DUPONT PIONEER

Agronomy Sciences Research Summary

Canadian Edition - 2014

Introduction

According to estimates, North American farmers produced over 14 billion bushels of corn in 2013, the largest corn crop in history. The average yield of over 160 bu/acre was exceeded only in 2009. The soybean crop was estimated at more than 3.25 billion bushels, which was higher only twice previously.

These results were achieved due to abundant spring rainfall that replenished soil moisture reserves throughout the Midwest and was then followed by generally favorable summer conditions in most states and provinces. However, some major production areas experienced progressively worsening drought stress during grain fill, which resulted in reduced yields.

Insufficient summer rainfall and other adverse weather conditions are the most serious risks faced by growers. For this reason, DuPont Pioneer researchers are developing hybrids and varieties that perform better under drought stress than historical seed products. Pioneer® brand Optimum® AQUAmax® corn hybrids are prime examples of these efforts, but other crops are benefitting as well.

In addition to adverse weather, grain price fluctuations also present a risk to the profitability of farming operations. To help reduce this exposure, DuPont Pioneer conducts studies each year designed to improve crop management practices. Results of these studies are made available to customers in multiple formats, including this Agronomy Sciences Research Summary. Growers can use this information to help optimize production decisions in their farming operations for increased yields and profits.

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Row Width in Corn Grain Production

Narrow row corn is generally defined as any row spacing less than 30 inches. These spacings increase the distance between plants in a row, potentially increasing yields due to more efficient use of available space and resources. However, yield benefits of narrow rows have not been large or consistent enough so far to motivate growers to switch from 30-inch rows in most areas of North America. This review article discusses narrow row corn trends and research results.

Current Practices

The vast majority of corn acres in the U.S. and Canada are currently planted in 30-inch rows (Figure 1). This percentage has increased over recent years, from 80% in 2007 to 85% in 2012, while the percent of corn acres in wider row spacings (36- and 38-inch) has declined (data not shown). Adoption of narrow row corn has been very limited, with row spacings less than 30 inches currently used on less than 5% of corn acres in the U.S. and Canada. The most common narrow-row spacing is 20-inch, followed by 22-inch and 15-inch.

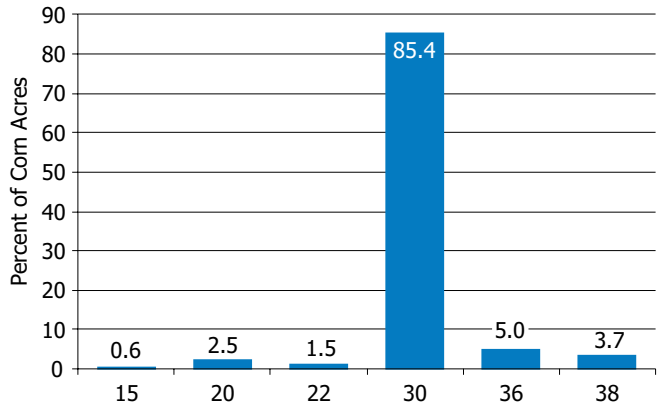


Figure 1. Corn row spacings (in inches) in North America as a % of all acres, 2012. DuPont Pioneer Brand Concentration Survey.

Corn acreage planted in narrow rows has been relatively stable over the past several years, comprising a combined 4.2% of corn acres in 2007 and 4.6% in 2012 (Table 1).

Table 1. Corn acreage planted to the most common narrow-row spacings from 2007 to 2012 in North America. Source: DuPont Pioneer Brand Concentration Survey.

Row Width	2007	2008	2009	2010	2011	2012
inches	---------- acres (%) ----------					
15	0.4	0.3	0.4	0.4	0.4	0.6
20	2.4	2.5	1.9	2.7	2.5	2.5
22	1.4	1.5	1.5	1.2	1.4	1.5
All Narrow	4.2	4.2	3.9	4.2	4.2	4.6

Regional adoption of narrow rows varies widely, with the highest adoption rate in the Northern Corn Belt states of Minnesota, Wisconsin, North Dakota and South Dakota (Figure 2). The most common narrow-row spacing in this region is 22-inch (5%), followed by 20-inch (4%).

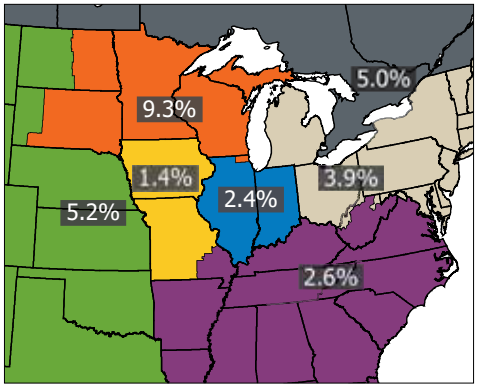


Figure 2. Narrow row corn adoption (15-, 20- and 22-inch) by region in North America as a % of total acres in 2012.

Source: DuPont Pioneer Brand Concentration Survey.

Recent Row-Spacing Research

University Research - Over the years, research on narrow row corn has produced variable results, which suggests that multiple factors likely influence corn yield response to row spacing. Yield benefits with narrow row corn have been observed more frequently in the northern portion of the Corn Belt in the area north of approximately 43°N latitude (line running roughly through Mason City, IA; Madison, WI; and Grand Rapids, MI) (Lee, 2006). In a survey of several recent university corn row studies comparing 15-, 20- or 22-inch rows to 30-inch rows, the greatest yield benefits with narrow rows were observed in experiments conducted in Minnesota and Michigan (Table 2). An average yield advantage of 2.8% with narrow or twin rows was observed in northern studies, compared to no advantage on average (-0.2%) for narrow rows in Iowa, Indiana and Nebraska (Figure 3).

Even among northern locations, however, yield benefits to narrow rows were inconsistent. For example, Van Roekel and Coulter (2012) found no yield advantage to narrow rows in research conducted during 2009 and 2010 at two southern Minnesota locations. Research at these same two locations in the early 1990s found an average 7.3% yield advantage for 20-inch over 30-inch rows (Porter et al., 1997).

DuPont Pioneer Research - Similar results were observed in DuPont Pioneer research. Results from 76 research studies conducted between 1991 and 2010 showed an average yield advantage of 2.7% with narrow or twin rows in the Northern Corn Belt states of Minnesota, North Dakota, South Dakota, Wisconsin and Michigan, compared to a 1.0% advantage across studies in Illinois, Iowa, Indiana, Missouri, Nebraska, Ohio and the southern tip of Ontario (Figure 3).

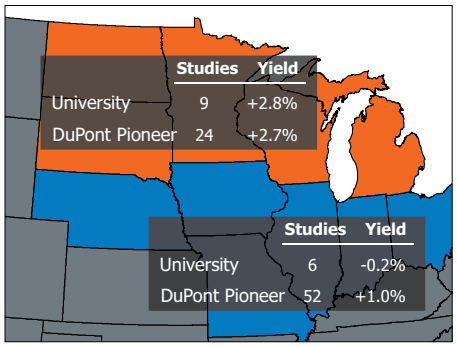


Figure 3. Average corn yield response to narrow rows in northern and central Corn Belt states observed in university and DuPont Pioneer studies conducted from 1991 to 2011.

DuPont Pioneer also conducted numerous on-farm research studies from 2010 to 2012 comparing yield in twin and 30-inch rows. Most of the studies were conducted in IL, IA and

Table 2. Yield advantage (%) of 15-inch, 20- or 22-inch, and twin rows compared to 30-inch rows observed in recent corn row-spacing research studies in the Midwestern U.S.

							Yield Increase vs. 30-inch		
Study	Location	Years	Locs	Hybrids	Yield Level	Populations	15	20 or 22	Twin
					bu/acre	1000 plants/acre	---------- % ----------		
1	Minnesota	92-94	3	6	100-150	25, 30, 35, 40		7.7	
2	Minnesota	97-99	1	1	100-150	33		6.2	
3	Minnesota	98-99	1	2	150-175	30	5.9	2.8	
4	Minnesota	09-11	6	3	175-200	16.5, 22, 27.5, 33, 38.5, 44		4.5*	
5	Michigan	98-99	6	6	175-200	23, 26, 30, 33, 36	3.8	2.0	
6	Nebraska	09-11	1	3	200-225	28, 33, 38, 42			1.4
7	Iowa	00-02	1	3	150-175	20, 28, 36, 44	1.2		
8	N. Dakota	06-08	1	2	>225	25, 30, 35	0.0		2.0
9	Michigan	98-99	1	1	150-175	24, 30, 34	0.5	0.8	
10	Wisconsin	98-01	1	1	175-200	34.5**	0.0		
11	Iowa	97-99	1	3	150-175	20, 28, 36	0.0		
12	Iowa	95-96	1	3	150-175	20, 28, 36	-0.6		
13	Minnesota	09-10	2	3	150-175	16.5, 22, 27.5, 33, 38.5, 44		-1.0	
14	Indiana	09-11	1	3	>225	28, 33, 38, 42			-1.0
15	Iowa	97-99	6	6	150-175	24, 28, 32, 36	-1.9		

1: Porter et al., 1997; 2: Johnson and Hoverstad, 2002; 3: Sharratt and McWilliams, 2005; 4: Coulter and Shanahan, 2012; 5: Widdecombe and Thelen, 2002; 6: Novacek et al., 2013; 7: Pecinovsky et al., 2002; 8: Albus et al., 2008; 9: Tharp and Kells, 2001; 10: Pedersen and Lauer, 2003; 11,12: Pecinovsky et al., 2002; 13: Van Roekel and Coulter, 2012; 14: Robles et al., 2012; 15: Farnham, 2001.

*Average yield increase at 38,500 and 44,000 plants/acre. A significant row spacing by population interaction was observed.
**Approximate final stand, which differed from target populations.

MN; although, side-by-side comparisons were also done in CO, IN, KS, MO and OH. A total of 192 paired comparisons across 44 locations showed no overall yield advantage to twin rows over 30-inch rows (Figure 4).

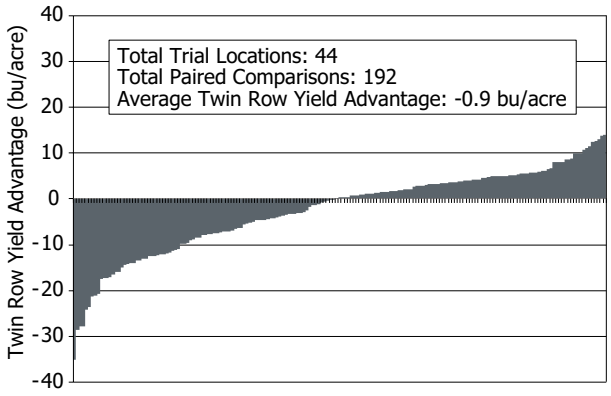


Figure 4. Yield advantage of twin rows compared to 30-inch rows in 2010-2012 DuPont Pioneer on-farm research studies.

Rationale of Narrow Row Corn

Narrow rows reduce the crowding of plants within a row, reducing competition among individual plants and potentially enhancing their utilization of available light, water and nutrients. However, this does not explain why corn yield increases are observed in some cases but not in others and why narrow rows seem to provide a more consistent benefit in the northern Corn Belt. Identifying environmental and agronomic factors that tend to favor narrower rows can help determine the best fit for this practice in current and future corn production systems.

Light Interception - Research has shown a strong relationship between improved yields in narrow rows and increased light interception (Andrade et al., 2002). Corn at a constant density can intercept more solar radiation when planted in narrow rows. This advantage is substantial during vegetative growth stages but diminishes as the crop approaches flowering. (Nafziger, 2006; Novacek et al., 2013; Robles et al., 2012; Sharratt and McWilliams, 2005; Tharp and Kells, 2001). By the time the plants reach silking, there is little or no difference in light interception between 30-inch and narrow rows. In addition, 30-inch rows in the Midwest have been shown to routinely capture over 95% of photosynthetically active radiation (PAR), which may be sufficient to maximize yield. Thus, narrow rows do not always have an inherent advantage.

Central (Midwest) vs. Northern Locations - Increased light interception is generally thought to be the reason that yield increases with narrow rows tend to be more frequent in the Northern Corn Belt (Thelen, 2006). In the absence of major water or nutrient limitations, corn yield is largely driven by the amount of solar radiation intercepted during the critical period for yield determination immediately before and after silking.

In the Central Corn Belt, this period normally begins in mid-July, about three weeks past the summer solstice (June 21, the

date of maximum daylength). In mid- to late-July, these central locations are still receiving above 95% of maximum sunlight. Thus, sunlight may not often be yield-limiting, and the ability of narrow rows to capture more available sunlight may not be important. In northern locations, the critical period of yield determination occurs as much as a week later, and in addition, days shorten more rapidly. This means that many northern locations are receiving a lower % of their maximum solar radiation during the critical period. Thus, the ability of narrow rows to capture more available sunlight may be important to yield determination in the North.

Water and Nutrient Recovery - The more equidistant plant spacing in narrow rows creates a more uniform distribution of roots within the soil profile, which reduces competition among individual plants for water and nutrients (Sharratt and McWilliams, 2005). Research has shown that narrow rows can improve nitrogen (N) use efficiency of corn by increasing the ability of the crop to recover N from the soil (Barbieri et al., 2008). This can improve yield in N-deficient conditions. Narrow rows have the added benefit of improving light interception when canopy development is limited by N deficiency. However, both of these advantages are reduced as N availability increases and may not result in increased yield when N is adequate (Barbieri et al., 2000; Barbieri et al., 2008).

The potential of narrow rows to increase yields by improving water uptake is less clear. Barbieri et al. (2012) found that narrow rows increased water uptake during the early stages of crop growth, but this advantage diminished as the season progressed. Total seasonal crop evapotranspiration ultimately did not differ between row spacings. Conversely, Sharratt and McWilliams (2005) found that narrow row corn did have greater total soil water extraction in one year of a two-year study. In any case, research does not indicate any broad advantage to narrow-row corn under drought stress conditions.

Potential Interacting Factors

Plant Population - Some have speculated that crowding within the row could limit yields at future (higher) plant densities. Average corn seeding rates in the U.S. and Canada have increased linearly by over 5,000 seeds/acre in the last 20 years. If that trend continues, seeding rates of over 40,000 plants/acre will be common in the next 20 years. Row-spacing studies in corn have routinely tested for interactions with plant population and specifically, whether or not narrow rows have a higher optimum density than 30-inch rows. Several university studies (Table 2) have included plant populations in excess of 40,000 plants/acre and have found little evidence that narrow rows have a higher optimum population (with the exception of a study in far northwestern Minnesota) (Coulter and Shanahan, 2012). DuPont Pioneer research also found no increased advantage for narrower (twin) rows at high populations.

Hybrids - A common question is whether certain hybrids are more suited to narrow rows than others and if future genetic improvements may eventually produce hybrids specifically optimized for narrow rows. Many university row-spacing studies have included multiple hybrids but generally have found no difference in response to narrow rows. Of the 12 studies summarized in Table 2 that included more than 1 hybrid, only 1 (Study 15) reported a significant hybrid by row-spacing

interaction (Farnham, 2001). Out of six hybrids tested in this study, one yielded better in 15-inch rows, one yielded better in 30-inch rows, and four did not differ.

DuPont Pioneer on-farm twin-row studies conducted in 2010 included several locations with multiple hybrids, some with as many as 10 hybrids. Among 14 hybrids that were tested at 3 or more locations, no significant differences in yield between twin rows and 30-inch rows were observed nor were any hybrid by row-spacing interactions observed among hybrids compared at multiple locations (data not shown).

It has been suggested that improvements to stress tolerance in high population environments may yield new hybrids particularly suited to a high-density, narrow- or twin-row system. The idea of optimizing hybrids for narrow-row production has typically focused on leaf architecture, assuming that plants with more narrow and upright leaves may be more suited to narrow rows. Research thus far, however, has not shown a relationship between leaf architecture and yield response to row spacing among contemporary hybrids.

A study conducted in Michigan compared performance of six hybrids with differing leaf architecture in narrow rows (Widdicombe and Thelen, 2002). Of these hybrids, two had erect leaf orientation, three had semi-upright leaves and one had wide leaves. Average corn yield was significantly higher in narrow rows, but performance did not differ among hybrids. Research in Minnesota comparing two hybrids of differing leaf architecture also found no difference in yield response to narrow rows (Sharratt and McWilliams, 2005).

Conclusions

The extensive history of research on corn row spacing has repeatedly shown that it is a very complex issue with many interacting factors. However, the accumulated body of DuPont Pioneer and university research conducted over the past 20 years does not indicate that the current standard 30-inch row spacing is limiting to corn productivity for most of the Corn Belt. Yield results in the Northern Corn Belt have tended to be more positive for narrow rows but still have shown a high degree of variability. Studies that have included multiple hybrids have generally found no difference in hybrid performance among row spacings, indicating that growers currently in narrow row systems are not limited in their choice of corn products for maximum performance.

Sources - *Enter this link in your browser to view sources:*

https://www.pioneer.com/home/site/us/agronomy/library/row-width-corn-grain-production/#sources

Planting Depth Effects on Corn

Early corn planting recommendations in most Corn Belt areas are to plant 1.5 to 2 inches deep to ensure adequate moisture uptake and seed-to-soil contact. Deeper planting may be recommended as the season progresses and soils become warmer and drier. Planting shallower than 1.5 inches is almost never recommended at any planting date or in any soil type.

Growers who plant at depths less than 1.5 inches expect that seed will emerge more rapidly due to warmer soil temperatures closer to the surface. This is an important consideration, as corn growers across the Corn Belt are planting earlier to complete planting before yield potential begins to decrease after the first week of May. Particularly in soils that crust, speed of emergence is critical to establish plant stands before heavy rainfalls "seal" the soil surface.

When corn is planted 1.5 to 2 inches deep, the nodal roots develop about 0.75 inches below the soil surface. However at planting depths less than 1 inch, the nodal roots develop at or just below the soil surface (Figure 1). Such excessively shallow planting can cause slow, uneven emergence due to soil moisture variation; and rootless corn ("floppy corn syndrome") later in the season when hot, dry weather inhibits nodal root development (Figure 2).

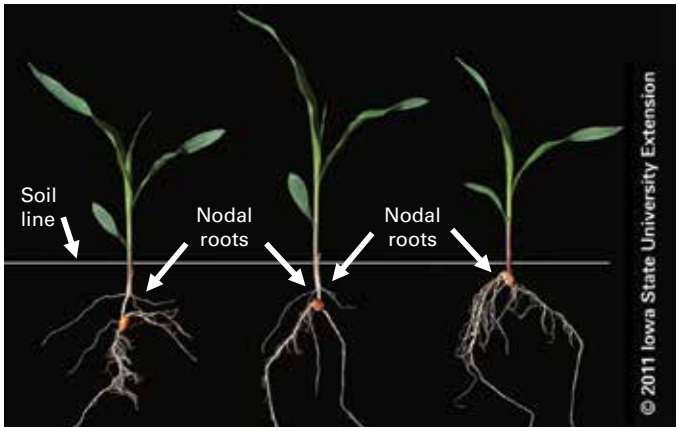


Figure 1. Planting depth (2.5" on left to 0.5" on right) determines the placement of nodal roots, which are developing too near the soil surface in shallow-planted corn plant at right.

Study Justification and Objectives

Well-documented effects of shallow planting on root development has led to the assumption that planting depth may play a role in managing the drought susceptibility of a hybrid. According to some agronomists, shallow plantings increase stress and result in less developed roots, smaller stalk diameters, smaller ears and reduced yields. However, data substantiating such claims are limited.

Although previous research has generally documented faster emergence rates with shallower planting depths, the comparisons have often included deeper planting depths than the recommended ranges, and results are highly influenced by temperature and rainfall in the given season. Recent studies comparing planting depths that are within the depth ranges commonly used by growers are limited, and none have attempted to compare hybrid differences between planting depths.

Figure 2. Rootless corn syndrome caused by shallow planting and dry soils conditions.

DuPont Pioneer has worked to introduce hybrids with improved drought tolerance to provide more yield stability on variable and droughty soils. Hybrids with higher levels of drought tolerance may provide improved yield stability in shallow-planted situations while also providing improved performance at normal planting depths, though this has not been documented. Improving our understanding of newer hybrid responses to planting depth across planting dates and over different soil types may help improve our understanding of hybrid management and positioning. Incorporation of differing planting dates and soil types will allow a more robust analysis of the impact of temperature, soil water holding capacity and crusting potential over the course of the study.

The objectives of this research study were:

- to evaluate the effect of planting depth on stand establishment of Pioneer® brand corn products
- to evaluate the grain yield response of corn products with different drought tolerance ratings to varying planting depths
- to assess if planting depth effects varied across growing environments that differed by soil type and planting date.

Study Description

Locations - This study was conducted by Dr. Peter Thomison in conjunction with the 2011 Ohio State University Ohio Corn Performance Test (OCPT) and established at 10 locations (Hebron, Washington Court House, S. Charleston, Greensville, Van Wert, Hoytville, Upper Sandusky, Bucyrus, Wooster and Beloit).

