of the mold are directly related to its stage of growth. *Cladosporium* can be powdery white in the early stages, to black in later stages and all colors of green in the stages in between. If the surface of the kernels where this mold is located is rubbed, the discoloration can be completely removed.

Concerns: This disease can be fairly common but usually does not cause extensive damage to the ears, and does not cause any feeding toxicity.

Kernel Sprout

Kernel sprouting can occur when moisture becomes trapped in the husk, allowing kernels to absorb it and sprout (Figure 8c-3). Hybrids having an upright ear at maturity, with an open husk may be more susceptible. Significant and continuous rainfall at harvest favors kernel sprout.

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8c. Diseases: Ear Rots

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Management

Sampling for Mycotoxins. For reliable results, consult a lab approved for mycotoxin testing by the Grain Inspection, Packers and Stockyard Administration (GIPSA). There are different certifications for various mycotoxins, so it is important to make sure the lab receiving the samples is certified to analyze for the suspected mycotoxin. If a field is suspected of having aflatoxins or other mycotoxin, it is important to communicate with the insurance provider. Crop insurance may not cover aflatoxin losses if the sample is taken after the grain has been stored. A sample should be a composite of several subsamples as the distribution of aflatoxin or other mycotoxins in a field is not uniform. When sampling during harvest, subsamples can be collected at 30 second intervals while the combine is unloading[37]. A 10 pound sample is recommended when submitting a sample to a GIPSA approved testing facility. Samples are commonly shipped in gallon freezer bags when samples are taken during harvest, the grain is under 20% moisture content, and samples are delivered to the lab in the fewest days possible. Removing as much air as possible from the bag and sealing the top of the bag with additional tape can help maintain the integrity of the bag during shipment[36]. Proper sample labeling is critical in order to utilize the lab results effectively. Labs often have forms that can be filled out electronically or on hard copy; therefore, contact the lab prior to shipping to help assure that all paperwork is completed properly.

During Harvest and Storage. Proper grain harvesting, drying, and storage are important when these diseases are evident. Tips for harvesting and storing grain from fields with prevalent ear rot infection include[32]:

- Allow corn to mature in the field to 23 to 25% moisture content. If lodging concerns exist, consider harvesting early since down corn is more likely to rot.

- Combine should be adjusted to minimize kernel damage and maximize cleaning.
- Corn should be dried to 13 to 14% moisture content prior to storage.
- Grain should be stored at cool temperatures (36° F to 44° F) after drying.
- Grain should be checked periodically for temperature, wet spots, and insects.
- Consider applying antifungal treatments to grain.

Future Years. Since many ear rot pathogens remain viable in the soil for several years, carefully scout fields with a history of ear rot, even if management practices are employed to decrease inoculum pressure. Some options to help decrease the risk of ear rot infection include crop rotation, heavy tillage, planting hybrids with insect protection traits, and good fertilization. Planting a package of hybrids with different maturities and growing degree unit (GDU) requirements to flowering, as well as rotating germplasm planted in the same field from year to year, are also good practices to help reduce the effect of ear rots.

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8d. Diseases: Stalk Rots

The majority of lost yield potential from stalk rots can be attributed to premature plant death that interrupts grain fill, and stalk lodging that can cause harvest losses. High yield potential and/or other stresses are often associated with stalk rots. Corn-on-corn fields can be at higher risk for stalk rots due to the additional stresses that are common for corn-on-corn, as well as the fact that most of the pathogens that cause the common stalk rots overwinter in corn residue. It is important to scout fields for stalk rots and lodging and potentially adjust harvest schedules accordingly to try and minimize loss of grain and yield potential.

Conditions that Favor Stalk Rots

Stalk rot development is generally favored by early season environmental conditions that favor high yield potential and kernel set followed by late season stress. These conditions also favor stalk cannibalization.

Stalk Cannibalization. As maturing kernels accumulate carbohydrates late in the season, nutrients in the plant may be in short supply. This is amplified in years with excellent yield potential and kernel set, followed by stress conditions during grain fill. Examples of common late season stresses include foliar diseases, insect damage, drought, and cloudy weather. Nutrients are often remobilized from lower leaves and stalks to meet the demand from the developing kernels. This remobilization often results in disintegration of pith cells and affects the amount of lignin in cell walls of the rind, which can lead to physiological stalk lodging (Figure 8d-1). Lignin is made up of a complex of sugar molecules, and binds cellulose fibers together and 'cements' corn tissues. Stalk cannibalization can increase the susceptibility of a corn plant to stalk rots, which also increases the risk of stalk lodging.

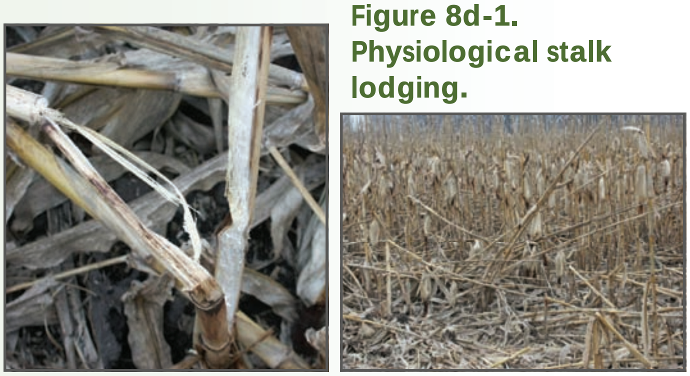

Figure 8d-1. Physiological stalk lodging.

Figure 8d-2. Stalk rots such as Anthracnose stalk rot (middle) and Diplodia stalk rot (right) can result in disintegration of pith tissue, compared to a healthy stalk (left).

General Symptoms

Stalk rot symptoms first appear as the leaves turn a dull gray-green, similar in appearance to frost or drought damage. In a few days, the leaves turn brown. Death of susceptible hybrids may follow in seven to ten days[39]. The lower internodes turn from green to tan or dark brown and are spongy and easily crushed. Several of the pathogens can result in pith tissue disintegration. Stalks split lengthwise may reveal only the vascular strands remaining intact (Figure 8d-2).

Anthracnose Stalk Rot

Anthracnose in corn has a leaf blight phase and a stalk rot phase. Top die-back is a significant symptom of the stalk rot phase. The leaf blight is

Figure 8d-3. Gibberella stalk rot is often pink in color and originates at the nodes.

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8d. Diseases: Stalk Rots

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an indicator that the pathogen is present in the field, but does not confirm that the stalk rot phase will be an issue.

Top Die-Back. In fields with heavy anthracnose stalk rot pressure, it is common to observe that a portion of the plant above the ear dies prematurely while the lower plant remains green. This symptom is known as top die-back and it can be observed at any time after tasseling (Figure 8d-4). As the stalk rot phase progresses, the pith and the vascular system become completely rotted reducing the water translocation to the top leaves, especially when water availability is reduced in the soil. With the disease and moisture shortage interaction, the top leaves tend to dry down and die as a consequence of reduced water supply.

Stalk Rot Phase. Early infection may kill plants before pollination, but onset usually occurs just before plants mature. Usually, the entire plant dies and several nodes are rotted. Late in the season, generally after plants show signs of early death, a shiny black discoloration develops in blotches or streaks on the stalk surface, particularly on lower internodes. Internal stalk tissue may become black and soft, starting at the nodes (Figure 8d-5). Stalks may also have discolored pith while the rind remains green. Lodging typically occurs higher on the stalk than with other stalk rots[40].

Gibberella

Stalks infected with Gibberella often have a characteristic pink to reddish discoloration of the pith and vascular strands (Figure 8d-3). Fruiting bodies called perithecia look like bluish-black specks on the rind of the stalk and can be scraped off with a fingernail[39].