Plot Design - The experiment was replicated three times in a randomized complete block arranged in split-plot layout. The main plot was planting depth and subplot was hybrid. Plot size was 4 30-inch rows 25 feet in length. Force® 3G soil insecticide was applied in a T-band to all plots.

Hybrids and Planting Depth Treatments - Three Pioneer® brand corn products, Pioneer® P0965$_{AM1}$™ brand corn (AM1, LL, RR2, 108 CRM), Pioneer® P0891$_{AM1}$™ brand corn (AM1, LL, RR2, 109 CRM) and Pioneer® hybrid 35H42 (HX1, LL, RR2, 107 CRM) were planted at three planting depths (0.5, 1.5, and 2.5 to 3 inches). The drought scores for the three products were 8, 7 and 6, respectively. The Pioneer drought rating scale is from 1 to 9 (9 = best).

Seeding Rate, Measurements - Seeding rate was 34,000 seeds/acre. Measurements during the growing season included early stand, late emergers ("runts"), stalk diameter, final stand, ear weight, "nubbins", grain yield, stalk and root lodging, and test weight. Weather data were recorded at each site.

Applied Questions

How did planting depth affect corn yields?

2011 - Grain yields, averaged across locations and hybrids, were 13% and 15% greater for the 1.5- and 3-inch planting depths, respectively, than the 0.5-inch planting depth (Figure 3).

- At 8 of the 10 sites, yields of the 3-inch planting depth treatment exceeded those of the 0.5-inch planting depth treatment (data not shown).
- At 5 of the 10 sites, yields of the 1.5- and 3-inch treatments were similar; the 1.5-inch treatment out-yielded the 3-inch treatment at 1 site (data not shown).

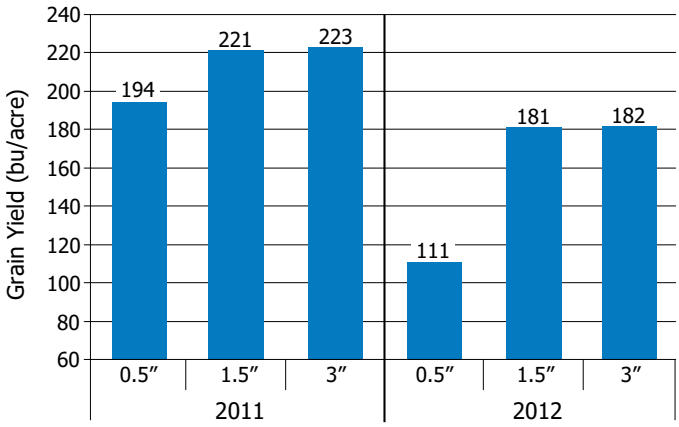


Figure 3. Corn yield response to planting depth in 2011 and 2012.

2012 - Grain yields averaged across locations and hybrids were 40% greater for the 1.5- and 3-inch planting depths than the 0.5-inch planting depth (Figure 3).

- At 9 of the 10 sites, yields of the 1.5-inch and 3-inch planting depth treatments were greater than those of the 0.5-inch planting depth (data not shown).
- At 6 of the 10 sites, yields of the 1.5-inch and 3-inch treatments were similar (data not shown).

Did planting depth affect stand establishment, and was this associated with yield effects?

2011 - The lower yield of the shallow planting treatment in Figure 3 was associated with a reduced final stand – 27,200 plants/acre for the 0.5-inch depth vs. 34,200 and 34,000 for the 1.5-inch and 3-inch planting depths, respectively (Figure 4).

- The lower yield was also associated with many more "runts" – 28% for the 0.5-in. depth vs. 5% and 4% for the 1.5-inch and 3-inch depths, respectively (data not shown).

2012 - The lower yield of the shallow planting treatment was associated with a lower final stand – 19,500 plants/acre for the 0.5-inch depth vs. 32,000 and 30,900 plants/acre for the 1.5-inch and 3-inch planting depths, respectively (Figure 4).

- The lower yield was also associated with many more "runts" – 31% for the 0.5-inch depth vs. 6% and 3% for the 1.5-inch and 3-inch planting depths, respectively.

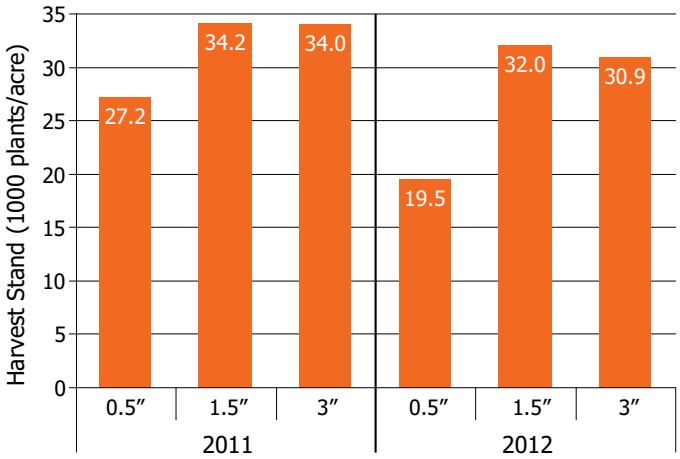


Figure 4. Harvest stand response to planting depth in 2011 and 2012.

Did corn products differ in their yield response to planting depth?

Although differences in yield were evident among hybrids, the three hybrids exhibited similar yield responses to varying planting depth (Figure 5).

- Averaged across locations, the yield of P0965AM1™ exceeded that of the other 2 hybrids by about 11 to 15 bu/acre at each planting depth.

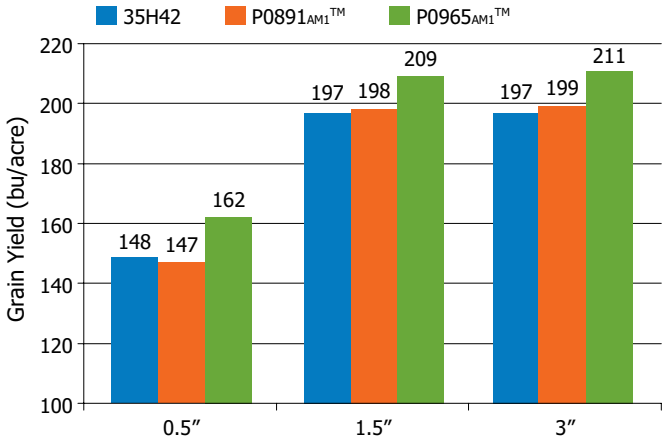


Figure 5. Corn product yield response to planting depth in 2011 - 2012.

Did differences in hybrid drought tolerance ratings affect yield response to planting depth?

Drought tolerance rating effects could not be separated from hybrid genetic effects in this study. However, similar to the prior question, there was no evidence that differences in hybrid drought tolerance ratings among the hybrids affected response to planting depth (Figure 5).

- P0965AM1™, the hybrid with the highest drought tolerance score, was consistently higher yielding than the other two hybrids at all planting depths.

Do not use these or any other data from a limited number of trials as a significant factor in product selection. Product responses are variable and subject to a variety of environmental, disease, and pest pressures. Individual results may vary.

Corn Plant Population Update

DuPont Pioneer has been conducting plant population studies with corn hybrids for over three decades. These studies test for complex G x E x M (genetics x environment x management) interactions, which frequently play a key role in maximizing yield potential and reducing risk. DuPont Pioneer researchers target representative environments based on maturity zone, expected yield (high or low), specific stresses (drought, pest pressure, high residue, early planting, etc.) and other unique location characteristics that might result in repeatable hybrid x population responses.

Hybrid improvements in stress tolerance have led to higher populations and increased yield potential over the years. Introductions of new traits and technologies as well as continual breeding improvements validate the need for ongoing plant population research. Growers can use the multi-year and multi-location results to identify the best potential planting rates specific to their hybrid, location and management practices.

Plant Population Trends

Each year, Pioneer surveys farmers regarding the seeding rates currently used on their farms (Figure 1).

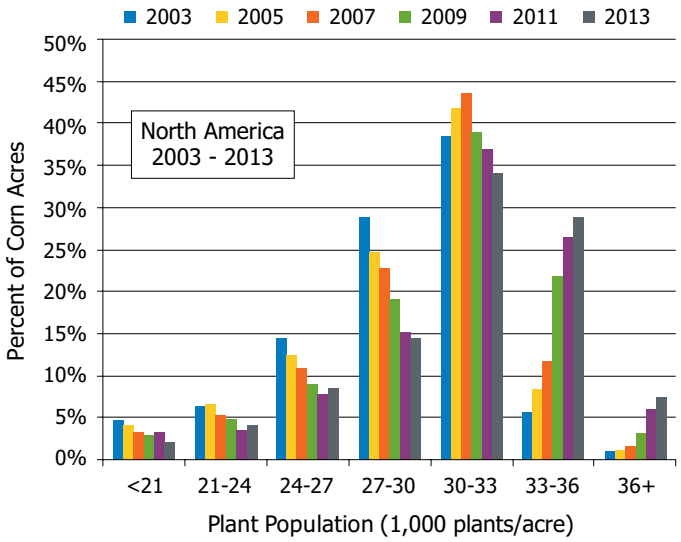


Figure 1. Distribution of reported corn seeding rates, DuPont Pioneer Brand Concentration Survey, 2013.

This survey shows that about 30% of corn acres in North America are currently planted between 30,000 and 33,000 seeds/acre. However, the fastest growing category is 33,000 to 36,000 seeds/acre, which has increased from less than 12% of corn acres in 2007 to almost 30% of corn acres in 2013. The 36,000+ category is also gaining acres but at a slower rate of about one percentage point per year. In the major corn-producing states of Iowa, Illinois and Minnesota, the percent of acres planted over 33,000 seeds/acre is well over 50%, generally due to more productive soils (data not shown).

DuPont Pioneer Plant Population Trials

Pioneer has conducted plant population research at over 700 locations throughout the U.S. and Canada in the last 12 years, generating over 180,000 quality data points (Figure 2).

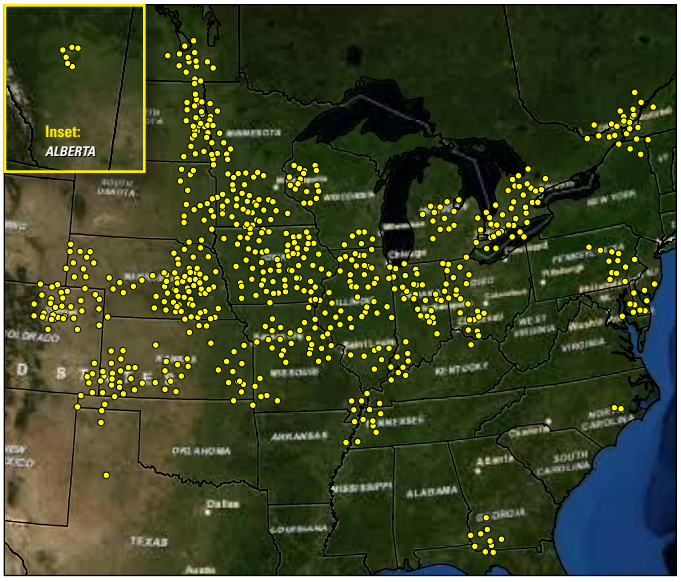


Figure 2. DuPont Pioneer plant population test locations in North America, 2001-2012.

Results Grouped by Time Period

These data were divided into four-year groupings to evaluate if progress was made in increasing hybrid tolerance to high plant density stress. Specifically, yield data of the five highest yielding hybrids from each of three different periods, 2001-2004, 2005-2008 and 2009-2012 were averaged within each grouping, and yield response to plant population was plotted (Figure 3).

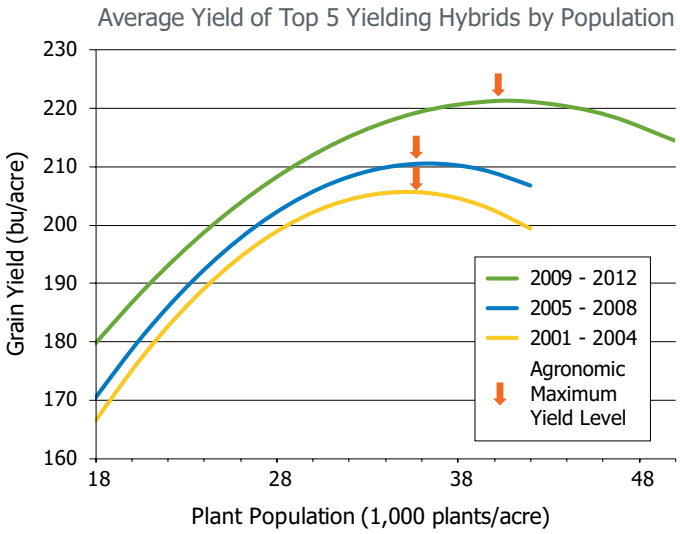


Figure 3. Average yield of top five yielding hybrids in each four-year period by population, 2001-2012.

For the top 5 yielding hybrids per time period, the plant population that maximized yield increased from 36,000 plants/acre in the two earliest groups to 40,000 plants/acre in the most current hybrid group (2009-2012). In addition, yield increased by 10.7 bu/acre in the most current group over the previous 4-year period (Figure 3). These yield gains are consistent with those of previous genetic studies that have indicated a 1.0 to 1.5% per year yield increase attributable to genetic improvement alone. To accomplish these increases, DuPont Pioneer corn breeders have selected for superior tolerance to drought, high plant

density, pests and other stresses. In this study, the benefits of improved agronomic practices (use of seed treatments, foliar fungicides, etc.) may also have contributed to yield gains.

Results by Field Productivity Level

Grouping locations with similar yields is a useful way to analyze plant population results because it can indicate which populations are needed for the yield levels growers intend to achieve. Like previous DuPont Pioneer studies, the 2006 to 2012 trials across the U.S. and Canada show that corn hybrid response to plant population varies by yield level (Figure 4). On inspection, it is apparent that the response curves become steeper and the peak moves farther to the right as yield levels increase. In other words, the seeding rate required to maximize yield increases as yield level increases. Differences are most noticeable between the top and bottom curves, but in fact, this effect is progressive across the entire range of yield levels.

Optimum Economic Seeding Rate

As yields increase with each increment of higher seeding rate, a point is reached where the yield benefit from the next addition of seed no longer exceeds the cost of the seed. That point is the optimum economic seeding rate. By definition, it is the seeding rate that generates the most income when seed cost and grain price are factored in. The red arrows on the graph indicate the optimum economic seeding rate using a corn grain price of $4.40/bu and a seed cost of $3.25/1,000 seeds (Figure 4). The calculation assumes that a 5% overplant is needed to achieve the target plant population.

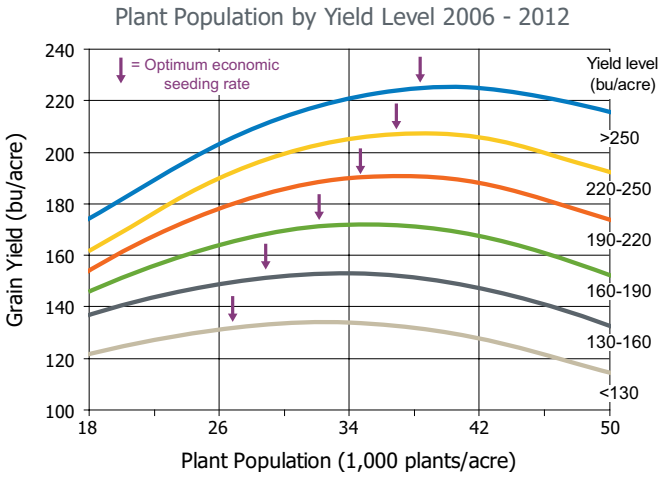


Figure 4. Corn yield response to population and optimum economic seeding rate by location yield level, 2006-2012.

As the graph indicates, the optimum economic seeding rate varies from about 27,000 seeds/acre for locations yielding less than 130 bu/acre to about 38,300 seeds/acre for yields over 250 bu/acre. For the high yield levels common in many areas of the Midwest in 2013 (190-220 bu/acre), the studies indicate an optimum economic seeding rate of 34,600 seeds/acre. A higher corn price relative to the seed cost would increase the seeding rate recommendations.

Results by Hybrid Maturity

Population response of five comparative relative maturity (CRM) groups is shown in Figure 5. These data show a fairly similar response of hybrid maturities to plant population.

DuPont Pioneer corn plant population trial.

Previous research has shown that early maturity hybrids (<100 CRM) may require higher populations to maximize yield. Although this trend can still be detected when examining the response curves closely, it is a smaller difference than in the past. This change may be the result of different genetic backgrounds predominant in early maturities historically vs. currently, or other unknown factors.

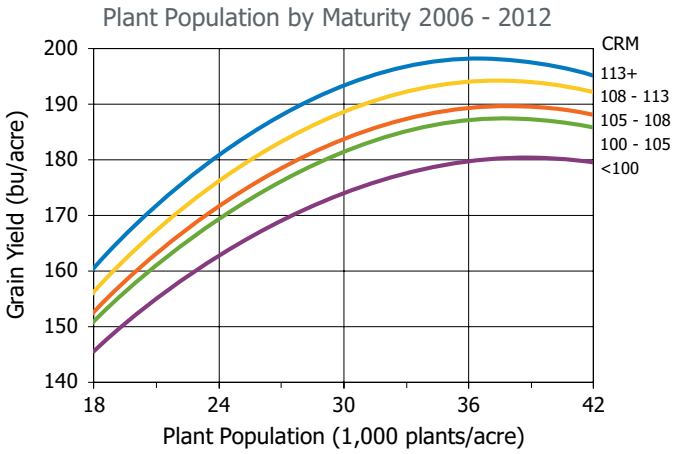


Figure 5. Yield response to plant population for corn hybrids from five maturity (CRM) ranges, 2006 to 2012.

Seeding Rate Recommendations

Challenging growing environments may reduce corn plant populations below optimum levels. These conditions can occur when planting into no-till or high-residue seedbeds, or cloddy or compacted soils. Soil-borne diseases and soil insects can also diminish stands. All of these factors can interact to challenge stand establishment, and effects are magnified when planting early into cold, wet soils. Therefore, consider the following points when choosing your seeding rate:

- In general, plan to drop 5% more seeds than the target population to account for germination or seedling losses.
- Boost target seeding rates by an additional 5% for extreme or challenging environments such as those described in the paragraph above.
- In areas with perennial drought stress, seeding rate targets are lower. Base your seeding rate on the specific hybrid population response at the historical yield level of the field.

Optimizing Seeding Rates for Corn Hybrids

Corn plant population trial.

Optimizing corn seeding rates is critical to achieving top yields and profits. Corn hybrids demonstrate inherent differences in their response to plant population. This is due to their unique genetic makeup that controls traits such as drought tolerance, ear size, leaf architecture, silking ability, silk timing relative to pollen shed, standability and other characteristics. In addition, each hybrid's population response may be affected by the yield level (i.e., stress level) of the growing environment. Grower goals and preferences are a final component of the plant population decision.

Because of hybrid differences, each hybrid must be tested in multiple environments that include a wide diversity of growing conditions, rainfall patterns, soil types, management practices and other factors that ultimately determine yield. Only by adequate testing can hybrid plant population responses be clearly understood and optimally applied. For this reason, DuPont Pioneer researchers broadly test corn hybrids at a range of plant populations in multiple environments across North America. Hybrid x population response graphs are then developed from the results.

In the seeding rate response graphs that follow, the "optimum economic seeding rate" (represented by the triangle below each curve) is the seeding rate at which maximum profitability is achieved when considering seed cost, grain price and yield.

There are three possible curves on each graph, representing data grouped by these yield levels: 1) greater than 200 bu/acre, 2) between 150 and 200 bu/acre, and 3) below 150 bu/acre (see legend below). The economic optimums were calculated using a seed cost of $3.25/1,000 seeds and a corn grain price of $4.00/bu. A five percent overplant is assumed to achieve desired stands.

Legend for Seeding Rate Response Curves

Yield Range	Estimated Optimum Economic Seeding Rate
High: > 200 bu/acre:	▲
Mid: 150-200 bu/acre:	▲
Low: < 150 bu/acre:	▲
Grain Price ($/bu):	$4.00
Seed Cost ($/1,000 seeds):	$3.25
Rate Adjusted for Stand Loss:	5%

The hybrid seeding rate response curves on the following pages are provided for informational use only. Please contact your Pioneer sales professional for information and suggestions specific to your operation. Product performance is variable and subject to soil type, management practices, and any number of environmental, disease and pest pressures. Individual results may vary.