Fusarium Stalk Rot

Fusarium stalk rot appears similar to Gibberella and Diplodia, except that the discoloration of infected tissues commonly varies from whitish pink to salmon. Fusarium stalk rot is often diagnosed in

Figure 8d-4. Photo above shows the comparison of a pith infected with Anthracnose (top) to a healthy pith (bottom). Photo to the right shows a corn plant exhibiting top die-back.

Figure 8d-5. Anthracnose stalk rot develops black blotches (left). Diplodia develops black dots (right). Neither can be scratched off with fingernail.

the absence of symptoms of other stalk rot pathogens.

Diplodia Stalk Rot

This rot is distinguished from other stalk rot diseases by the numerous, tiny, raised black dots (pycnidia) produced by the fungus on the stalk surface, clustered on or near the lower nodes of

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8d. Diseases: Stalk Rots

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infected stalks. These black dots are embedded in the stalk and cannot be scraped off with a fingernail (Figure 8d-5)[39]. Dry conditions early in the season followed by warm (80° to 87° F), wet weather two to three weeks after silking favor the development of Diplodia stalk rot[40].

Charcoal Rot

Hot dry weather encourages development of charcoal rot. Unlike some of the other stalk rot pathogens, the risk of charcoal rot is similar for corn-on-corn and rotated corn because several other crops, including soybean and sorghum, are hosts[40]. One of the key identifying characteristics of charcoal rot is the presence of small black specks (sclerotia) along the strands of vascular tissue (Figure 8d-6)[40].

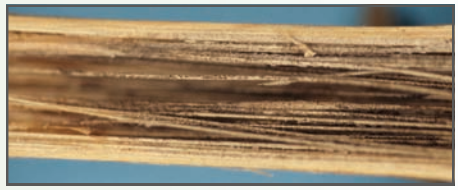

Figure 8d-6. Charcoal rot has small black specks along the strands of the vascular tissue.

Management Options Prior to Harvest

Plants severely damaged by the stalk rot are unlikely to remain standing until the normal harvest period. Therefore, preparations should be taken to harvest problem fields early. Although high grain drying costs may be a concern when harvesting wet grain, this expense will likely be a better option compared to the loss of yield potential due to increased lodging later in the fall. Scouting fields for potential stalk lodging can be broken down into two methods.

The Pinch Test. Examine the lower nodes of ten plants in a row in several places in the field. Squeeze or pinch each stalk a couple of nodes above the ground. If more than 10% of the stalks collapse easily when squeezed, that field may need to be slated for an early harvest.

The Push Test. For ten plants in a row, in several locations in the field, push each stalk 45 degrees from upright. If more than 10% of the stalks lodge when pushed, an early harvest may be prudent.

Harvesting Tips

Fields with considerable lodging should be harvested early to minimize the risk of increased lodging and ear rots. Although drying costs are a concern when harvesting wet grain, this expense will likely be a better option compared to potential yield loss due to increased lodging and ear rots later. Harvesting tips to protect yield potential include:

- Harvest against the angle of the down corn to maximize lift into the header.
- Harvest when dew is present to help minimize fluff.
- Use corn reel if needed.
- Time should be taken in the field to make necessary combine adjustments.
- The combine should be properly adjusted to minimize broken kernels and excess fines as they can lead to spoilage in storage.
- Over-threshing should be avoided.
- Combines should be set to blow out as much of the fines and foreign material as possible.
- The combine operator's manual should be referenced for manufacturer suggested cylinder adjustments, speed and clearance settings.

Grain Storage Tips

Once the grain is harvested, there is still a risk for loss, especially if some of the grain has higher moisture levels. Tips to minimize grain storage losses include[38]:

- Wet corn should not be stored in wagons or

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trucks longer than six hours.

- Wet grain should be dried or put it in a holding bin for drying using forced air to keep it cool.
- Storing wet grain without aeration for one to two days can decrease storage life by two to three months.
- Mold growth can begin within 24 hours and accelerate rapidly if wet corn is left in a wet bin too long.
- Moisture content of every load should be checked and dryer controls reset based on changing moisture content levels.
- Grain should be dried to 16% moisture content within 24 hours and cooled to the outside air temperature within 48 hours.
- Bins should be aerated to ensure corn is at a uniform temperature.
- Stir augers should be used to maintain airflow.

Stored corn should be inspected every one to two weeks in the fall and spring and once every two to four weeks after conditions in the bin have stabilized during the winter months.

Management Options for the Following Season

Tillage. Burying the residue can help decrease inoculum.

Crop Rotation. Planting a non-host crop such as soybeans can help reduce inoculum. In fields with a severe anthracnose problem a two-year rotation away from corn might be considered.

Tolerant Hybrids. Hybrids are often given ratings for tolerance to the leaf blight phase as well as the stalk rot phase of anthracnose. Tolerance to one phase is not an indicator if the hybrid will have tolerance to the other phase.

Minimizing Stress and Cannibalization. Stalk rots can become more prevalent as a corn crop endures additional stress. Stresses such as foliar diseases, insect damage, drought, and others can increase the risk of stalk cannibalization which can increase the risk of stalk rots. Hence, if foliar fungal diseases are likely to occur, damage from stalk rots can be reduced by managing those diseases with fungicides.

Fertility. Stalk rots can be more common and severe in fields with imbalanced and increased fertility. Plants grown in fields with high nitrogen and low potassium are very susceptible to stalk rots[40].

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9. Hybrid Selection for Corn-on-Corn

Hybrid selection is no easy task and selecting hybrids that can handle the additional stress that can be associated with corn-on-corn environments can be even more challenging. Several hybrid characteristics should be evaluated. Regardless of the environment, the first selection criteria should be yield potential. When evaluating hybrid performance, there is a strong trend for the best hybrids to perform well in most environments. Some potential hybrid weaknesses can be minimized by management decisions such as fungicide applications, timely harvest, or nutrient management. To help minimize the acres that are at higher risk of insect damage, products with dual-mode protection of above and below ground pests, such as a Genuity® SmartStax® RIB Complete® corn blend with a 5% refuge, should be utilized.

A common question is if a hybrid is good for corn-on-corn. Although that is a simple question, there is not a simple answer. Some aspects of corn-on-corn can be addressed with hybrid characteristics, but others cannot. There are no perfect corn hybrids and all hybrids are likely to experience more biotic and abiotic stresses when placed in a corn-on-corn environment.

Yield. Data can often be pulled for yield performance on corn-on-corn acres, but the year effect can be quite large. Consider if you pulled data from 2009 and 2010. The years are so different that any real hybrid differences were likely masked. Decisions are generally better if based on multi-year data, with evaluation of the data by year as well. It is important to look at enough data to be meaningful. Evaluating data from a larger geography to increase the number of locations evaluated can be helpful.

The hybrid on the right has stronger early emergence than the hybrid on the left.

KEYS TO HELP MAXIMIZE YIELD POTENTIAL WHILE MINIMIZING RISK WHEN SELECTING HYBRIDS FOR CORN-ON-CORN:

1) Build a Package
2) Analyze Adequate Yield Data
3) Match Hybrid Characteristics with Agronomic Needs of Your Fields and Farming Operation

Agronomic Characteristics. While there is no substitute for actual yield data, there are many hybrid characteristics that are generally believed to be more important when hybrids are to be placed in corn-on-corn situations. In many cases there is more perception and a personal opinion than hard evidence to support these beliefs. Some agronomic

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9. Hybrid Selection for Corn on Corn

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characteristics to consider include:

1) **Strong Emergence and Early Vigor.** The effects of cooler and wetter soils due to heavy residue can be challenging in corn-on-corn.
2) **Insect Tolerance.** To help minimize the acres that are at higher risk of insect damage, products with dual-mode protection of above and below ground pests, such as a Genuity® SmartStax® RIB Complete® corn blend with a 5% refuge, should be utilized.
3) **Disease Tolerance.** Diseases such as GLS, NCLB, many common stalk rots, ear rots, seedling blights, and in some areas Goss's Wilt are all potentially more severe for corn-on-corn. Many of the common foliar diseases can be effectively managed with fungicide applications.
4) **Root and Stalk Strength.** With the potential for increased traffic, more compaction and overall poorer soil structure, root growth and development can be more challenging. Heavier disease pressure and increased plant stress can negatively affect stalk quality.