Pioneer® Brand Corn Products

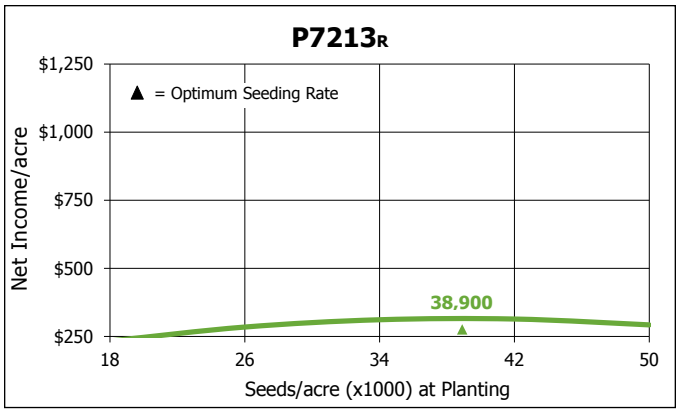


Figure 1. P7213R (72 CRM, RR2) seeding rate response.

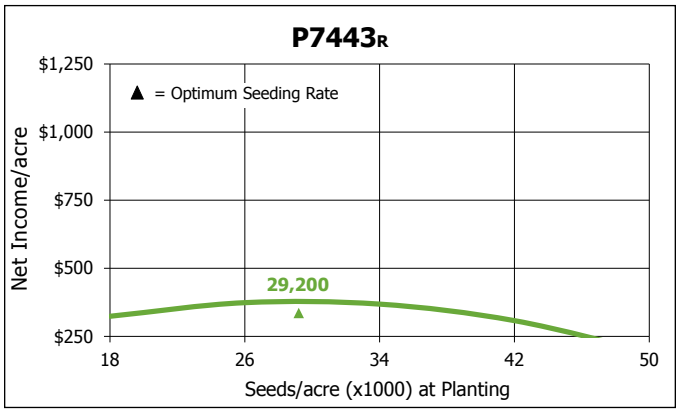


Figure 2. P7443R (74 CRM, RR2) seeding rate response.

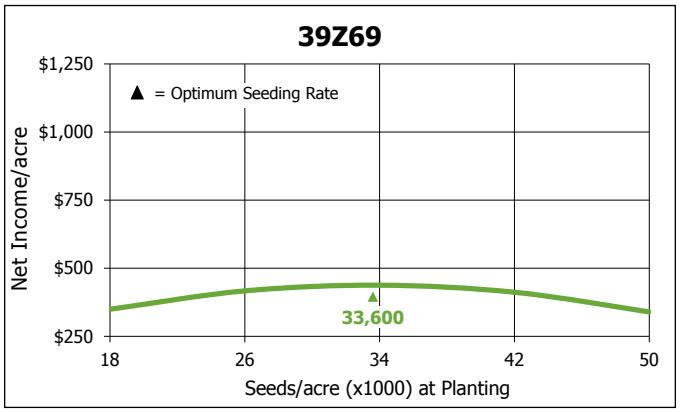


Figure 3. 39Z69 (77 CRM, HX1, LL, RR2) seeding rate response.

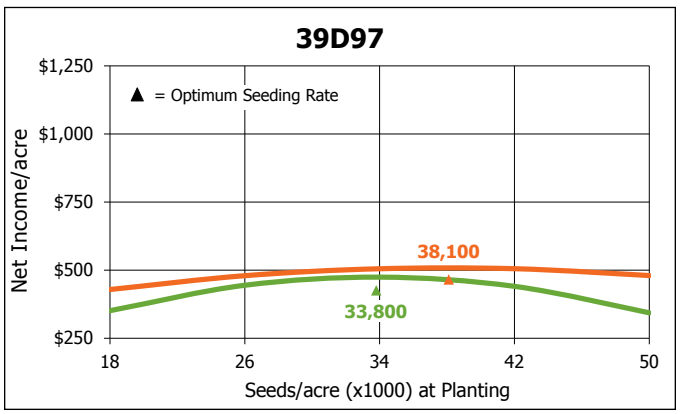


Figure 4. 39D97 (79 CRM, HX1, LL, RR2) seeding rate response.

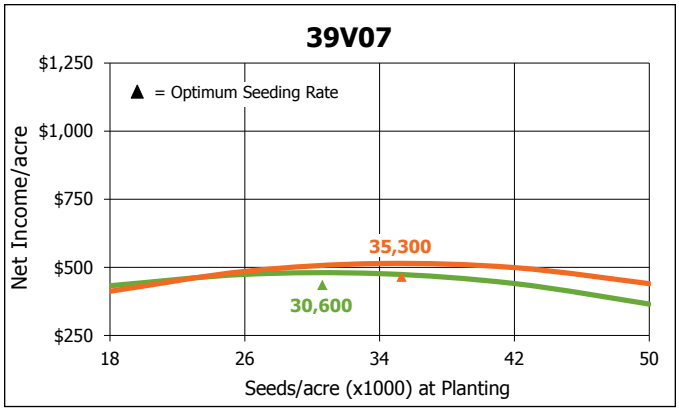


Figure 5. 39V07 (80 CRM, HX1, LL, RR2) seeding rate response.

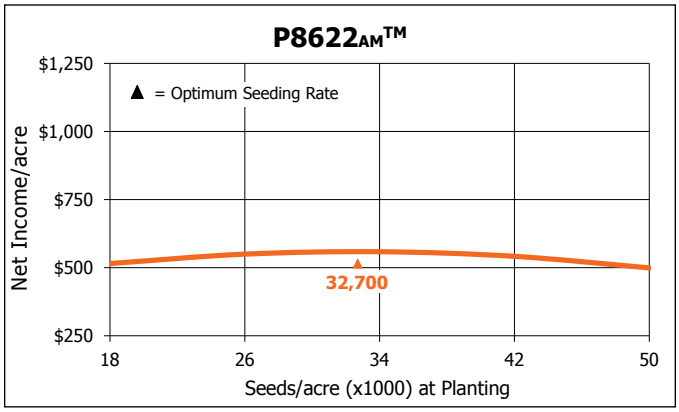


Figure 6. P8622AM™ (86 CRM, AM, LL, RR2) seeding rate response.

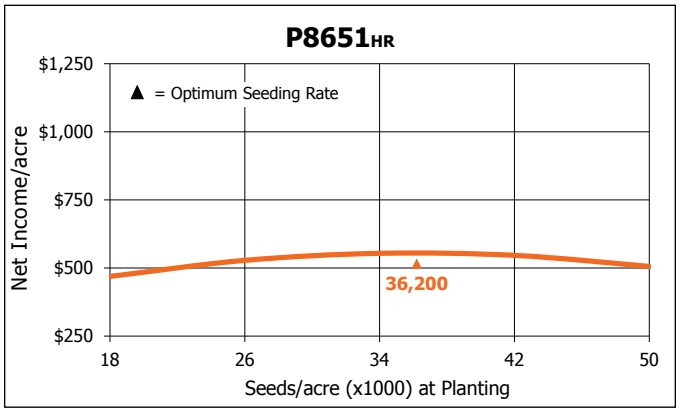


Figure 7. P8651HR (86 CRM, HX1, LL, RR2) seeding rate response.

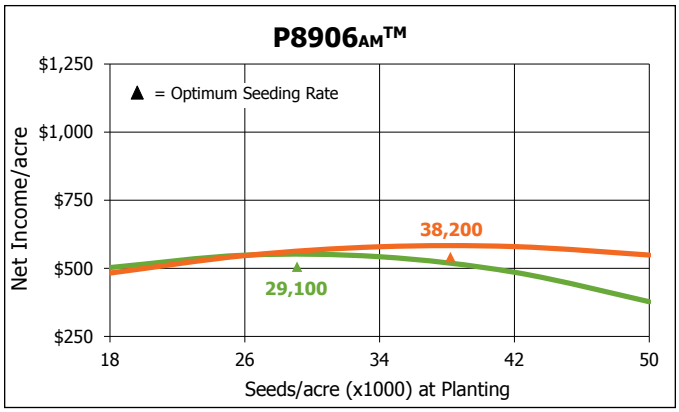


Figure 8. P8906AM™ (89 CRM, AM, LL, RR2) seeding rate response.

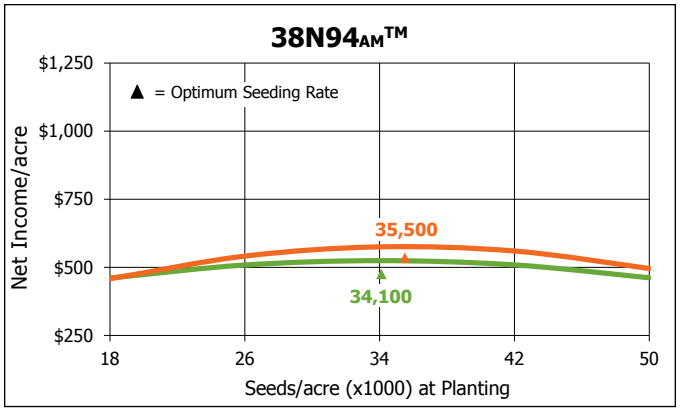


Figure 9. 38N94AM™ (92 CRM, AM, LL, RR2) seeding rate response.

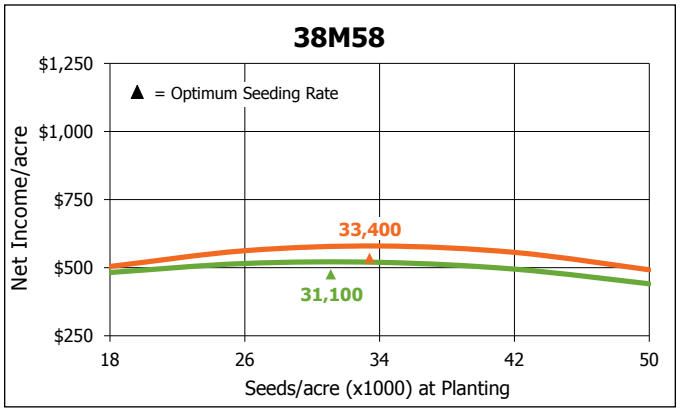


Figure 10. 38M58 (94 CRM, HX1, LL, RR2) seeding rate response.

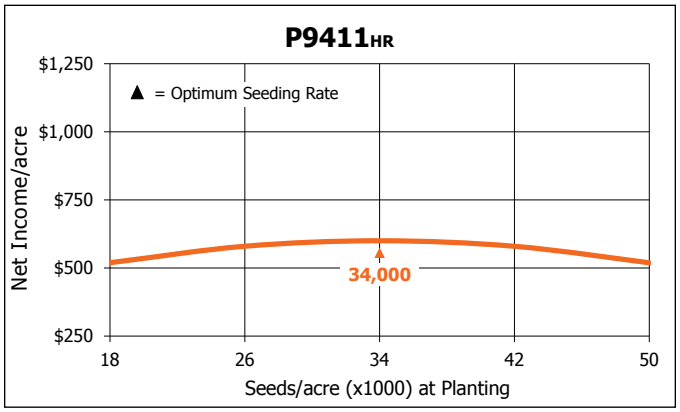


Figure 11. P9411HR (94 CRM, HX1, LL, RR2) seeding rate response.

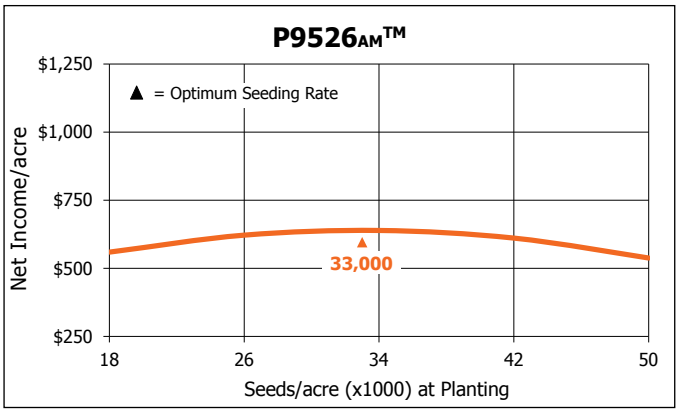


Figure 12. P9526AM™ (95 CRM, AM, LL, RR2) seeding rate response.

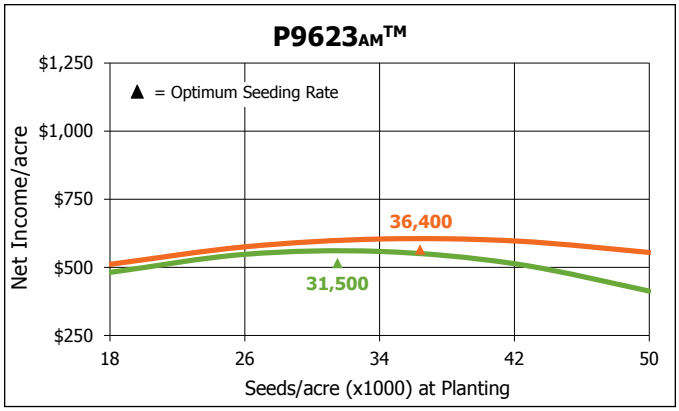


Figure 13. P9623AM™ (96 CRM, AM, LL, RR2) seeding rate response.

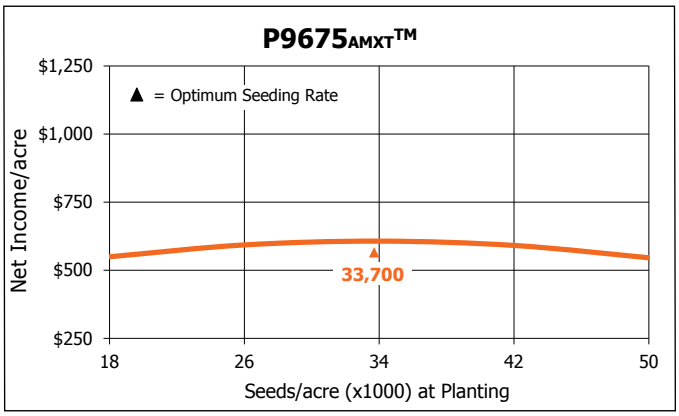


Figure 14. P9675AMXT™ (96 CRM, AMXT, LL, RR2) seeding rate response.

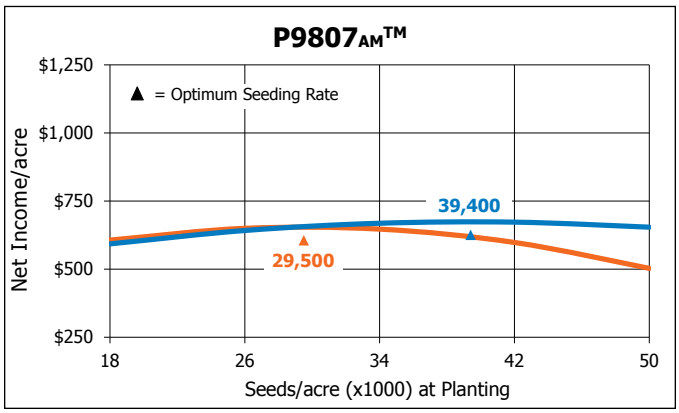


Figure 15. P9807AM™ (98 CRM, AM, LL, RR2) seeding rate response.

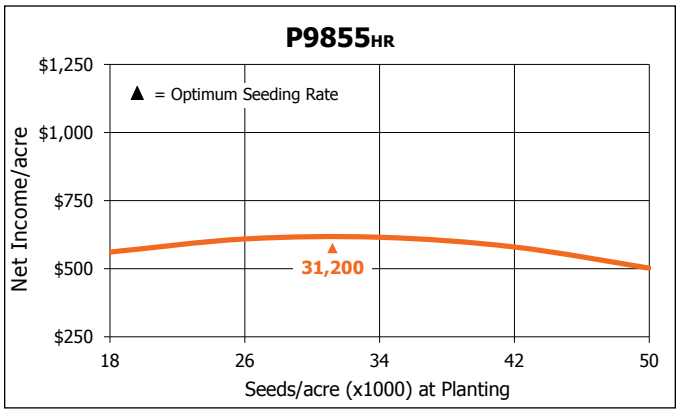


Figure 16. P9855HR (98 CRM, HX1, LL, RR2) seeding rate response.

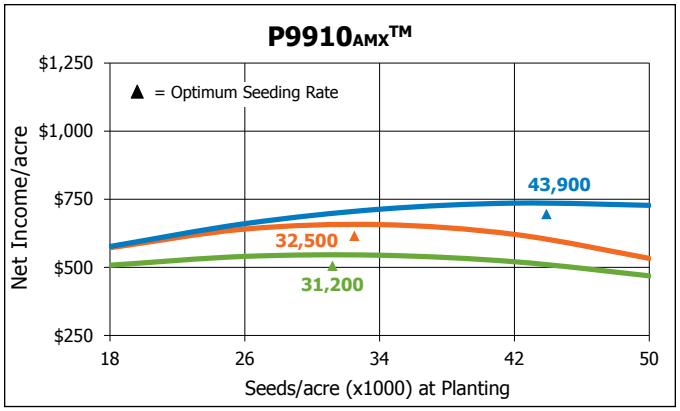


Figure 17. P9910AMX™ (99 CRM, AMX, LL, RR2) seeding rate response.

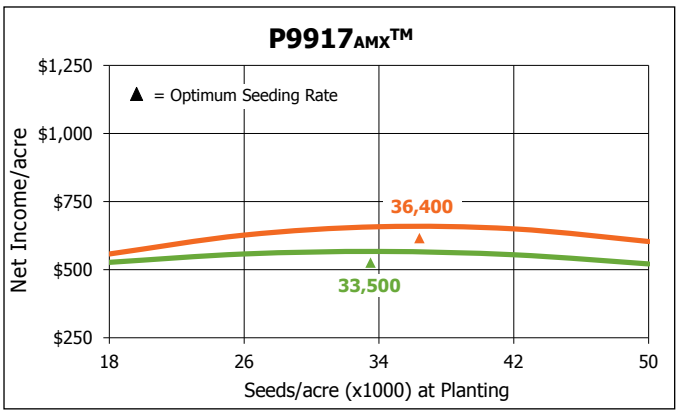


Figure 18. P9917AMX™ (99 CRM, AMX, LL, RR2) seeding rate response.

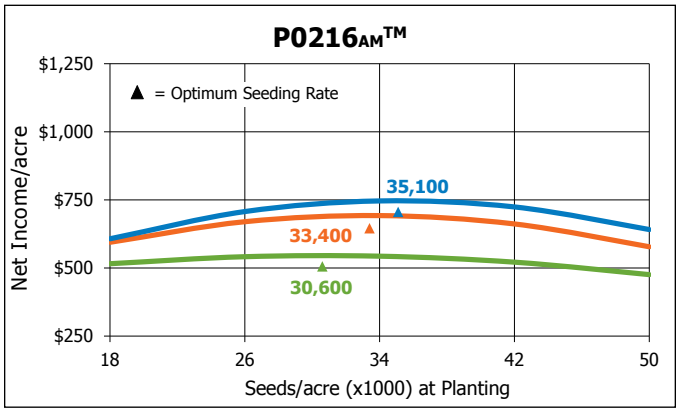


Figure 19. P0216AM™ (102 CRM, AM, LL, RR2) seeding rate response.

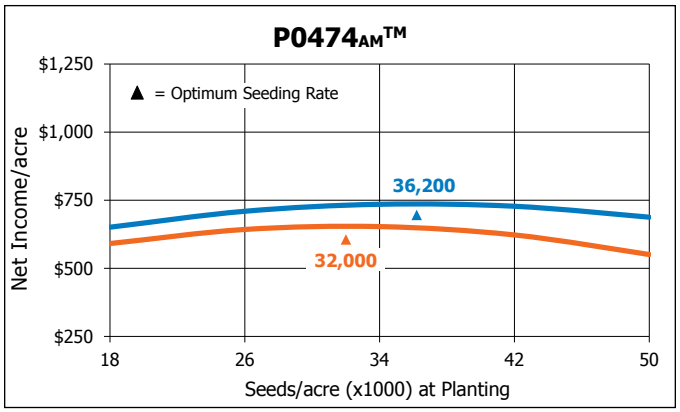


Figure 20. P0474AM™ (104 CRM, AM, LL, RR2) seeding rate response.

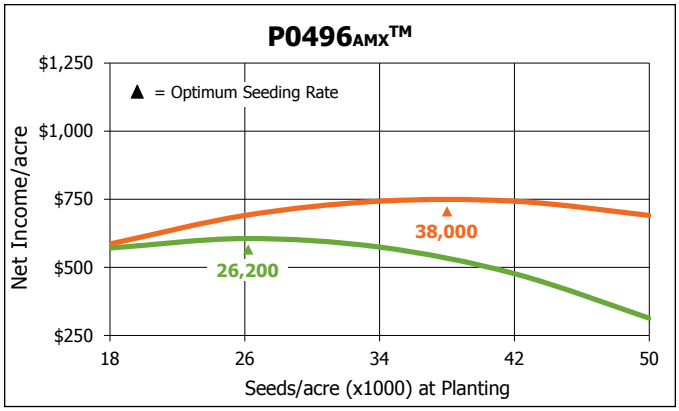


Figure 21. P0496AMX™ (104 CRM, AMX, LL, RR2) seeding rate response.