Others. There are several other aspects of corn-on-corn that are not directly correlated to a specific hybrid characteristic. Generally adaptability to limited N due to immobilization from high residue levels is not a common rating for hybrids. The ability to maintain ear size and yield potential in a late season drought is not captured by a single hybrid characteristic rating. There are simply several aspects of corn-on-corn that are not understood and there is not a perfect formula for selecting hybrids for corn-on-corn based on hybrid characteristics. There are certain characteristics that should be selected when a hybrid will be placed in corn-on-corn, but they do not make it infallible for corn-on-corn.

Hybrids should be selected and placed with using as much information as possible. However, there is not a 'perfect' hybrid, and a hybrid's performance will vary based on the year and environment. In summary, it is important to select a package of three to five hybrids to help mitigate the risks that are uncontrollable.

1	3	5	7	9
Slight Infection Few lesions on lower leaves.	*Light Infection* Lesions on lower leaves.	*Moderate Infection* Lesions on lower and middle leaves.	*Heavy Infection* Lesions on lower and middle leaves, extending to upper leaves.	*Very Heavy Infection* Lesions on all leaves. Plants may be prematurely killed.

Examples of various ratings on a 1 to 9 disease rating scale.

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10. Insect Management for Corn-on-Corn

Most insect pests in corn are not greatly influenced by crop rotation. Corn rootworm is the exception. Best management practices (BMP) such as crop rotation and using multiple modes of action can help manage fields with high corn rootworm (CRW) pressure. The dual modes of action for protection against CRW in Genuity® SmartStax® RIB Complete® corn blend provide excellent control of CRW. Utilizing multiple modes of action when planting Genuity® VT Triple PRO® products or Genuity® VT Triple PRO® RIB Complete® corn blends, by using a soil-applied insecticide (SAI) at planting along with foliar insecticide applications the prior year, will help reduce CRW damage.

Background

High CRW pressure can result in the performance of single-trait CRW products, such as YieldGard VT Triple®, Genuity® VT Triple PRO®, or Genuity® VT Triple PRO® RIB Complete® corn blend being less than expected. We implemented BMP tailored to these specific agricultural systems to help manage CRW and maximize yield potential. As a point of reference, in 2011, efficacy claims represented less than two-tenths of one percent of the total number of acres planted to this technology.

To help assess the adoption and effectiveness of various BMP, Monsanto followed up on all of the fields from 2011 where high CRW pressure was reported to have caused unexpected damage:

- Grower intentions for utilizing various BMP in the 2012 growing season were gauged prior to planting (Figure 10-1).
- Node injury scores (NIS) were collected from fields that employed the BMP of planting a Genuity® SmartStax® RIB Complete® corn blend or planting a Genuity® VT Triple PRO® or YieldGard VT Triple® product with a SAI.
- Strip trials were established to evaluate the effectiveness and consistency of various *B.t.* corn technologies on several of these fields that had less than expected performance in 2011.

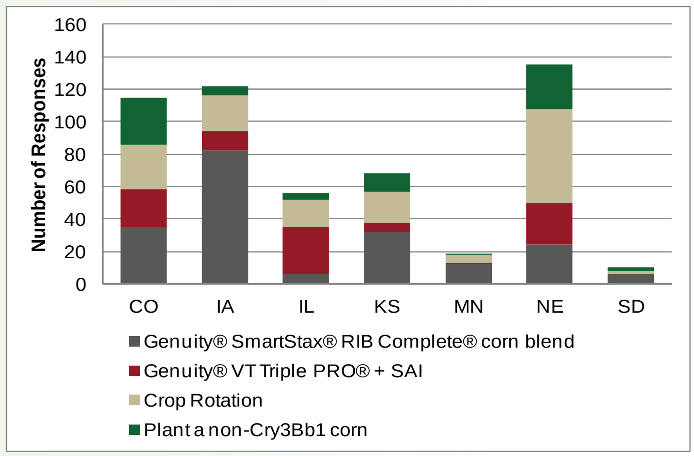

Figure 10-1. Results of a survey conducted to evaluate intentions of growers who experienced less than expected performance of single-trait CRW products in 2011 to implement BMP for the 2012 growing season. Source: 2012 Monsanto Data.

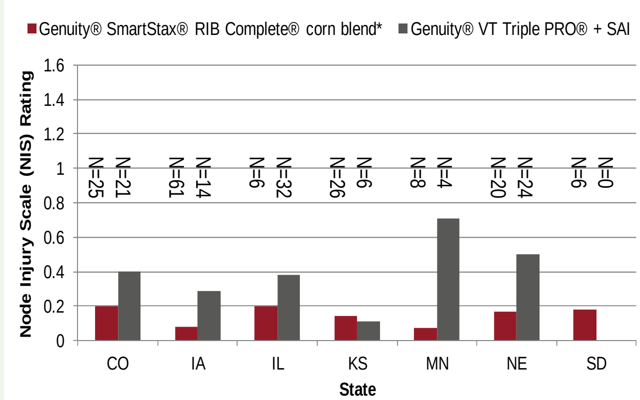

Figure 10-2. Effect of various BMPs on average node injury scale (NIS) ratings in fields that had high CRW pressure, reported by state. SAI = soil applied insecticide. Source: 2012 Monsanto Data. *Average NIS potentially takes into account non-*B.t.*/refuge plants.

Performance of BMP in 2012 Fields With High CRW Pressure in 2011

Effectiveness of BMPs Implemented by Farmers. In fields planted back to corn in 2012, 25 roots per BMP were dug and evaluated. Most often, there was one BMP employed per field; either planting Genuity® SmartStax® RIB Complete® corn blend or Genuity® VT Triple PRO® corn with a SAI. Both BMPs provided very good control (Figure 10-2). Genuity® SmartStax® RIB

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10. Insect Management for Corn-on-Corn

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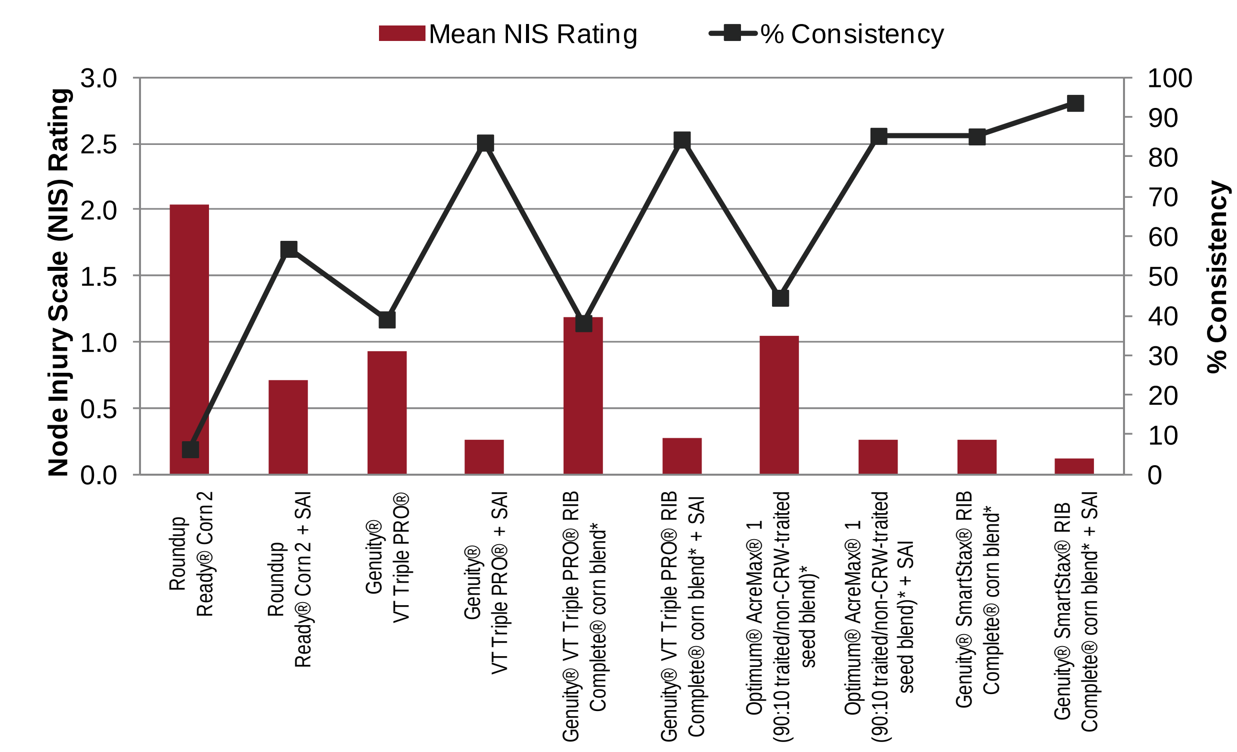