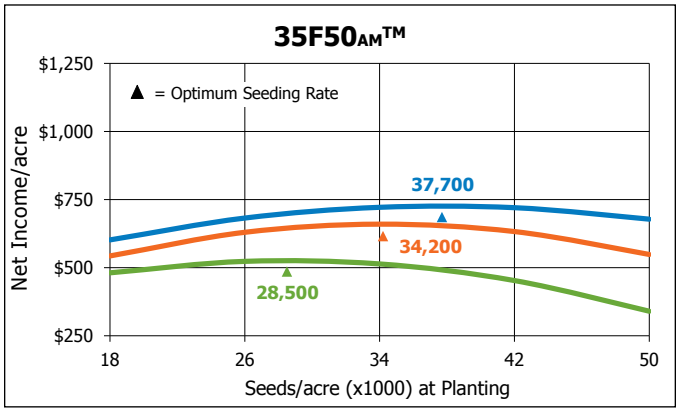


Figure 22. 35F50AM™ (105 CRM, AM, LL, RR2) seeding rate response.

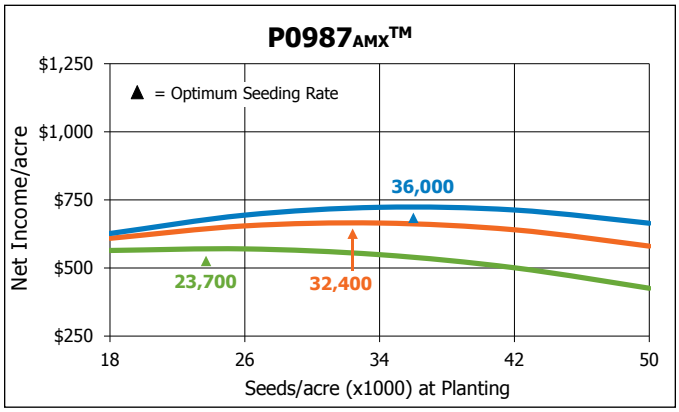


Figure 23. P0987AMX™ (109 CRM, AMX, LL, RR2) seeding rate response.

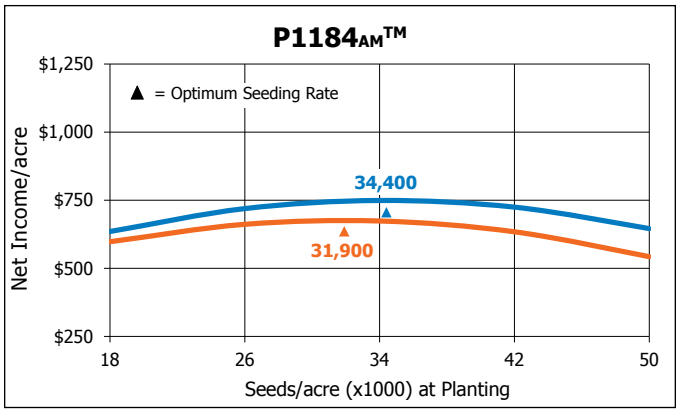


Figure 24. P1184AM™ (111 CRM, AM, LL, RR2) seeding rate response.

Notes

AGRONOMY SCIENCES

RESEARCH UPDATE

Growing Corn Under Film

2013

Objectives

- Evaluate the agronomic and economic effect of the Samco System on grain corn production in in the <2500 CHU zone.
- The Samco System utilizes a specialized planter which plants, applies pre-emerge herbicide and lays down a transparent and degradable film in one pass.
- The system was designed to create a greenhouse effect within the soil zone from planting through mid-vegetative stages, reducing time to emergence, tassel and maturity.

Study Description

Plot Layout: 4 rows, 500+ ft long

Locations: 6 corn grain trials in southern Ontario
14 grain and silage trials in Quebec

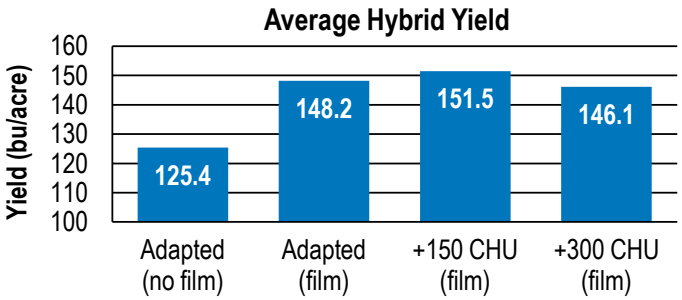
Entries: Adapted hybrid, no film
Adapted hybrid with film
+150 CHU hybrid with film
+300 CHU hybrid with film

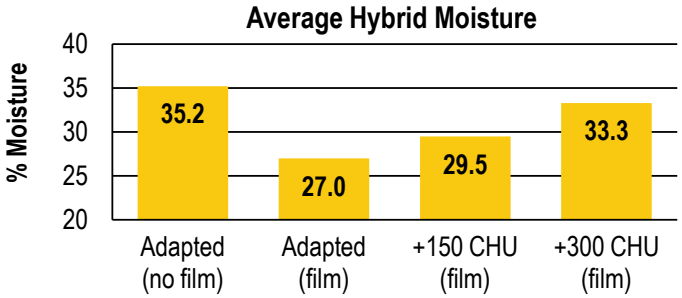
- Grain sites utilized an adapted hybrid as well as hybrids with maturity ratings approximately 150 CHU and 300 CHU greater than the adapted hybrid to evaluate whether an economic yield gain could be realized with fuller season hybrids in the <2500 CHU zone.
- Results reported here are averages of three southern Ontario locations with yield data available at time of publication.

Trial location near Dundalk, Ontario (June 7, 2013).

Preliminary Results

- Use of the Samco system reduced the time to emergence and tasseling with adapted hybrids relative to the same hybrids grown without film.
  - Average 5.7 days faster to reach VE (emergence).
  - Average 12 days faster to reach VT (tassel).
- Average corn yield was substantially greater and moisture at harvest reduced with adapted hybrids grown under film.
- Fuller season hybrids grown under film had greater average yields and similar or lower moisture at harvest compared to adapted hybrids grown without film.





Discussion

- Results of this study show that Samco system may allow growers to plant fuller season hybrids and obtain similar moisture at harvest with higher genetic potential hybrids.
- Yield of corn grown under film was likely limited in this study due to variable emergence. Better results may be produced with newer models of planters and experienced operators.
- Utilization of this system would be best positioned to:
  - Fill early market corn contracts
  - Grow corn (especially high value silage) in areas with frost risk and short growing seasons

2013 data are based on average of all comparisons made in 20 locations through November 21, 2013. Multi-year and multi-location is a better predictor of future performance. Do not use these or any other data from a limited number of trials as a significant factor in product selection. Product responses are variable and subject to a variety of environmental, disease, and pest pressures. Individual results may vary. All products are trademarks of their manufacturers.

RESEARCH UPDATE

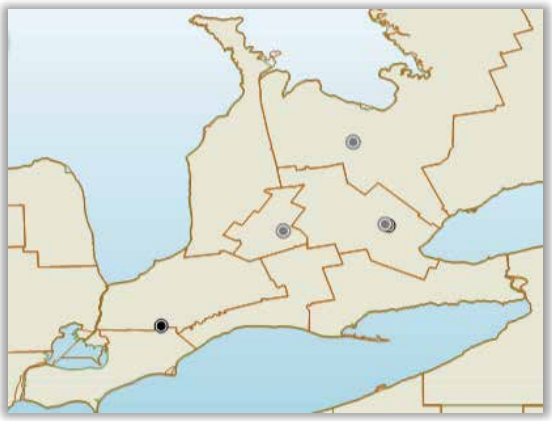
Pioneer® Field360™ Studio Software Agronomy Trials 2013

Objectives

- Demonstrate the capabilities of Pioneer® Field360™ Studio software mapping and data analysis tools using on-farm agronomy trials.
- Contribute to product positioning with the resulting hybrid population and performance data generated.

Study Description

- Growers with as-planted and as-harvested mapping capabilities collaborated with DuPont Pioneer for this project.
- Strip trials were planted using a split-planter design with two hybrids planted in each pass.
- The first pass was planted at a standard seeding rate for that operation. The second pass was planted at 5,000 seeds/acre above the standard rate.
- As-planted and as-harvested maps were submitted to Pioneer Field360 Studio software for upload and analysis.



Four trials were planted across SW Ontario.

PIONEER® FIELD360™

Summary

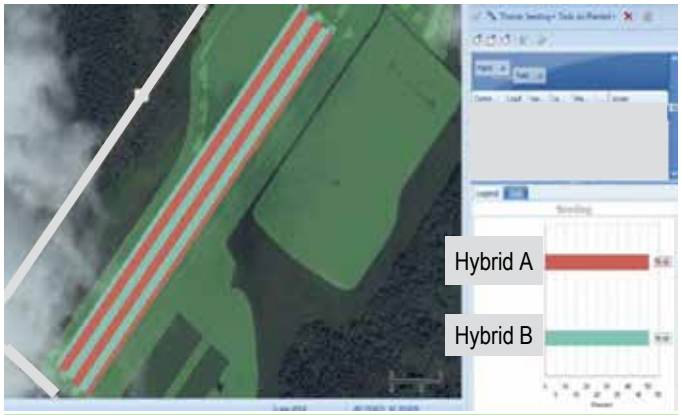


Figure 1. Pioneer® Field360™ Studio software hybrid as-planted map.

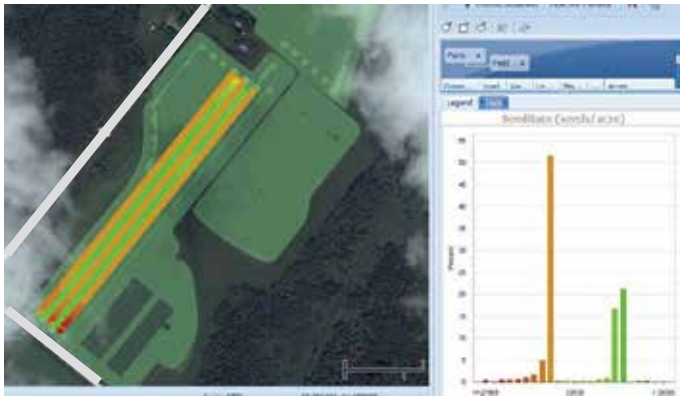


Figure 2. Pioneer® Field360™ Studio software seeding rate map.

- Pioneer Field360 Studio software maps confirm that the planned hybrids were planted using the split-planter design (Figure 1) and that the desired seeding rates were met (Figure 2).
- Yield maps can be overlaid onto these as-planted maps to make management decisions, such as variety selection and hybrid-specific seeding rate recommendations (yield data from 2013 trials were not available at the time of publication).
- Other crop factors, such as soil type, elevation, crop moisture, soil fertility and historical yield results can also be used to make more integrated management decisions and provide a basis for variable rate seeding and fertilizer prescriptions.

Corn Stalk Quality

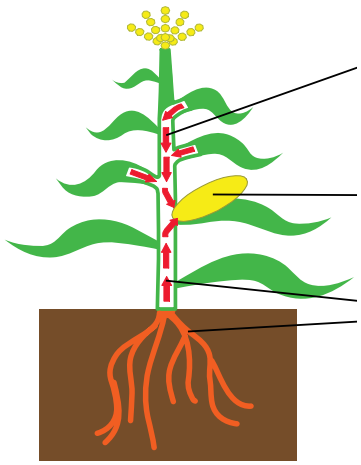
Many different stresses to corn plants can lower stalk quality, with the result that stalk problems occur in some fields each year throughout North America. Drought stress, reduced sunlight, insect and disease pressure, and hail damage are stresses that can result in poor stalk quality. Even good growing conditions can lead to stalk problems when followed by a less favorable environment. Cropping history, soil fertility, hybrid genetics and micro-environment effects can heighten the problem in certain fields. Growers should monitor their fields as harvest approaches to identify stalk quality problems, and if necessary, prepare to harvest before field losses occur.

Photosynthesis and Carbohydrate Translocation

Through photosynthesis, leaves of corn plant capture sunlight and carbon dioxide (CO_2) to produce sugars (photosynthates), which are directed to the actively growing organs of the plant. Early in plant development, sugars move to the roots, where they are converted to structural carbohydrates and proteins. As plants continue to grow, sugars are directed to the stalk for temporary storage.

Following pollination, kernel development places a great demand on the plant for carbohydrates. When the demands of the developing kernels exceed the supply produced by the leaves, stalk and root storage reserves are tapped.

Environmental stresses, such as drought and low available sunlight, decrease photosynthate production and force plants to extract even more stalk carbohydrates, which preserves grain fill rates at the expense of the stalk. Disease lesions, insect feeding and hail damage also limit photosynthate production by reducing the functional leaf area of the plant.



As carbohydrates stored in the roots and stalk are mobilized to the ear, these structures begin to decline and soon lose their resistance to soil-borne pathogens. High temperatures increase the rate at which the fungi invade and colonize the plant. Though pathogens play a key role in stalk rot development, it is primarily the inability of the plant to provide sufficient photosynthates to the developing ear that initiates the process.

Stalk Rots Often Begin as Root Rots

Root rot beginning in the basal stalk region.

Stalk-rotting fungi inhabit the soil in the root zone of corn plants, surviving on discarded cells and nutrients excreted by the roots. They are prevented from invading the roots and stalk by metabolites produced in the plant. Though unable to overcome healthy living tissue, these opportunistic fungi rapidly invade weakened and dying roots as the plant redirects carbohydrates from the roots to kernels. After the roots are colonized, the infection spreads to the stalk (Dodd, 1983).

As vascular tissues in the plant become plugged by fungal mycelial growth, water supply to the plant becomes restricted. Wilting and premature death of the plant eventually follows. External discoloration of the lower stalk becomes evident as deterioration of the inner stalk tissue progresses. The structural integrity of the stalk is diminished by this decay, and the plant is susceptible to lodging. Storms and high winds provide the forces needed to topple the weakened stalks.

The Growing Environment

Almost any stress applied to the plant will reduce photosynthesis and resultant sugar production in the leaves.

Drought Stress - The decrease in photosynthetic rates due to drought stress has been well documented in research studies. Water relations within the plant and CO_2 and O_2 exchange are directly affected. In addition, if leaf rolling occurs during drought, the effective leaf surface for collection of sunlight is reduced.

In research studies that withheld water from plants beginning at the mid-grain-fill stage, photosynthesis was eventually shut down (Westgate and Boyer, 1985). Subsequent grain development depended entirely on stalk carbohydrate reserves.

Reduced Sunlight - Photosynthesis is most efficient in full sunlight. Studies show that the rate of photosynthesis increases directly with intensity of sunlight. In fact, photosynthesis rates are reduced more than 50% on an overcast day compared to a day with bright sunshine (Moss et. al., 1960). Prolonged cloudy conditions during ear fill often result in severely depleted stalk reserves.

Reduction of Leaf Area - Any reduction in leaf area will limit total photosynthesis. Leaf area may be reduced due to hail, frost, disease lesions, insect feeding or mechanical injury. Whenever functional leaf area is reduced prior to completion of ear fill, stalks will be weakened.

Early Favorable Conditions Followed by Stress - If favorable conditions exist when the number of kernels per ear is being established (V10 to V17), the eventual demand for photosynthates will be large. Each potential kernel represents an additional requirement for translocatable sugars from the plant. If stress conditions develop during ear fill that render the plant unable to produce enough sugars, stalks will suffer.

Research has demonstrated that the number of kernels per ear on stalk-rotted plants is often greater than that of adjacent healthy plants (Table 1). The additional demand for carbohydrates by larger ears often results in greater depletion of the stalk, leading to eventual stalk rot.

Table 1. Comparison of kernel numbers between plants with rotted stalks and adjacent plants with healthy stalks.*

Year	No. of Hybrids Tested	No. of Plant Pairs	Rotted Stalks	Adjacent Healthy Stalks	Diff.
			No. of Kernels / Plant		
Year 1	40	112	562	495	67**
Year 2	30	65	648	587	61**

* From Dodd, 1980. ** Significant at the .001 prob. level.

Soil Fertility

Research studies have documented that soil fertility has a profound effect on stalk quality. Most notable are studies which show that a combination of high nitrogen and low potassium can severely reduce stalk quality. Researchers suggest that yearly applications of N and K (actual N, K as K_2O) should be approximately at the ratio of 1 to 1 for favorable balance in the corn plant and to reduce the risk of stalk rots and stalk breakage.

High nitrogen (N) is associated with greater kernel number, which increases the demand for carbohydrates to the ear. Higher N also aids the movement of these carbohydrates out of the stalk and into the ear by increasing the rate of translocation within the plant.

The role of potassium (K) in preventing premature plant death has long been established. Potassium functions in the building of leaf and stalk tissue, as well as regulating water movement within the plant. Increases in K have been associated with increased photosynthetic rate.

Hybrid Differences / Foliar Fungicide Applications

Carbohydrate Partitioning - Some hybrids naturally partition more carbohydrates to the stalk. Though useful in a poor stalk quality year, that trait may limit yield potential in a more normal environment. As hybrids are developed, researchers must be careful to select those with highest harvestable yield potential across many years and environments. Too much emphasis on stalk quality alone could result in lower yield potential most years. Many carefully selected hybrids with very good stalk quality may appear inadequate during a one-year-in-ten stalk-lodging event.

Leaf Disease Resistance - Hybrids prone to leaf diseases may lose significant leaf area, weakening the stalks. For this reason, foliar fungicide applications may reduce stalk lodging in years with high levels of fungal leaf diseases. DuPont Pioneer rates its hybrids for resistance to major leaf diseases to aid customers in their decisions about fungicide applications.

Stalk Rot Resistance - Susceptibility to specific stalk rot pathogens also increases the stalk-lodging risk. Pioneer provides hybrid ratings for resistance to major stalk rots.

Other Effects

Micro-Environments - Oftentimes, even small differences between fields or between areas in the same field can determine whether corn stands or lodges. Differences in soil fertility, soil moisture, plant-to-plant spacing, insect feeding or wind gusts can push plants past the lodging threshold. These effects are difficult to predict; however, scouting in the fall can identify problem fields, and early harvest can reduce field losses.

Plant Population - Multi-year research studies show that stalk lodging is increased only slightly at higher plant populations. For example, a summary of DuPont Pioneer research from 35 high-lodging environments from 2004 to 2007 showed that percent stalk lodging increased only about 1% for each 2,000 plant/acre population increase.

Reducing Harvest Losses Due to Stalk Lodging

Careful scouting and harvesting fields according to crop condition can help prevent field losses due to low stalk quality. Corn loss potential should be weighed just as heavily as grain moisture in deciding which fields to harvest first. Scouting fields approximately two to three weeks prior to the expected harvest date can identify fields with weak stalks predisposed to lodging. Fields with high lodging potential should be slated for early harvest.

Collapsed corn stalk.

Weak stalks can be detected by pinching the stalk at the first or second elongated internode above the ground. If the stalk collapses, advanced stages of stalk rot are indicated. Another technique is to push the plant sideways 15 to 20 inches at ear level. If the stalk crimps near the base or fails to return to the vertical position, stalk rot is indicated. Check 20 plants in five areas of the field. If more than 10 to 15% of the stalks are rotted, that field should be considered for early harvest.

DuPont Pioneer Research Emphasizes Stalk Quality

DuPont Pioneer corn breeders and plant pathologists use aggressive techniques to weed out hybrids with poor stalk quality, including manual and mechanical push tests that mimic the forces of wind on corn plants. In addition, plants are inoculated with stalk rot organisms where appropriate to help ensure that susceptible genotypes do not escape detection. Plant pathologists monitor disease incidence and assist breeders in their efforts to inoculate, screen and characterize products. Research trials conducted by corn breeders are designed to measure product performance for all important traits across a wide range of growing conditions.

Pioneer IMPACT™ plots further test product performance, including characterization of stalk quality, thus determining proper placement of new product releases. Pioneer uses information from both breeder and IMPACT plots to develop stalk lodging ratings for all its hybrids to aid customers in selecting appropriate hybrids for their fields.

Common Nitrogen Fertilizers and Stabilizers for Corn Production

Nitrogen (N) fertilizer is a critical input in corn production, but it is subject to loss under wet field conditions. Losses may be moderate or severe, depending on the form of N fertilizer applied and the type of weather conditions that follow. Nitrogen stabilizers (also called "additives") are available to help reduce N losses from the soil. These products must be used with compatible N formulations to be effective. The most common forms of N fertilizer are shown in Table 1.

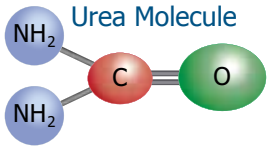
Table 1. Nitrogen fertilizers most commonly used for field crop production in North America.[1]

Fertilizer	Form	% N
Anhydrous ammonia	Gas, applied as liquid from pressurized tank	82%
Urea	Solid	46%
Urea-ammonium nitrate solutions	Liquid	28% - 32%

[1] These forms account for over 80% of N applied for corn production.