Figure 10-3. Effect of soil-applied insecticide (SAI) on average root damage ratings in High Pressure Fields. Source: 2012 Monsanto Technology Development Trials at seven locations: Delaware and Buena Vista Counties in Iowa, Sherman County in Kansas, Kit Carson and Yuma Counties in Colorado, and McLean and Whiteside Counties in Illinois. *Average NIS potentially takes into account non-*B.t.*/refuge plants.

Complete® corn blend had an average NIS score of 0.2 or less. Genuity® VT Triple PRO® corn with a SAI generally had an average NIS score of 0.5 or less except for in Minnesota. Two of the four fields evaluated in Minnesota that were planted to Genuity® VT Triple PRO® corn with a SAI had notably higher NIS scores.

Evaluation of Various *B.t.* Corn Technologies in Strip Trials. In 2012, strip trials were conducted in fields that had high CRW pressure in 2011. The agronomic practices were those common for the region. Soil fertility was managed to obtain a high yield potential. A protocol was established to evaluate the effect of SAI on average root damage ratings of Genuity® SmartStax® RIB Complete® corn blend, Genuity® VT Triple PRO® corn, Genuity® VT Triple PRO® RIB Complete® corn blend, DuPont Pioneer® Optimum® AcreMax® 1 corn products, and a non-*B.t.* check (Roundup Ready® Corn 2). In fields with high CRW pressure, the most effective and consistent control of CRW was provided by Genuity® SmartStax® RIB Complete® corn blend with its dual modes of action against CRW, and using a SAI when Genuity® VT Triple PRO® products or Genuity® VT Triple PRO® RIB Complete® corn blends were planted (Figure 10-3).

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10. Insect Management for Corn-on-Corn

In Summary

Using BMP such as rotation, planting Genuity® SmartStax® RIB Complete® corn blend with its dual modes of action against CRW, and using a SAI when Genuity® VT Triple PRO® products or Genuity® VT Triple PRO® RIB Complete® corn blends are planted, can help manage high populations of CRW.

Best Management Practices for High Populations of Corn Rootworm

1) CROP ROTATION.

Crop rotation, to soybean or an alternative crop, is one of the most effective methods to lower CRW pressure in the field. However, in areas of the Corn Belt with extended diapause populations of northern corn rootworm (NCRW) or the soybean variant of western corn rootworm (WCRW), rotation should be used as one part of a multiple tool, integrated pest management system for prevention of CRW root damage.