Anhydrous ammonia, NH_3, is the most basic form of N fertilizer. Ammonia, a gas at atmospheric pressure, must be compressed into a liquid for transport, storage and application. Consequently, it is applied from a pressurized tank and must be injected into the soil to prevent its escape into the air. When applied, ammonia reacts with soil water and changes to the ammonium form, NH_4^+. Most other common N fertilizers are derivatives of ammonia transformed by additional processing, which increases their cost. Due to its lower production costs, high N content that minimizes transportation costs, and relative stability in soils, anhydrous ammonia is the most widely used source of N fertilizer for corn production in N. America.

Unfortunately in Canada escalating insurance costs over safety issues has drastically reduced retail outlet availability. Anhydrous still remains the most efficient form of N fertilization as its soil conversion to the Nitrate molecule occurs over a prolonged period reducing early season N losses from volatilization or denitrification. The need for deep banding Anhydrous also provides the positional advantage of N placement well below the carbon zone in a corn after corn or wheat crop rotation.



Urea is a solid fertilizer with relatively high N content (46%) that can be easily applied to many types of crops and turf. Its ease of handling, storage and transport; convenience of application by many types of equipment; and ability to blend with other solid fertilizers has made it the most widely used source of N fertilizer in the world.

Urea-ammonium nitrate (UAN) solutions are also popular nitrogen fertilizers. These solutions are made by dissolving urea and ammonium nitrate (NH_4NO_3) in water to create 28%, 30% or 32% N-containing solutions.

Other N-fertilizer choices include ammonium sulfate, calcium nitrate, ammonium nitrate and diammonium phosphate.

Nitrogen Fertilizers and Soil Reactions

Anhydrous ammonia is applied by injection six to eight inches below the soil surface to minimize escape of gaseous NH_3 into the air. NH_3 is a very hygroscopic compound and once in the soil, reacts quickly with water and changes to the ammonium (NH_4^+) form. As a positively charged ion, it reacts and binds with negatively charged soil constituents, including clay and organic matter. Thus, it is held on the soil exchange complex and is not subject to movement with water.

Soil Reactions - Over time, with soil temperatures that support biological activity, NH_4^+ ions are converted to the nitrate (NO_3^-) form by soil bacteria in the process of **nitrification**. Nitrification generally occurs at soil temperatures above 50° F and increases at higher temperatures. However, some limited activity occurs below 50° F as well. Ammonium is converted first to nitrite (NO_2^-) by the action of *Nitrosomonas* bacteria and then to nitrate by *Nitrobacter* and *Nitrosolobus* bacteria.

Only after the nitrification process has converted ammonium to negatively charged ions repelled by clay and organic matter in the soil complex, can ammonium N be lost from most soils by leaching or denitrification. Plants can take up N in both the ammonium and nitrate forms. Thus, if N can be held as ammonium until uptake by plants, it is at little risk of loss (except on sandy soils that cannot bind much ammonium.)

Urea readily dissolves in water, including soil water. Thus, it can be "incorporated" into the soil by sufficient rainfall or irrigation (½ inch is typically suggested). Otherwise, it should be incorporated by tillage to reduce losses.

Soil Reactions - Urea applied to the soil and not incorporated by water or tillage is subject to volatilization losses of N as urea undergoes hydrolysis to carbon dioxide and ammonia:

$$(NH_2)_2CO + H_2O \longrightarrow CO_2 + 2(NH_3)$$

Urea hydrolysis is catalyzed by urease, an enzyme produced by many bacteria and some plants, and thus, is ubiquitous in soils. The biological degradation of urea by urease that releases the N for plant use also makes it subject to volatilization (as NH_3, a gas) depending on whether the reaction occurs in the soil or on the soil surface. If within the soil, the ammonia quickly reacts with soil water to form NH_4^+, which is then bound to the soil. If it occurs at the soil surface, the gaseous ammonia can easily be lost into the air. If plant residue is abundant on the soil surface, it increases bacterial populations, concentration of urease, and volatilization losses of urea.

UAN solutions are mixtures of urea, ammonium nitrate and water in various proportions. All common UAN solutions (28%, 30% and 32%) are formulated to contain 50% of actual N as amide (from urea), 25% as ammonium (from ammonium nitrate) and 25% as nitrate (from ammonium nitrate).

Soil Reactions - The urea portion of UAN solutions reacts just as dry urea does (see previous section on urea). If applied on the surface, the amide-N in the solution may incur losses due to volatilization, but if UAN is incorporated by tillage or sufficient water, the NH_3 quickly reacts with soil water to form NH_4^+. This NH_4^+, as well as the NH_4^+ derived from ammonium nitrate in the solution, adheres to soil components at the application site and is not subject to immediate losses. Like N applied as anhydrous

ammonia, this N will either be taken up by plants in the NH_4^+ form or converted to NO_3^- by soil bacteria.

The remaining 25% of N in UAN solutions is in the nitrate (NO_3^-) form. Because it is negatively charged, it will not adhere to clay and organic matter particles (which are also negatively charged) but rather, will exist as an anion in the soil solution. Because it moves with water, it is easily taken up by plant roots but is also subject to losses by leaching and denitrification. Leaching is defined as moving below the root zone of plants; denitrification is loss of nitrate to the air as N_2 gas under anaerobic conditions (flooded or saturated soils).

Nitrogen Stabilizers / Additives

Nitrification inhibitors are compounds that slow the conversion of ammonium to nitrate, thus prolonging the period of time that nitrogen is in the "protected" form and reducing its loss from the soil. Several compounds have proven effective for this purpose, but only nitrapyrin and DCD (dicyandiamide) have current widespread use in North American agriculture.

Nitrapyrin, 2-chloro-6-(trichloromethyl) pyridine, works by inhibiting *Nitrosomonas* bacteria. Nitrapyrin has a bactericidal effect, actually killing part of the *Nitrosomonas* population in the soil. Thus, it is effective until the bacterial population recovers in the zone of application and diffusion. Its activity is very specific to *Nitrosomonas.* Nitrapyrin products for delaying nitrification of ammoniacal and urea fertilizers include N-Serve® 24 (launched in 1976) and Instinct® (launched in 2009).

DCD (dicyandiamide) - Products containing only DCD are generally used with N solutions and liquid manure. In the U.S., products that contain DCD include Guardian®-DF, Guardian®-DL 31-0-0, Guardian®-LP 15-0-0 and Agrotain® Plus.

When to Consider Nitrification Inhibitors - The highest value of nitrification inhibitors should be realized when NO_3^- losses are expected to be high from leaching or denitrification, including these conditions: tile-drained soils when leaching potential is high, wet or poorly drained soils, and fields with preplant N application. On the other hand, nitrification inhibitors are usually least valuable when NO_3^- losses are unlikely, for example, when N is applied sidedress, as crop demand is high at this time (Ruark, 2012).

Urease inhibitors are compounds that inhibit the action of the urease enzyme on urea and thus, delay urea hydrolysis. This allows some time for urea to be incorporated into the soil (e.g., by rainfall) where volatilization losses are unlikely when hydrolysis occurs. Only one product has been widely used in agriculture as a urease inhibitor. That product, N-butyl-thiophosphoric triamide or NBPT, is a structural analog of urea and as such, inhibits urease by blocking the active site of the enzyme. NBPT is the active ingredient in the Agrotain family of urease-inhibiting products.

Agrotain®, with the active ingredient NBPT, is an additive for use primarily with urea (applied to urea by the retailer) and secondarily with urea-ammonium nitrate solutions. **Agrotain® Ultra** is a more concentrated formulation of Agrotain. (Most Ontario outlets are handling Agrotain Plus)

Eventually, these products degrade, allowing urea hydrolysis to naturally occur. Once in the NH_4^+ form, N from urea is subject to denitrification to NO_3^-, a form that may be lost from the soil. Agrotain and Agrotain Ultra provide no activity against nitrifying bacteria.

Agrotain® Plus is an additive specifically for UAN solutions, according to the product label. Agrotain Plus contains both the urease inhibitor NBPT and the nitrification inhibitor DCD. Thus, it acts against both the volatilization and nitrification processes that lead to N losses from UAN solutions. However, it does not protect the portion of the solution originally in the nitrate form (i.e., the 25% of the N content of the solution derived from nitrate in ammonium nitrate).

When to Consider Urease Inhibitors - Urease inhibitors may be considered when the incorporation of broadcast urea-containing fertilizers cannot be accomplished within 2-3 days of application or a quarter inch of rainfall is not anticipated. Research shows that N loss from surface-applied urea can be significant; loss is greatest with warm, windy weather and a moist soil surface. Urease activity increases as temperature increases; thus, hydrolysis is normally completed within 10 days at a temperature of 40° F and within 2 days at a temperature of 85° F. Hydrolysis is also highly correlated with the organic matter, total N and cation exchange capacity (CEC) of the soil and increases as any of these factors increase. Urease inhibitors help prevent volatilization, potentially for two weeks or more, thus increasing the chances that rainfall will incorporate urea before losses occur.

Performance of N Stabilizers

N stabilizers/additives have been widely tested over many years. Research results vary widely, from no advantage to yield increases of more than 20%. This is not surprising; when conditions favor N losses for a period and an N stabilizer has been applied (and is not yet degraded), a large benefit is predictable. On the other hand, in conditions not conducive to N losses, little advantage would be expected. Therefore, N stabilizers can be considered as "insurance" to help protect against N losses should conditions develop that favor losses.

Regional performance differences for N stabilizers are expected, as soil and climate factors vary greatly across regions of North America. Soils differ by texture, drainage, organic matter, pH, slope and other variables. Climate differs by temperature extremes and durations, rainfall amounts and patterns and other variables. Because of these geographical differences, making decisions about the value of N stabilizers in each farming operation is complex. In order to make the best decisions, research results that represent your field and climate should be examined, and local prices for N fertilizers and stabilizers should be used.

This decision should take into account all factors that influence the risk of N loss for a particular field. These include geographic location; topography; soil type; residue level; form of N fertilizer applied; timing of application relative to crop growth; expected rainfall, temperature and soil moisture levels; and other factors. Even so, N stabilizers will not be cost effective every year, especially when conditions are not conducive for N losses. However, N stabilizers can provide some insurance against the risk of N losses in many susceptible fields. What may be of greater importance is your awareness that far more substantial N losses can be associated with liquid or dry preplant Urea N sources and that sidedressing offers far less risk of N losses in either a very dry or very wet year.

RESEARCH UPDATE

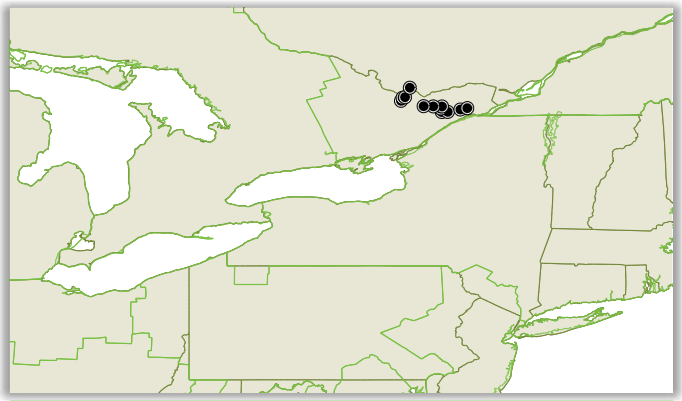
Corn Yield Response to Seed-Applied Micronutrients 2013

Rationale and Objective

- Previous research in the United States has shown evidence of a potential corn yield benefit from seed-applied micronutrients.
- On-farm trials were conducted in eastern Ontario and western Quebec to determine yield response of corn treated with Awaken® ST seed-applied micronutrients compared to untreated corn.

Study Description

Plot Layout:	Field-length strips
Replicates:	1-2 per location
Locations:	14 locations in eastern Ontario and western Quebec in 2013
Treatment:	Awaken ST, Untreated
Rate:	390 ml/100 kg of seed
Pioneer® Hybrid:	P9675YXR (YGCB, HXX, LL, RR2)



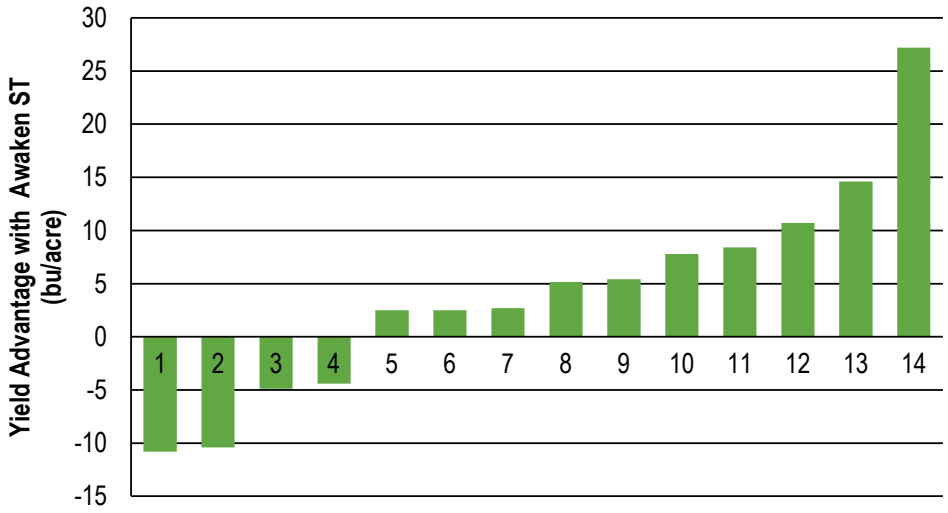
Location of the 14 seed-applied micronutrient trials conducted in eastern Ontario and western Quebec in 2013.

Awaken® ST

- Awaken ST is a nutritional seed treatment containing 6% nitrogen, 1% soluble potash, 5.05% zinc, 0.25% copper, 0.25% manganese, 0.25% iron and 0.03% boron.

Results

- Corn yield was significantly increased (α = 0.1) by an average of 4.1 bu/acre when treated with Awaken ST seed treatment compared to corn without seed-applied micronutrients.
- A positive yield response was observed in 71% of the trials.
- Awaken ST seed treatment did not significantly affect grain moisture or test weight (data not shown).

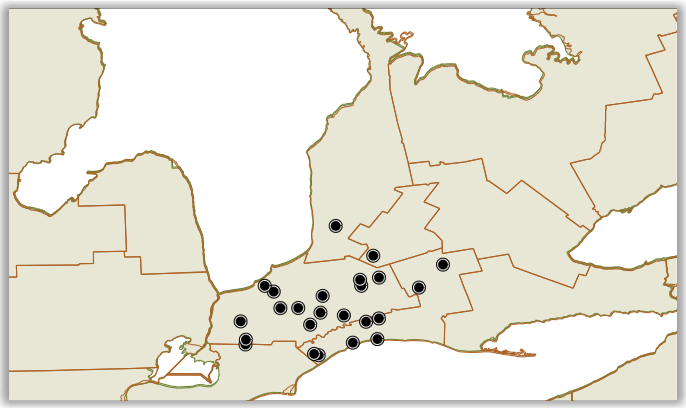


RESEARCH UPDATE

Proline® Foliar Fungicide Effect on Corn Yield and Deoxynivalenol (DON) 2013

Background

- Gibberella ear rot, caused by the fungus *Fusarium graminearum*, is the most important corn disease associated with mycotoxin contamination in the Great Lakes region of North America.
- *F. graminearum* infection and deoxynivalenol (DON) accumulation in grains are frequently reported in southwestern Ontario.
- Previous research has shown that the use of triazole fungicides including prothioconazole, or Proline® foliar fungicide, can reduce DON contamination levels in grain corn.
  - Small plots trials conducted in 2010 and 2011 found a 67% toxin reduction associated with fungicide applied at full silking, relative to the untreated control.



Locations of 24 field-scale Proline foliar fungicide corn grain trials conducted in southern Ontario in 2013.

Objective

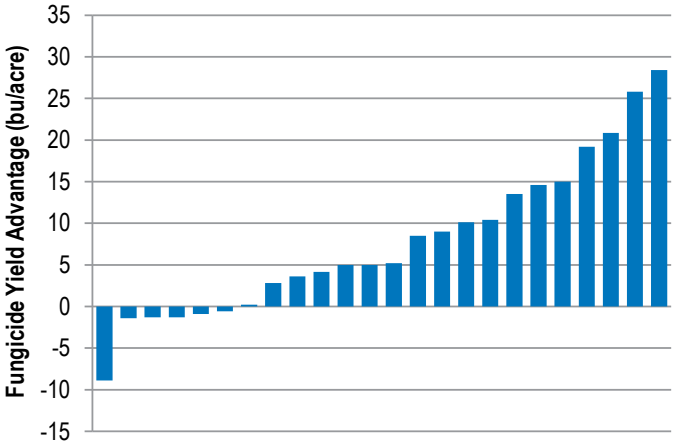
- The objective of this trial was to determine the effect on corn yield and DON levels of Proline foliar fungicide applied at full silk under field-scale conditions.

Study Description

Locations: 24 locations across southern Ontario
Pioneer® Hybrid: P0094$_{YHR}$ (YGCB, HX1, LL, RR2)
Treatments: Proline foliar fungicide at full silk, Untreated
Application Method: 19 with ground application, 5 with aerial application (helicopter or plane)

Results

- Average yield advantage of corn treated with Proline at full silk compared to the same hybrid without fungicide was 9 bu/acre. There was a positive yield response at 71% of the locations.
- Average DON levels in 2013 were low, only 14% of the trials had grain with a DON over 1 ppm in the untreated sample.
- We found that overall the corn treated with Proline had 27.7% less DON ppm, than the same hybrid without the fungicide treatment. Those fields with DON levels of 1ppm or greater in the untreated check had DON reductions of 50.1%.
- Whether fungicide is applied by ground or air, timing and targeting are critical. The application must occur between full tassel and before the silks begin to turn brown. The fungicide must hit and cover the silks to effectively reduce DON.
- We suspect that most of the yield advantage observed in this study resulted from leaf disease control.



YGCB, HX1, LL, RR2 - Optimum® Intrasect® contains the Herculex® I gene and the YieldGard® Corn Borer gene for resistance to corn borer. **YGCB** – The YieldGard® Corn Borer gene offers a high level of resistance to European corn borer, southwestern corn borer and southern cornstalk borer; moderate resistance to corn earworm and common stalk borer; and above average resistance to fall armyworm. **HX1** - Contains the Herculex® I Insect Protection gene which provides protection against European corn borer, southwestern corn borer, black cutworm, fall armyworm, western bean cutworm, lesser corn stalk borer, southern corn stalk borer, and sugarcane borer; and suppresses corn earworm. **LL** - Contains the LibertyLink® gene for resistance to Liberty® herbicide. **RR2** - Contains the Roundup Ready® Corn 2 gene that provides crop safety for over-the-top applications of labeled glyphosate herbicides when applied according to label directions. YieldGard®, the YieldGard Corn Borer design and Roundup Ready® are registered trademarks used under license from Monsanto Company. Herculex® I Insect Protection technology by Dow AgroSciences and Pioneer Hi-Bred. Herculex® and the HX logo are registered trademarks of Dow AgroSciences LLC. Liberty®, LibertyLink®, the Water Droplet Design, and Proline® are trademarks of Bayer. PIONEER® brand products are provided subject to the terms and conditions of purchase which are part of the labeling and purchase documents. 2013 data are based on average of all comparisons made in 21 locations through November 22, 2013. Multi-year and multi-location is a better predictor of future performance. Do not use these or any other data from a limited number of trials as a significant factor in product selection. Product responses are variable and subject to a variety of environmental, disease, and pest pressures. Individual results may vary.

Managing Goss's Wilt in Western Canada

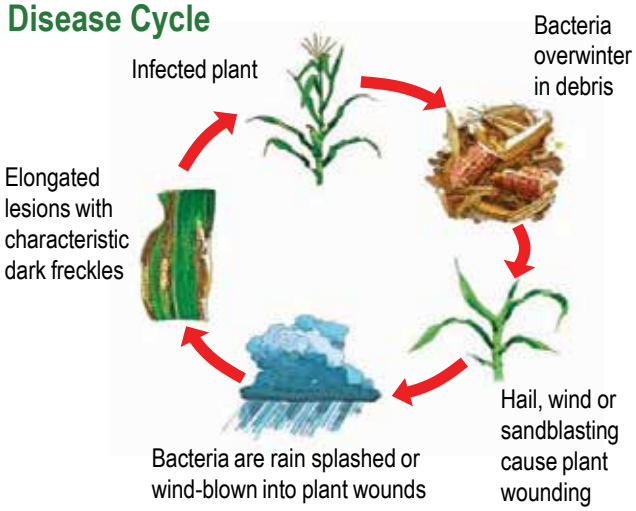
Disease Facts

- Disease is caused by a bacterial pathogen that over-winters in residue of corn and grassy weeds.
- In recent years, Goss's wilt has been observed moving across the Central and Northern Corn Belt states.
- In 2013, Goss's was confirmed in Louisiana, Montana and Alberta, Canada (see map at right).
- Depending on conditions, disease may cause only minor problems or devastating damage with grain yield losses approaching 50%.

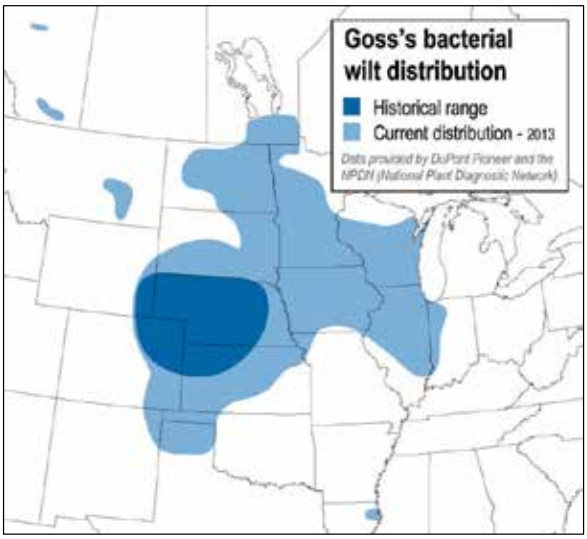
Goss's Wilt Development

- Bacteria infect plant tissue through wounds caused by wind, hail, sandblasting, etc.
- Lesions develop along leaf vascular tissues and may progress rapidly under wet or humid conditions.
- Goss's wilt can affect the plant at early growth stages and can spread throughout the canopy after infection.
- Scout for symptoms near silking.
- Yield reduction is caused by reduced healthy leaf area, leading to premature plant death.
- Bacteria are transported from infected fields to near-by fields by wind carrying infected soil or stubble.
- Goss's survives in corn residue & several grassy weeds.

Disease Cycle

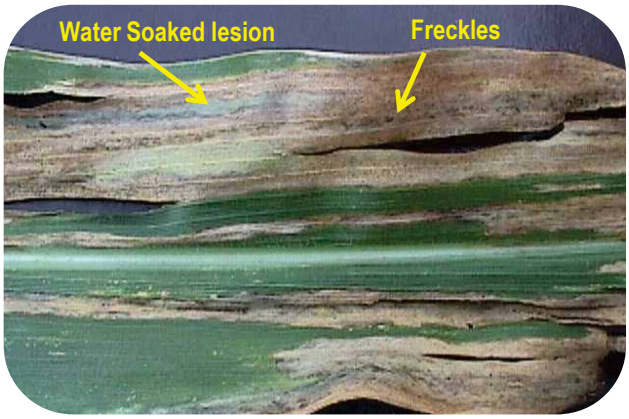


Presence of Goss's Wilt in Corn in North America



Goss's Wilt Symptoms

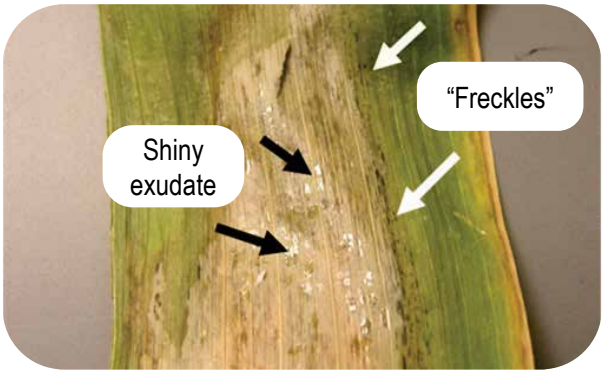
- Early leaf symptoms are elongated lesions of water soaked, grayish-green tissue that progress to long, wavy lesions with water-soaked margins.
- Look for dark green or black freckles within the lesions.
- Under wet and humid conditions, the bacteria appear as a shiny exudate on lesion surface.
- Symptoms often appear on upper leaf canopy and spread downwards with wet conditions.
- Symptoms often first appear in small patches along field edges where debris from adjacent fields blow in.



DuPont Pioneer Agronomy Sciences

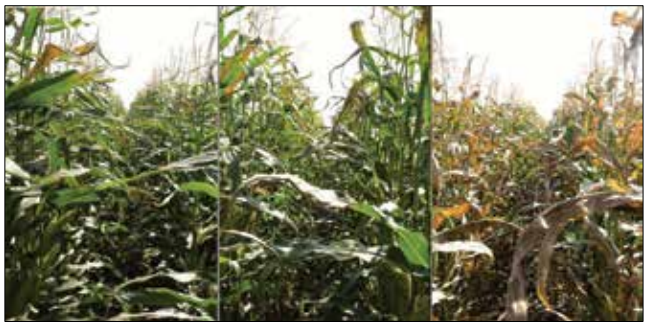
Distinguishing Features of Lesions

- **Freckles** – dark green to black water-soaked spots, often near lesion edges (white arrows).
- **Shiny Exudate** – bacteria ooze to leaf surface and may appear shiny after drying (black arrows).



Breeding for Resistance

- DuPont Pioneer has been screening and breeding for Goss's wilt resistance for decades in the Western U.S.
- Over the last few years, this bacterial disease has spread into the Northern Corn Belt of the U.S. as well as Manitoba and Alberta in Canada.
- DuPont Pioneer researchers in Canada were able to leverage the vast experience and knowledge available within Pioneer to diagnose, characterize and select resistant early-maturity genetics.
- Research work has led to, and will continue to improve, Goss's wilt resistance in corn hybrids sold in western Canada.



Hybrids have inherent genetic differences in tolerance to Goss's wilt. Pictured above is a sampling of three different Pioneer® brand hybrids exhibiting varying degrees of tolerance to Goss's wilt in a PKP trial.

Photo courtesy of Adam McKnight, Bud McKnight Seeds.

Field of Pioneer® hybrid 39V05 (RR2) planted into a previous field of corn that was susceptible to Goss's wilt.

Aerial photo was taken in August 2012 courteously of Arty's Air Service, Winkler, Manitoba.

Goss's Wilt Management

1. Genetic Resistance

- Use as a primary management method.
- DuPont Pioneer researchers inoculate, screen and rate hybrids for resistance.
- Hybrids are also rated under natural infestations in affected states.
- DuPont Pioneer researchers screen hybrids locally in Manitoba to increase levels of resistance.
- See your local Pioneer sales professional for help in selecting appropriate hybrids for your field.

2. Reduce Corn Residue

- Disease can become problematic in corn-on-corn, high-residue fields.
- Crop rotation is effective in reducing residue.
- Tillage encourages residue breakdown.

3. Control Grassy Weeds

- Several grassy weeds are hosts for the bacteria, including green foxtail and barnyardgrass.

4. Prevention/Avoidance

- Harvest and till affected fields last, and clean equipment to avoid spreading the pathogen to uninfected fields.

5. **Fungicide application is NOT effective** for this bacterial disease.

[1] Pioneer® brand products are provided subject to the terms and conditions of purchase which are part of the labeling and purchase documents.

[2] Product responses are variable and subject to a variety of environmental, disease and pest pressures. Individual results may vary.

[3] **RR2** - Contains the Roundup Ready® Corn 2 gene that provides crop safety for over-the-top applications of labeled glyphosate herbicides when applied according to label directions. Roundup Ready® is a registered trademark used under license from Monsanto Company.

Northern Leaf Blight Race Shifts

Northern leaf blight (NLB), also called northern *corn* leaf blight, is found in humid climates wherever corn is grown. It has spread in recent years due to hurricanes and other major weather events, which carry the organism from south to north across the U.S. and Canada. Use of race-specific genes for resistance has become more complex due to changes in the causal organism, *Exserohilum turcicum.* Multiple races of this fungus have been identified in some areas, and races are shifting in many areas where the first resistance gene was deployed. DuPont Pioneer corn breeders are incorporating multiple resistance genes into hybrids for more stable, long-term protection.

Disease Development and Symptoms

The northern corn leaf blight organism overwinters in diseased corn leaves, husks and other plant parts. Spores are produced on this crop residue when environmental conditions become favorable in spring and early summer. These spores are spread by rain splash and air currents to the leaves of new crop plants where primary infections are produced. Infection occurs when free water is present on the leaf surface for 6 to 18 hours and temperatures are 65 to 80° F.

NLB symptoms on corn leaf.

Secondary spread occurs from plant to plant and field to field as spores are carried long distances by the wind. Infections generally begin on lower leaves and then progress up the plant. However, in severe NLB outbreak years (that have high spore levels), infections may begin in the upper plant canopy.

Heavy dews, frequent light showers, high humidity and moderate temperatures favor the spread of NLB. Development of disease lesions on the ear leaf or above and significant loss of green leaf area can result in yield loss.

Races of NLB

There are multiple races of NLB documented in N. America; Race 0, Race 1 and Race 23N are the most prevalent. Ferguson and Carson (2007) reported a survey of NLB races that indicated the frequency of Race 0 isolates decreased from 83% in 1974 to 50% in the 1990s. During this same period, Race 1 isolate frequency increased. Low levels of Race 23 and 23N were present throughout the 20-plus years. The authors attribute the decrease in Race 0 to the widespread use of the Ht1 gene by the sweet corn and hybrid corn industries, which has provided control of Race 0 but not of Race 1.

The resistance genes are named "Ht" based on the previous NLB fungal name *(H)elminthosporium (t)urcicum.* The common sources of resistant Ht genes are dominant genes and provide resistance to the various key races as shown in Table 1.

DuPont Pioneer Breeders Target Multiple NLB Races

To provide disease resistance to NLB when multiple races might be present, two or more Ht genes may be needed. For example, a combination of Ht1 and Ht2 genes would provide resistance to Races 0, 1 and 23N, the predominant races of NLB in the U.S. and Canada. Because of these multiple races of NLB, Pioneer breeders are incorporating additional Ht genes in their hybrid development programs (i.e., a "multi-genic" approach). Susceptible and resistant NLB lesion types are shown in Figures 1-3.

Table 1. Common sources of resistance Ht genes.

Pathogen	Host (Ht) reaction to each race			
Et Race Designation	Ht1 gene	Ht2 gene	Ht3 gene	HtN gene
0	R	R	R	R
1	S	R	R	R
2	R	S	R	R
12	S	S	R	R
23	R	S	S	R
23N	R	S	S	S
123N	S	S	S	S

Figure 1. Susceptible response, early lesions. Plant has no resistance, but lesions have not had time to more fully develop.

Figure 2. Susceptible response, later lesions. With time, lesions have expanded to form large areas of necrotic tissue. Entire leaves may eventually become necrotic.

Figure 3. Resistant response to Race 0 (top two lesions). Note the chlorotic halo around lesions and restricted development of lesions. Susceptible response to Race 1 (bottom lesion).

Evaluation of Hybrids for NLB Reaction

DuPont Pioneer evaluates corn hybrids in multiple environments to observe their reaction to NLB infection. Inoculated plots as well as "natural infection" sites are used to establish disease pressure. Both basic research trials (small plots) and advanced testing trials (larger IMPACT™ plots) are used for this hybrid characterization process. Use of numerous widespread locations, including those with a history of extreme NLB incidence, helps ensure that some environments will provide severe NLB pressure to challenge even the best hybrids. It also helps provide exposure of hybrids to as many race variants of NLB as possible. The critical time for evaluating disease damage begins in the early reproductive stages of development.

The DuPont Pioneer 1 to 9 NLB scoring system is based on "leaf loss" from the disease; a score of "9" indicates no leaf loss and a score of "1" denotes 95% leaf loss in the presence of the disease. In determining overall hybrid ratings, experimental hybrids are compared to hybrids of "known" response to NLB. This provides a "relative" rating system in which new hybrids are characterized as accurately as possible relative to established hybrids that are more familiar in the marketplace.

Managing NLB in Corn Production

Effective management practices that reduce the impact of NLB include selecting resistant hybrids, reducing corn residue, timely planting and applying foliar fungicides.

Resistant Hybrids

When photosynthesis is limited by loss of green leaf area due to disease lesions, corn hybrids remobilize stalk carbohydrates to developing ears. When this occurs, stalk quality is reduced, often resulting in harvest losses. Hybrids with higher leaf disease scores tend to maintain leaf health and overall plant health longer into the grain filling period. This maintenance of plant health helps hybrids achieve higher yields, better stalk standability and increased grain harvestability.

For these reasons, selection of resistant hybrids based on disease reaction characterization scores is an important first step in managing NLB. The DuPont Pioneer NLB rating reflects a hybrid's expected performance against the major NLB races predominant in the adapted area. As race shifts inevitably occur, continued testing by DuPont Pioneer researchers may result in a rating adjustment for some hybrids. Use of multigenic resistance by breeders increases hybrid stability as NLB races shift over time.

When selecting hybrids, consider all important traits needed for a field. In addition to NLB resistance, select hybrids with high yield potential, appropriate insect resistance traits, suitable (usually full-season) maturity for the area, and data from multiple locations and years that demonstrate consistent performance. Strong emergence, stalk strength and drought tolerance are other agronomic characteristics to consider in helping to optimize stands and harvestable grain yields.

Reducing Previous Corn Residue

Reducing corn residue decreases the amount of NLB inoculum available to infect the subsequent crop. Crop rotation is one effective method of reducing residue. In addition, any form of tillage that places soil in contact with corn residue promotes decomposition and decreases the amount of residue that survives to the subsequent cropping season. Stover harvest for cellulosic ethanol production or animal feed is another means to reduce corn residue and disease inoculum. However, reducing corn residue does not protect against spore showers carried into a field on wind currents.

Timely Planting

Timely planting can often help hybrids escape the most severe damage from NLB if crop development outpaces normal disease progression. The latest-planted corn in an area may be infected when plants are smaller, resulting in the disease progressing more rapidly relative to the crop. However, in cases of high disease incidence, both early- and late-planted corn may be severely damaged.

Foliar Fungicide Application

Various foliar fungicides are available to help control or suppress NLB development. Though fungicides are routinely used by growers to protect against several common leaf diseases, NLB may not always be controlled as completely as some other diseases. This is because of the more rapid life cycle of NLB, which may be as short as one week under favorable conditions. Because NLB sporulates so rapidly, it is more difficult to time a single fungicide application. Consequently, selecting resistant hybrids is a crucial first step in managing NLB where incidence is historically high.

The decision to use a fungicide must be based on the disease risk factors of the field, including hybrid susceptibility, cropping sequence, tillage system, location, disease history, yield potential, the price of corn and expected weather during reproductive development. In fact, weather conditions anticipated during ear fill are a primary factor for disease development and often have the most impact (along with hybrid disease rating) on the profitability of fungicide applications.

A summary of 289 DuPont Pioneer on-farm trials where previous crop and tillage practices were reported is shown below (Figure 4). Results show an inverse relationship between tillage intensity and yield response to foliar fungicide application in both corn following corn and corn following soybean. These results clearly indicate that rotation and tillage have a positive impact on reducing disease pressure.

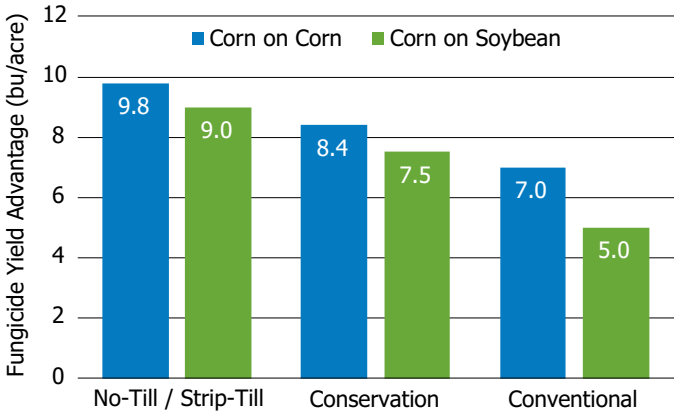


Figure 4. Average yield response to foliar fungicide application as influenced by tillage and previous crop in on-farm trials (289 trials, 2007 to 2011) (Jeschke, 2012).

Other studies (results not shown) show a similar relationship between hybrid disease rating and yield response to fungicides; the more resistant the hybrid, the less advantage achieved by fungicide application. Hybrids with a score of "6" or greater often show little or no economic benefit from a fungicide application under moderate infestation levels.

Most foliar fungicides commonly used for corn are labeled for NLB control (but verify by checking label). Labels contain important precautions, directions for use, and product warranty and liability limitations. Always read and follow these directions and precautions when applying fungicides.

RESEARCH UPDATE

Corn Herbicides to Control Glyphosate-Resistant Canola Volunteers 2013

Background

- With the rapid adoption of glyphosate-resistant corn in Western Canada, glyphosate-resistant canola volunteers have become a major weed concern to corn producers in the region.
- The Pest Management Regulatory Agency now allows herbicides to be tank-mixed if they have individual registrations on the crop and have a common application timing.
- Several herbicide options are available to control glyphosate tolerant canola volunteers in corn; however, some herbicides may have undesirable effects on corn.

Objectives

- Assess crop injury and yield effects of various herbicides tank-mixed with glyphosate to control glyphosate-resistant canola volunteers in glyphosate-resistant corn.
- Identify the most suitable post-emergence strategy for managing glyphosate-resistant canola volunteers in glyphosate-resistant corn.

Study Description

- The study compared the crop response of four industry leading hybrids (Pioneer® brand and competitive) with five different herbicide treatments (Table 1).
- Treatments were compared to a single application of glyphosate-only as a check.
- Herbicide treatments were applied at recommended rates at the V3 growth stage.
- Treatments were replicated four times per location at six locations over three years (2011-2013).

Table 1. Herbicide treatments.

	Treatment	Application Rate/Acre
1	Gly Only (Check)	1 L/acre (360g ae)
2	Gly + Dicamba	1 L/acre + 0.243 L/acre
3	Gly + 2,4-D	1 L/acre + 0.4 L/acre (600g/L)
4	Gly + MCPA Amine	1 L/acre + 0.45L/acre
5	Gly + Bromoxynil	1 L/acre + 0.48 L/acre
6	Gly / Bromoxynil (Split Application*)	1 L/acre + 0.48 L/acre

* Glyphosate and bromoxynil applied separately at V3 stage.

- Herbicide injury scores were recorded at:
  - 3-5 days after treatment
  - 7-10 days after treatment
  - 21-24 days after treatment
- Other recorded observations include:
  - Brittle snap counts
  - Yield (bu/acre) & moisture (%)
  - Test weight (lbs/bu)

Results

- Crop injury symptoms were similar among hybrids tested.
- The most severe and persistent herbicide injury resulted from the 2,4-D treatment on all hybrids (Figure 1 and 3).
- 2,4-D showed the highest brittle snap in all hybrids (Table 2).
- On average, 2,4-D reduced yield by 13.5% (Table 3) and lowered test weight by 4.4 lbs/bu (Table 4).

Figure 1. Crop response to herbicides tank-mixed with glyphosate 10 days after treatment.

Results

- MCPA amine treatment increased brittle snap relative to the glyphosate-only check and produced extensive onion-leafing symptoms.
- Dicamba treatment increased brittle snap (Table 2) and stalk lodging (data not shown), and it significantly reduced yield and test weight.
- 2,4-D, MCPA amine and dicamba treatments all resulted in stunted plants and poor brace root development when compared to the bromoxynil treatments and glyphosate-only check (Figure 2).
- Bromoxynil treatments caused some leaf burn but produced no growth inhibition or brittle snap, and plants recovered quickly.

Figure 2. Corn treated with glyphosate + MCPA amine (left) and glyphosate only (right).

Figure 3. Corn treated with glyphosate + 2,4-D.

Table 2. Brittle snap (%) observed with four hybrids and six herbicide treatments.

	Gly Only	Dicamba	2,4-D	MCPA Amine	Bromoxynil	Bromoxynil (Split App)
	Brittle snap (%)					
Hybrid A	0	8	21	10	0	0
Hybrid B	0	11	25	8	0	0
Hybrid C	0	15	20	12	0	0
Hybrid D	0	7	27	7	0	0
Average	**0**	**10**	**23**	**9**	**0**	**0**

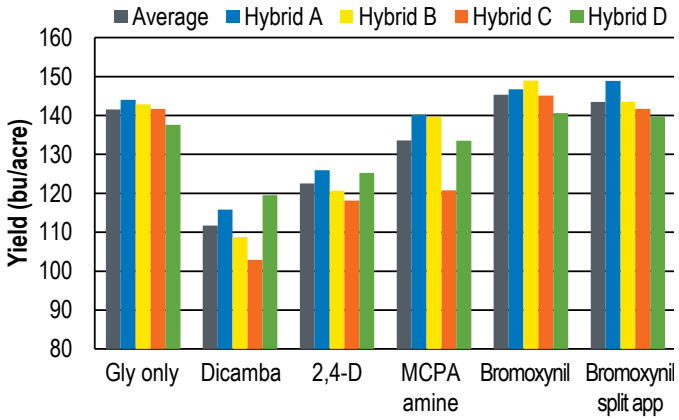


Figure 4. Hybrid yield by herbicide treatment.