2) PLANT CORN WITH MULTIPLE CRW TRAITS.

Under high CRW pressure, the dual modes of action of Genuity® SmartStax® RIB Complete® corn blend provide the most consistent control of CRW compared to other control options (Figure 10-3).

3) PLANT CORN WITH A SINGLE CRW TRAIT + INSECTICIDE.

- When Genuity® VT Triple PRO® products or Genuity® VT Triple PRO® RIB Complete® corn blends are planted in fields with high CRW pressure, a SAI or comparable CRW insecticide should be applied. While SAI can be helpful, their efficacy can be highly dependent on environmental conditions. Liquid in-furrow applications are an option, but generally are not preferred in high CRW pressure situations.
- Chemigation for larval control can be effective; however, it should be reserved for a rescue treatment should the in-furrow application not provide acceptable control and significant larval activity is observed.
- Use of foliar application(s) to control beetles and reduce egg laying and subsequent CRW pressure the following year may be another approach to achieve management with multiple modes of action.

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11. What About Rotating with Soybeans?

Upon continual evaluation of what crop production practices are most beneficial for a farming operation, the option of rotating to soybeans should be one to evaluate carefully and thoroughly, especially if some of the drive to consider rotation is out of emotion from poor corn performance and not evaluation of economics and agronomics. Items to consider when evaluating more crop rotation in an operation are discussed below.

Economics. Generally the reason people grow corn-on-corn is that it is more profitable, despite the additional input and labor costs. Even if yields might not have been as hoped for corn-on-corn fields, the true factor that needs to be evaluated is the profitability of those fields versus soybean fields.

Yield Expectations. Expectations for corn-on-corn yield potential should be set appropriately. In much of the Midwest in 2010 and 2011 corn-on-corn yields were often much lower than expectations. Expectations were very high due to how well corn-on-corn had performed in 2007, 2008 and 2009. With three years where little or no yield penalty for corn-on-corn versus rotated corn was observed, and two years where the yield penalty was quite large, it is likely the average would be somewhere in the middle. While it is likely that corn-on-corn will usually perform better than what it has in 2010 and 2011, having expectations that it will consistently have yield potential equal to rotated acres is not realistic. Research and experience have shown that most of the time corn-on-corn will yield less than rotated corn; how much less can vary widely. When considering different options for cropping systems, one should evaluate if a realistic yield goal for corn-on-corn is likely to be more profitable than soybeans. The answer to that question will vary by field and by operation.

Corn-on-Corn Agronomics. Economics is not black and white, as many agronomic variables come into play. Will rotating to soybeans be the best or most feasible way to deal with issues related to soil structure and compaction, residue management challenges, nutrient availability, and disease pressure from pathogens that overwinter in residue? The answers to these questions are likely to differ by field and operation. Rotating away from corn, even every 2 or 3 years, is one of the key tools to help manage corn rootworm.

Soybean Agronomics. Soybeans tend to yield better following multiple years of corn. There are a few variables that might contribute to a contradiction of that trend, such as soybean cyst nematode, sudden death syndrome, and various other pathogens which can overwinter for more than a year or two in the soil.

If rotation to soybeans does occur on some acres that have struggled the last two years with corn-on-corn, management strategies should be utilized to help maximize the yield potential and economic potential of the soybean crop. Treating soybeans as a crop of lesser importance or management requirement than corn tends to produce less than optimal results.

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12. Summary

Summary

As stated previously, accurately identifying and managing issues that can occur in corn-on-corn, requires an agronomic approach. There are several contributing factors to the challenges and success with corn-on-corn. Lessons can be learned from every year of corn-on-corn production, but future management decisions should be based on several years of experience. Constant evaluation of management practices can help improve performance; however, sometimes weather will be a larger factor than the management tools available for use. Using good management practices for all aspects of the agronomics of corn-on-corn and selecting proper hybrids are critical for maximizing corn-on-corn or continuous corn acres.

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