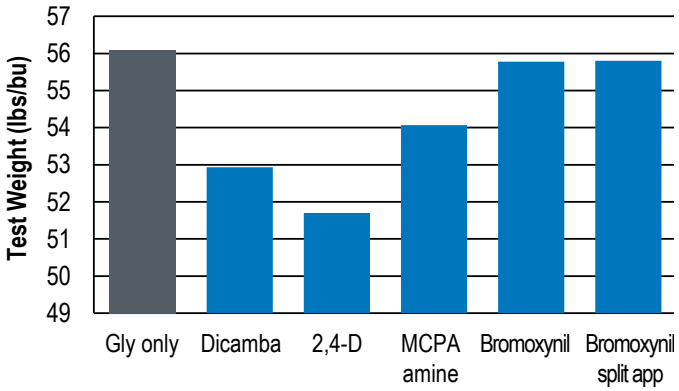


Figure 5. Average corn test weight by herbicide treatment.

Summary

- Bromoxynil treatments consistently provided excellent control of volunteer glyphosate-resistant canola with the lowest level of injury to corn among herbicides tested.
  - Bromoxynil treatments did not cause any crop stunting, growth restriction or brittle snap.
  - No reduction in corn yield (Figure 4) or test weight (Figure 5) was associated with the bromoxynil treatments.
- The growth inhibitor herbicides (2,4-D, dicamba and MCPA amine) caused extensive crop injury to all hybrids tested.
  - Injury symptoms included poor brace root development, stunting and brittle snap.
  - Crop injury associated with the growth regulator herbicides resulted in reduced corn test weight and yield.
- When applying bromoxynil herbicides to corn:
  - Apply during warm temperatures.
  - Use high water volumes (minimum 10-15 gal/acre).
  - Do not apply during or immediately following crop stress.
  - **Always read and follow herbicide label directions.**
- Consult with your local Pioneer Sales Representative for more information.

European Corn Borer (ECB) Management

Pest Facts

- ECB is one of the most damaging insect pests of corn. It was first discovered in Manitoba in 1948.
- Larvae feed on above-ground parts of a corn plant, chewing tunnels in corn stalks and ears.

Life Cycle

- Larvae overwinter in cornstalks, ears and other residue.
- Moths emerge from pupae in late June / early July and mate.
- Females lay egg masses on the underside of corn leaves near the mid-rib. Egg masses contain about 10 to 40 eggs.
- Egg masses are initially white and appear more black right before hatching (due to color developing in heads of larvae).
- Eggs hatch after 5 to 7 days, and larvae begin feeding. At this time they are small in size – about 1/10 inch.
- Newly hatched larvae appear white but become tan with black spots as they mature, attaining about 1 inch in length.
- At the end of the season, larvae tunnel into the stalk and prepare to overwinter.

Plant Symptoms and Impact on Crop

- "Window-pane" damage results from newly hatched (first instar) larval feeding on surface of corn leaf.
- "Shot hole" damage results from feeding inside the whorl.
- Tunneling in leaf mid-ribs as well as stalks, ear shanks and ears interferes with water and nutrient movement.
- Tunneling damage to the plant leads to reduced ear size and test weight. Heavy infestations may result in stalk breakage and ear droppage.
- Mature larvae feed on silks, kernels and cobs.
- This ECB feeding may result in moderate to severe yield loss.

Windowpane damage (left) and shot-hole damage (right) from European corn borer larval feeding.

Management

- ***Resistant (Bt) corn hybrids*** provide excellent control of ECB without harming beneficial insects.
  - Several Bt corn products to consider include Pioneer® hybrids **39D97** (HX1, LL, RR2), **P8107HR** (HX1, LL, RR2), **39B94** (HX1, LL, RR2), **P8210HR** (HX1, LL, RR2), **39V07** (HX1, LL, RR2) and **39Z69** (HX1, LL, RR2) as well as Pioneer® **P8193AM**™ brand corn (AM, LL, RR2).
  - Two new corn products are Pioneer® hybrid **P7632HR** (HX1, LL, RR2) and Pioneer® **P8016AM**™ brand corn (AM, LL, RR2).
- ***Fall tillage, mowing stalk residues or chopping*** the plant for silage can reduce overwintering populations.
- ***If using insecticides***, target young larvae (first and second instar) before they start tunneling into the stalk. Management by insecticides begins with scouting, using these methods:
  - Start in early July, and scout every 5 to 7 days. Look for egg masses or hatched larvae on 20 plants in 5 locations in field. Be sure to check for any feeding inside the whorl.
  - Calculate the number of corn borers pert plant, and compare against the economic threshold table below.

Larval stages of ECB. 1st instar at left; 5th instar at right.

Economic Threshold (number of larvae/plant)

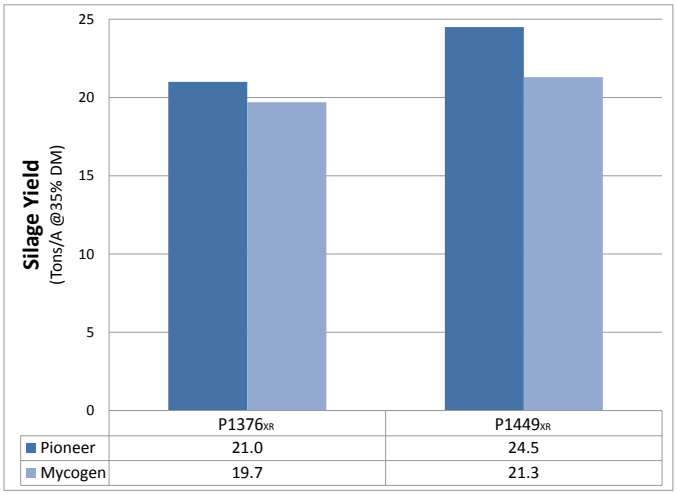
Control Costs[1]	Crop Value ($/acre)					
($/acre)	150	200	250	300	350	400
6	1.00	0.75	0.60	0.50	0.43	0.38
9	1.50	1.12	0.90	0.75	0.64	0.56
12	2.00	1.50	1.20	1.00	0.86	0.75
15	2.50	1.88	1.50	1.25	1.07	0.94
18	3.00	2.25	1.80	1.50	1.29	1.13
21	3.50	2.63	2.10	1.75	1.50	1.32
24	4.00	3.01	2.40	2.00	1.72	1.51
27	4.50	3.38	2.70	2.25	1.93	1.70

[1]Control costs = insecticide price ($/acre) and application costs ($/acre)
Source: http://www.gov.mb.ca/agriculture/crops/insects/fad46s00.html

DuPont Pioneer Agronomy Sciences

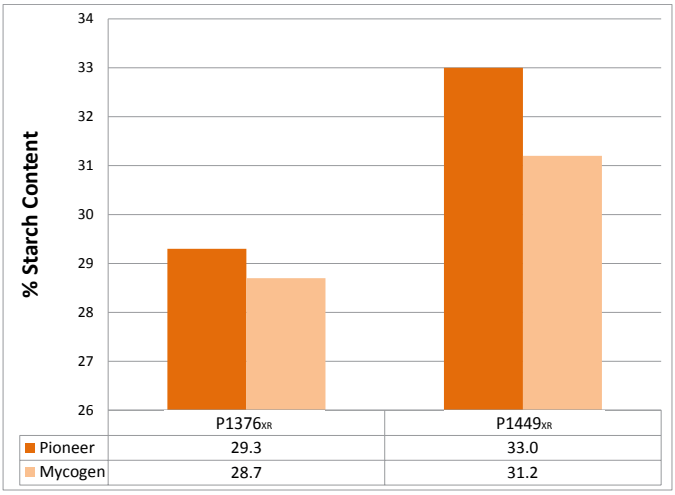
Pioneer® Brand Brown MidRib (BMR) Silage Products Versus Mycogen BMR: 2012-2013

Silage Yield of Pioneer® brand P1376XR (HXX, LL, RR2) and P1449XR (HXX, LL, RR2) versus Mycogen BMR



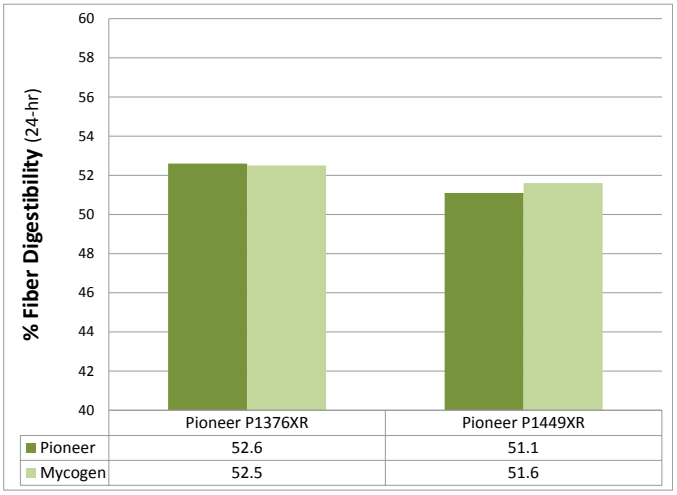
	P1376XR	P1449XR
Pioneer	21.0	24.5
Mycogen	19.7	21.3

Percent Starch of P1376XR and P1449XR versus Mycogen BMR



	P1376XR	P1449XR
Pioneer	29.3	33.0
Mycogen	28.7	31.2

Percent Fiber Digestibility (24-hr) of P1376XR and P1449XR versus Mycogen BMR



	Pioneer P1376XR	Pioneer P1449XR
Pioneer	52.6	51.1
Mycogen	52.5	51.6

Tons/Acre (35% DM): Whole plant yield adjusted to 35% dry matter.
% Starch: Percent starch (DM basis) in the whole plant.
% Fiber Digestiblity (24-hr): % degradable neutral detergent fiber (as a percent of total NDF, DM basis) in whole-plant samples in a 24-hr period.

BMR Products from DuPont Pioneer - Proven Performance for Silage Yield and Quality

- Superior yields in a variety of conditions averaging 1.3-3.2 tons per acre difference versus Mycogen BMR products.
- Superior starch content of forage averaging 0.6-1.8 % more starch versus Mycogen BMR.
- Similar Fiber Digestibility as Mycogen offering the proven benefit of high fiber digestibility corn silage.

Note: Data from DuPont Pioneer PK plots in northern Midwest and Northeast US for 2012 and 2013. There were a total of 124 comparisons for P1376XR, and 36 comparisons for P1449XR. All comparisons were against Mycogen BMR products with similar maturity and DM content at harvest (<7% DM difference). Product responses are variable and subject to any number of environmental, disease and pest pressures. Individual results may vary. Multi-year and multi-location data are a better predictor of future performance. DO NOT USE THIS OR ANY OTHER DATA FROM A LIMITED NUMBER OF TRIALS AS A SIGNIFICANT FACTOR IN PRODUCT SELECTION.

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RESEARCH UPDATE

Effect of Row Direction on Corn Grain Yield in Silage Production 2013

Rationale

- Where terrain permits, corn rows can be planted in either a north-south or an east-west direction.
- Sunlight penetrates more deeply into the plant canopy with north-south than with east-west rows.

Objectives

- Compare corn grain yields in silage production between corn rows planted north-south versus east-west directions.
- Compare grain yields at two plant populations.

Study Description

Location: 1 in central Illinois
Years: 2011-2012
Hybrids: 2 in 2011, 3 in 2012
Row Spacing: 30 inches
Factors:
Row Direction: North-south, East-west
Plant Population: 28,000 and 34,000 plants/acre

- Grain yield, kernel weight and kernels/ear were measured at the time of silage harvest.

Results

Row Direction

- Corn grain yield was significantly greater in north-south rows than in east-west rows in 2011, but did not differ between row directions in 2012.
- The average yield advantage of north-south rows over the two years of the study was 10%.
- The greater yield observed in north-south rows was largely attributable to significantly greater kernel weight.
- Number of kernels/ear was significantly greater in north-south rows in 2011 but not 2012.

Plant Population

- Grain yield was significantly greater with a plant population of 34,000 plants/acre than 28,000 plants/acre in both years of the study.
- The average yield advantage with the greater plant population was 25% over the two years of the study.
- The greater yield was primarily due to more ears/acre.
- Kernel weight was not affected by plant population.
- Plant population effect on kernels/ear was inconsistent between the two years of the study.

Measurement	East-West	North-South	Probability Level	28,000 plants/acre	34,000 plants/acre	Probability Level
Grain Yield at Silage Harvest (bu/acre)						
2011	110	130	P < 0.02	98	141	P < 0.01
2012	175	177	P < 0.67	170	182	P < 0.02
Weight/1000 kernels (g)						
2011	331	375	P < 0.01	349	347	P = 0.81
2012	322	342	P < 0.01	335	330	P = 0.47
Kernels/ear						
2011	486	540	P < 0.01	493	535	P < 0.02
2012	462	468	P = 0.65	487	442	P < 0.01

Research conducted by Dr. Paul Walker, Illinois State University, as a part of the DuPont Pioneer Crop Management Research Awards (CMRA) Program. This program provides funds for agronomic and precision farming studies by university and USDA cooperators throughout North America. The awards extend for up to four years and address crop management information needs of DuPont Pioneer agronomists, Pioneer sales professionals and customers.

2011-2012 data are based on average of all comparisons made in one location through Dec. 31, 2012. Multi-year and multi-location is a better predictor of future performance. Do not use these or any other data from a limited number of trials as a significant factor in product selection. Product responses are variable and subject to a variety of environmental, disease, and pest pressures. Individual results may vary.

RESEARCH UPDATE

Effect of Row Direction on Corn Silage Yield

2013

Rationale

- Where terrain permits, corn rows can be planted in either a north-south or an east-west direction.
- Sunlight penetrates more deeply into the plant canopy with north-south than with east-west rows.

Objectives

- Compare corn silage yields and milk per ton or per acre to corn rows planted north-south versus east-west directions.
- Compare silage and milk yields at two plant populations.

Study Description

Location: 1 in central Illinois
Years: 2011-2012
Hybrids: 2 in 2011, 3 in 2012
Row Spacing: 30 inches
Factors:
Row Direction: North-south, East-west
Plant Population: 28,000 and 34,000 plants/acre

- Plant weights were measured at silage harvest.
- Potential milk yield was calculated from nutrient composition of plants.

Results

Row Direction

- Corn silage yield was greater (average = 14%) with north-south than east-west rows in both years of the study.
- Milk/ton of silage was similar between north-south and east-west rows, but due to greater silage yield, milk/acre of silage averaged 12% more with north-south than east-west rows.
- Silage starch content was not affected by row direction.

Plant Population

- Silage yield was significantly greater (average = 19%) with a plant population of 34,000 plants/acre than 28,000 plants/acre in both years of the study.
- Predicted milk/ton of silage tended to be slightly lower with the higher plant population.
- Predicted milk/ton of silage harvested averaged 21% more with the higher plant population primarily due to the greater yield of silage dry matter per acre.

Measurement	East-West	North-South	Probability Level	28,000 plants/acre	34,000 plants/acre	Probability Level
Silage Yield, ton DM/acre						
2011	7.8	9.6	P < 0.01	7.5	9.9	P < 0.01
2012	9.4	9.8	P < 0.04	9.3	10.0	P < 0.01
Silage Starch, % of DM						
2011	28.1	27.1	P = 0.50	26.4	28.8	P = 0.10
2012	36.2	35.1	P = 0.15	35.7	35.6	P = 0.83
Milk, lb/ton silage						
2011	3136	3087	P = 0.54	3063	3159	P = 0.24
2012	3389	3374	P = 0.40	3407	3356	P < 0.01
Milk, ton/acre silage						
2011	12.2	14.8	P < 0.01	11.5	15.6	P < 0.01
2012	16.0	16.6	P = 0.22	15.9	16.8	P < 0.02

Research conducted by Dr. Paul Walker, Illinois State University, as a part of the DuPont Pioneer Crop Management Research Awards (CMRA) Program. This program provides funds for agronomic and precision farming studies by university and USDA cooperators throughout North America. The awards extend for up to four years and address crop management information needs of DuPont Pioneer agronomists, Pioneer sales professionals and customers.

Managing High-Moisture Corn

Introduction

The harvesting, storing, and feeding of high-moisture shelled corn (HMSC) or high-moisture ear corn (HMEC) is a popular practice among U.S. beef and dairy producers today. High-moisture grain production has several advantages and some disadvantages.

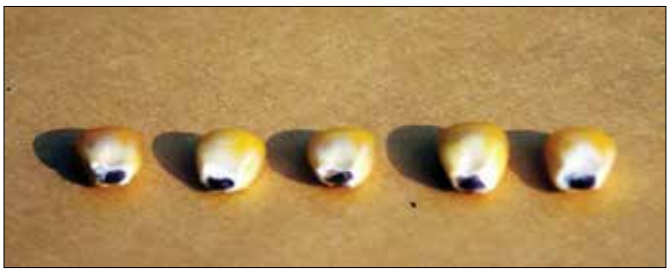
Agronomic and Economic Advantages

- harvesting several weeks earlier than harvest for dry storage, which contributes to reduced field and harvest losses of three to six percent
- elimination of drying costs
- generally a lower commodity cost associated with seasonal grain prices and discounts equivalent to drying and elevator dockage charges

Disadvantages

- loss of marketing flexibility compared to dry grain
- additional equipment may be needed for harvesting, handling, and packing high-moisture grain
- storage facilities are needed for a large quantity of grain
- harvest and ensiling can prove hectic
- storage losses can be large if the grain is not properly ensiled

Common storage methods used for storing high-moisture corn include processing and packing into upright silos, bags or bunkers, or storing the corn whole in oxygen-limiting silos. The storage method of choice will depend upon the type and size of the feeding operation. Regardless of the type of storage used, careful management is necessary to ensure proper preservation that optimizes the feeding value of high-moisture corn.



Formation of black layer at tip of the kernel

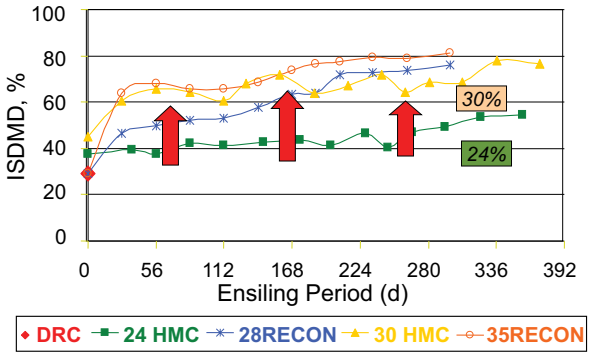
Harvest Management

High-Moisture Corn and High-Moisture Ear Corn

Recommended harvest moisture for HMC is between 26-32% kernel moisture. Optimal high-moisture corn harvest can typically begin once the corn has reached physiological maturity which is indicated by the formation of a black layer at the tip of the kernel. The milk line will have moved all the way down the kernel, and the presence of the black layer at the tip of the kernel indicates starch deposition is complete. Black layer is achieved at approximately 28-35 percent kernel moisture, depending upon hybrid and environmental conditions.

HMC is a relative term. 22-24 percent moisture HMC will have lower starch digestibility and feed much differently than 28-30% moisture HMC. Likewise, University of Nebraska research shows that wetter HMC (>26 percent moisture) becomes more digestible over time in storage (figure 1). Various laboratories offer starch digestibility tests to help nutritionists better quantify these changes over storage time.

In situ (Ruminal) Dry Matter Digestion



J.R. Benton, G.E. Erickson, and T.J. Klopfenstein, University of Nebraska, Lincoln; Abstract # 936. 2004 ASAS/ADSA Sessions St. Louis, MO

Owens and Thornton (1976) concluded from a review of 36 published beef feeding trials that for every one percent added moisture above 24 percent, dry matter intake decreased by about one percent when HMC was compared to dry rolled corn as the sole source of grain in the diet. They concluded that metabolizable energy content of HMC increases with moisture content. On average, energy value of HMC equaled dry corn at 23 percent moisture and increased by .3 percent for every one percent higher moisture.

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High-Moisture Ear Corn and Snaplage

Dairy and beef producers have recently adopted a relatively new method of harvesting high-moisture (HM) grain as earlage or snaplage (earlage and snaplage are used interchangeably here). Technically, earlage includes only grain and cob and is harvested with a combine adjusted to retain the cob portion. Snaplage is the harvest of whole ears including husks, shanks, cob and some leaves. This product is harvested with a snapping head mounted on a forage chopper with a kernel processor on-board. This allows for one-step harvest and kernel processing and results in substantial time and fuel savings compared to other methods.

Snapping head mounted on forage chopper

The optimal harvest moisture for HMEC is 34-40 percent moisture. The whole ear moisture will typically be four to six points higher in moisture than the grain moisture because the cob moisture is higher than that of the kernel. It is best to err on the wet, rather than dry side, when harvesting earlage. Wetter HMEC will have better palatability, higher cob digestibility, better fermentation and higher starch digestibility.

However, harvesting HMEC and HMC at higher than the recommended moisture contents will reduce dry matter yields and can lead to extensive fermentation, resulting in increased energy loss during storage. A common mistake is to let HMEC get too dry prior to harvest. Harvesting below the recommended moisture range also reduces dry matter yields due to the increased probability of ear drop and weather damage and makes it more difficult to pack and exclude air. Entrapped air increases the risk of mold growth and/or excessive heating which will lead to increased nutrient loss. Producers should consider adding water during ensiling if the moisture content drops below 25 percent for shelled corn or below 32 percent for high-moisture ear corn.

Proper adjustment of equipment can have a large influence on the quantity and quality of the harvested product. Consult your owner's manual for proper adjustment information. For HMEC, it is critical to retain corn ears, shanks and some leaves, but to avoid harvesting excessive leaf or stalk material. The leaves/shucks that are harvested should be cut up or shredded rather than having long leaf strands in the mixture. Adjust the kernel processor to maximize kernel and cob damage. The kernel processor roll gap will typically need to be set at < 3 mm.

Processing

The most common methods for processing high-moisture corn include: tub grinding (hammer mill), rolling or ensiling whole in oxygen-limiting structures. Like any ensiled product, high-moisture corn requires good management during packing and storage. Particle size reduction facilitates air exclusion during packing and helps avoid air penetration into the exposed face during feeding. The finer the corn is processed, the better it packs. The degree of processing required differs for dairies and feedlots. Dairies tend to process HMC finer because of the faster rate of passage through a cow's digestive system.

If kernel moisture drops below 25 percent, processors should roll or grind the corn finer and add water if possible. Grain that is ensiled with less than 26 percent moisture may have a slower and incomplete fermentation resulting in higher storage losses and poorer starch availability. Indeed, some studies indicate that grain ensiled with 19 to 26 percent moisture has a feeding value below either that of dry rolled corn or of wetter corn grain. Water can be added to ensiled grain to reconstitute its moisture content, but the amount of water needed to increase moisture content is immense. 1.5 percentage of the weight of grain as water is needed to increase moisture content by one percent. For example, 3.4 gallons of water is needed to increase the moisture content of one ton of high-moisture grain from 25 to 26 percent; 37 gallons of water is needed to increase the moisture content of dry corn from 15 to 26 percent.

If high-moisture corn is processed by a roller mill, all kernels should be broken into a minimum of four to six pieces, not just nicked or cracked. Hammer mills or tub grinders typically will produce smaller particles depending on the screen size and PTO speed. Ideally, it is desired to have all kernels broken, but to achieve this with a tub grinder, the product would likely be flour with excessive fines. A good goal is less than five percent whole kernels and less than 20 percent fines when using a tub grinder. The optimal degree of HMC processing represents a balance between maximum digestion and potential acidosis. Rolled HMC as compared to ground HMC simplifies bunk management (less fines) and will typically have higher dry matter intake (DMI) and average daily gain (ADG). However, feed efficiency is typically better with ground HMC. The processing method of choice is largely a nutritional preference depending on other available ration ingredients, amount of HMC fed and the type of cattle fed.

Tub ground HMC

Rolled HMC

The foregoing is provided for informational use only. Please contact your Pioneer sales professional for information and suggestions tailored for your operation.

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High Yield Production Practices for Soybeans

Achieving top soybean yields requires intensive management. All critical aspects of soybean production must be considered, including variety selection, planting practices, seed treatments, soil fertility, fungicide/insecticide applications (when needed), crop rotation and timely weed control.

Variety Selection for Top Yields

Matching soybean varieties to the specific requirements of individual fields is a core practice for maximizing yield. Geographic location alone can impact maturity, drought stress potential and pest pressure. Soil type, drainage and soil condition (e.g., compaction) affect stand establishment and moisture stress. Soil pH can result in iron deficiency chlorosis in some varieties. Field history of soybean cyst nematode (SCN), Phytophthora, white mold, sudden death syndrome and other diseases determine resistance traits needed in the variety. Previous crop can heighten or moderate expected disease pressure and thus impact variety selection.

In addition to appropriate disease and SCN resistance for the growing environment, all varieties considered should have high yield potential, good standability and ability to withstand environmental stresses. Your local Pioneer sales professional can help you select the best soybean varieties for each field, with proven yield performance across multiple environments.

Newest Varieties - Soybean breeders at DuPont Pioneer make yield gains and agronomic improvements every year using new genetic tools such as the Accelerated Yield Technology (AYT™) system and marker-assisted selection. Sampling top new varieties each year and ramping these up to substantial acreages quickly can have a significant impact on overall farm yields.

Planting Practices

Row Width - A review of soybean row-spacing studies published within the past decade generally confirms previous results comparing row widths (Figure 1). In 5 studies, drilled narrow rows outyielded 30-inch rows by an average of 4.1 bu/acre. Six studies that compared 30- and 15-inch rows found similar results, with 15-inch rows holding a 3.6 bu/acre yield advantage. Yields were similar between 15-inch and drilled narrow rows. For that reason, many growers wanting better uniformity of planting depth and seed placement, or in areas where white mold is common, have chosen 15-inch rows.

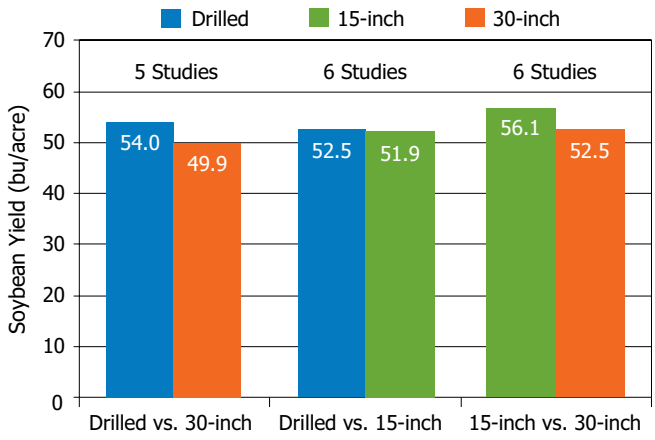


Figure 1. Average yield results from 7 soybean row spacing studies published during the last 10 years.

Full-season soybean variety.

Planting Date - Soybean planting is trending earlier, particularly in operations with a planter dedicated to soybeans. DuPont Pioneer and university studies have shown that planting soybeans in the last half of April or first part of May often increases grain yield. Early planting extends reproductive growth by initiating flowering earlier. This allows the crop to accumulate more nodes, increasing the potential for greater pod and seed number. In addition, recent studies indicate that full-season varieties respond better to early planting than short-season varieties.

Seed Treatments - Because of earlier planting and higher levels of crop residue on fields, soils are generally colder and wetter at planting, and seedling diseases have increased as a result. Consequently, more growers are seeing an advantage for fungicide seed treatments. Pioneer Premium Seed Treatment choices include next-generation fungicides with multiple modes of action that provide enhanced protection against a broad spectrum of early-season diseases including Rhizoctonia, Fusarium and Pythium. Adding an insecticide to the treatment reduces insect feeding that provides an entry port for disease infection.

Soil Fertility

Phosphorus (P) / Potassium (K) - Some soybean producers depend on residual corn fertility to supply nutrients to their soybean crop. When soils are routinely maintained at high or very high levels of P and K, this may be a safe strategy, but when P and K are low, yield reductions are likely. A 60 bu/acre soybean crop removes, in the grain, about 48 lbs P_2O_5 and 84 lbs K_2O from the soil. This is 33% less P but 55% more K than a 200 bu/acre corn crop removes in the grain. Soil testing can determine if field levels are adequate to supply these or other required amounts.

Soil pH - Many chemical and biological processes in the soil are affected by pH, and maintaining pH in the proper range will maximize the efficiency of other crop inputs and decrease the risk of yield losses. Soybeans thrive in the pH range of 6.0 to 6.8 (in mineral soils). Liming acid soils or utilizing varieties with good iron deficiency chlorosis scores on high pH soils will help prevent yield reductions.

Nitrogen (N) - Soybeans are high in protein and therefore in N, removing 3.5 to 4.0 lbs from the soil for each bushel of grain produced. This compares to less than one lb of N removed per bushel of corn grain produced. However, soybeans supply most of their own N needs by N fixation, and additional N is supplied by soil mineralization.

An N "budget" developed from a summary of over 100 research studies shows that soil and fixed N are generally sufficient to supply N needs at yields up to 60 bu/acre (Salvagiotti et al., 2008). As yields increase to 80 bu/acre and higher, an N deficit may result. This deficit grows at yields of 80 to 100 bu/acre, raising the possibility of a need for N fertilizer or manure to supplement natural sources. However, research studies have not shown consistent yield increases from N applications; rather, they have more often demonstrated that N fixation may be inhibited in the presence of elevated levels of soil nitrate (NO_3). Thus, much more research is needed regarding the yield benefit and cost-effectiveness of N applications to high yielding soybeans.

Foliar Fertilizer and Banding - In studies conducted in Iowa, foliar feeding increased yields only 15 to 20% of the time; however, it may be useful when soil nutrients are inadequately supplied, such as production on sandy soils or high-yielding irrigated fields. Studies in Iowa and Minnesota with banding fertilizer close to the row have not shown benefit; rather, stands were reduced and yields were not improved.

Foliar Fungicide/Insecticide Application

Between 2007 and 2011, DuPont Pioneer researchers conducted 148 trials comparing yield of untreated soybeans to those treated with a foliar fungicide and 52 trials that included an insecticide in the treatment. Trials were located in 11 states and 2 Canadian provinces. Across these trials, the average yield response to a foliar fungicide application was 2.5 bu/acre, with a positive response in 82% of the trials (Figure 2). When an insecticide was included, the average response increased to 5.3 bu/acre, and a positive yield response was observed in 94% of the trials.

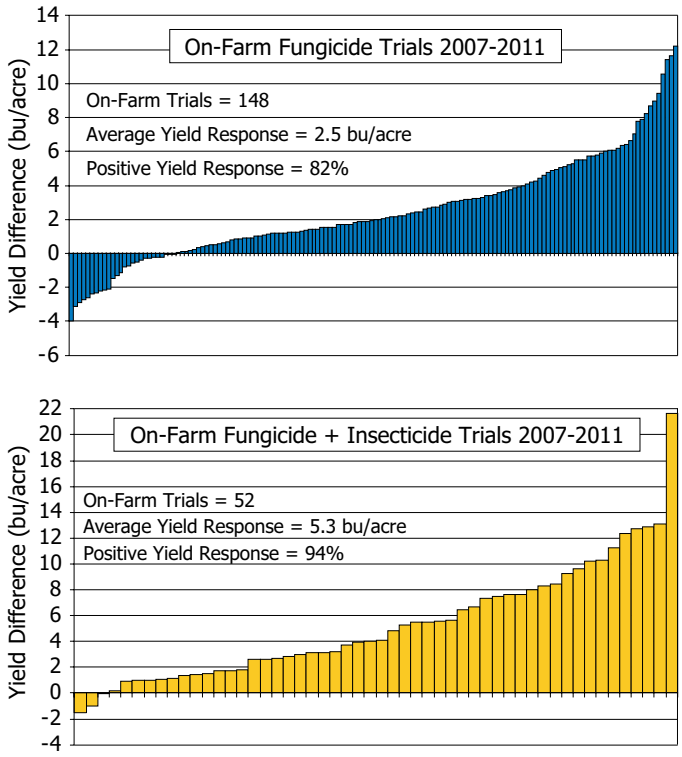


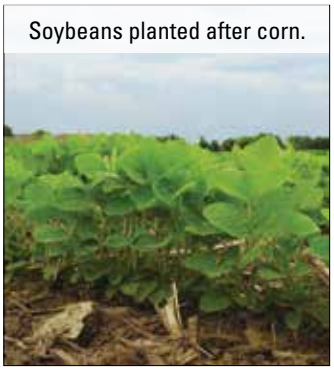
Figure 2. Average soybean yield response to foliar fungicide (top) and fungicide + insecticide (bottom) across DuPont Pioneer on-farm trials conducted from 2007 to 2011.

Fungal diseases that can be managed with foliar fungicides include anthracnose, Septoria brown spot, Cercospora leaf blight, frogeye leaf spot, pod and stem blight, and soybean rust. The most common insects with potential to lower soybean yield include soybean aphids, bean leaf beetles and a variety of stink bugs (green, brown, red-shouldered, red-banded and brown marmorated). Scout to determine if insect levels exceed economic thresholds, and use established integrated pest management (IPM) practices.

Crop Rotation

Crop rotation is important in all crops to break disease and insect cycles and increase yield. Diseases such as soybean cyst nematode, white mold, brown stem rot and sudden death syndrome survive in the soil or in crop residue and readily attack a successive soybean crop. Most soybean diseases survive more than one or two years in the soil, so rotation does not eliminate the problem. However, time away from soybeans diminishes the amount of disease inoculum available to infect the next crop, and thereby lessens its severity.

Rotation studies in MN and WI showed that soybeans in a corn/soybean rotation yielded 8% more than continuous soybeans. These studies were conducted in good growing environments where moisture was not severely limiting. Soybeans following 5 years of continuous corn yielded 15 to 17% more than continuous soybeans.


Soybeans planted after corn.

Other Practices for Increasing Soybean Yields

Tillage has long been used to bury crop residue, prepare a seedbed and control weeds. Current planting equipment and herbicides now allow growers to achieve excellent soybean stand establishment and weed control with little or no tillage. Research has shown that soybean yields are similar across conventional, minimum till and no-till. For this reason, growers can choose a tillage system that makes sense economically, environmentally and logistically, and focus on optimizing other management practices within that tillage system.

Weed Control - If weeds compete with soybeans for moisture, light and nutrients during the critical development period from the second trifoliate stage to beginning flowering, yield may be reduced even if weeds are ultimately controlled. The development of more and more weed populations resistant to glyphosate makes the use of other herbicide modes of action an important component of a weed management system. Use of a pre-emergence herbicide followed by glyphosate allows for multiple active ingredients to be applied, while also controlling weeds earlier than glyphosate-only programs.

Reference

Salvagiotti, F., K.G. Cassman, J.E. Specht, D.T. Walters, A. Weiss, and A. Doberman. 2008. Nitrogen uptake, fixation, and response to fertilizer N in soybeans: A review. Field Crops Res. 108:1-13.

Nitrogen Fertilizer for Soybean?

Soybean has high protein content, which is rich in N, so its needs for N are high. Fortunately, N-fixation and uptake of residual and mineralized N from the soil are usually sufficient to supply most of the N needs of a soybean crop. However, some soil fertility recommendations are now suggesting that N fertilizer applications may be needed at very high soybean yield levels. This article discusses the N needs of today's higher yielding soybean crops, sources of N supply to the crop and whether N fertilizer applications may be needed for maximum soybean yields.

Nitrogen Demands of a Soybean Crop

Soybean is high in protein, so its needs for N are high.

When soybean is harvested, a large amount of N is removed from the field. This is because soybean grain has very high protein content (~40% or more on a dry weight basis), and protein contains about 16% N. For example, 60 bu of soybean contains ~210 lb N in the grain and ~80 lb N in the above-ground plant tissues, totaling ~290 lb N (Salvagiotti et al., 2008). This is more N than a high-yielding corn crop requires – 200 bu of corn contains about 270 lb N in the above-ground plant portion. The important question is: "How much of this can come from N fixation and how much can come from the soil?"

Sources of Nitrogen for a Soybean Crop

Unfertilized soybean receives its N from only two sources: N fixation and soil N (Figure 1). A recent review of scientific papers compared the N demand of high-yielding soybean to the capacity of soybean to fix N from the air and obtain it from the soil (Salvagiotti et al., 2008). Because N concentration in soybean seed is fairly constant, N plant uptake from fixation and soil sources increases proportionally to grain yield (Figure 1).

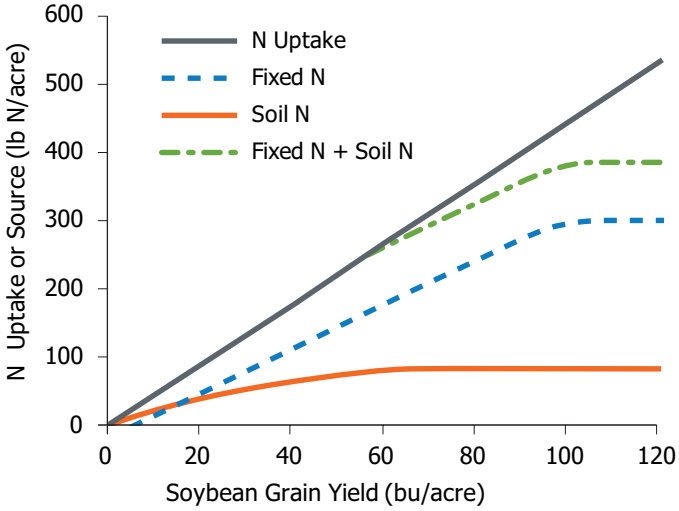


Figure 1. A generalized N budget for soybean. Adapted from Salvagiotti et al., 2008.

N-fixing nodules on soybean roots.

As Figure 1 indicates, average N fixed by soybean increases linearly with increasing yield, but only a portion of the total N requirement is met through N fixation (about 50 to 60% of the total N requirement at yields of 50 bu/acre or less). Based on the average of the 100+ studies represented in Figure 1, at a yield level of 60 bu/acre, fixed N provides about 180 lb of the 270 lb N uptake in soybean, or 65 to 70% of the total required N. For yields up to 60 bu/acre, the difference between total N uptake (i.e., plant requirement) and fixed N is usually provided by soil sources.

The N budget also illustrates that there may be a small N deficit for yields between 60 and 80 bu/acre, which means that yield could be restricted because of too little N. Realistically, conditions that are favorable for top soybean yields are usually conducive to high soil mineralization as well, so N would not always be limiting in this range. However, these studies clearly show that there are upper limits to the amount of N supplied by fixation (about 300 lb/acre) and soil sources (about 85 lb/acre). As yields increase above 80 bu/acre, it is clear that total N needs of the soybean crop will not be met by soil and fixation, and yield-limiting N shortfalls may occur without addition of N.

The Challenge of Applying N Fertilizer to Soybean

Recommendations vary regarding when, where and how N should be applied (if at all) in soybean production. Some indicate that soils with low organic matter, which mineralize less N, may potentially respond to N fertilizer. Others indicate that N fertilizer applied in the zone of N fixation (near the surface in the root zone) will inhibit N fixation, and the benefit of the additional N fertilizer is offset by less fixed N (see next page for more discussion of this). Regarding N timing, some say to apply N before flowering, while others indicate to apply during pod fill when the plant's demands for N are greatest.

In fact, there is neither clear proof from the scientific literature nor consistent anecdotal evidence to predict the conditions leading to a soybean response to fertilizer N. In addition, scientists have not yet been able to identify precisely when soybean will respond to N fertilizer and therefore, when to apply it. However, understanding more about a soybean plant's variable needs for N throughout its life cycle can provide some guidance for application timing. Nitrogen demand by soybean is illustrated in Figure 2.

Application at Early Reproductive Stages? At about 60 days after planting, or about the R4 growth stage, soybean begins to move N from the vegetative parts of the plant to the grain. This might suggest that the best time to apply additional N is prior to R4 (during the early reproductive growth stages) so that fertilizer N is readily available to the plant by R4. If this applied N could delay or minimize the shift of N from the vegetative parts to the seed, it may prolong the duration when the plant remains green and is moving carbohydrates to the seed and therefore, may increase overall grain yield.

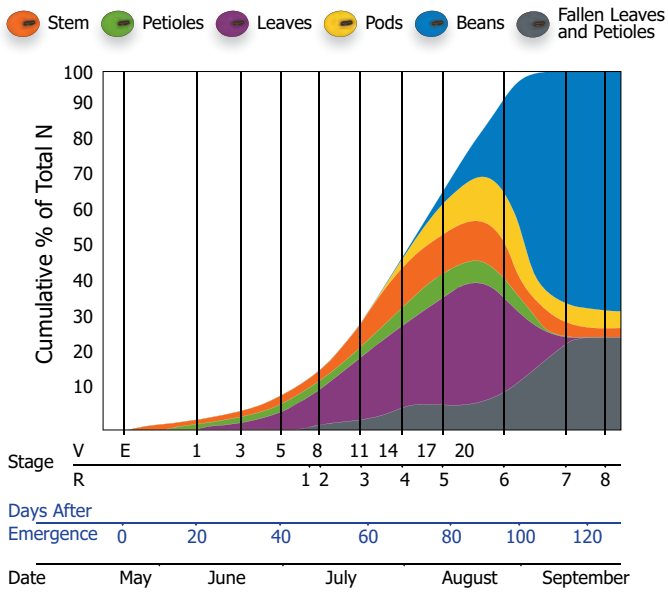


Figure 2. Nitrogen uptake of soybean by growth stage and date for various above-ground plant tissues. Adapted from Ritchie et al., 1982.

Although an N fertilizer application during early reproductive growth stages is during a period of great demand by soybean, it is not known if the N applied would be additive to the N fixed by the plant. Conversely, it could decrease N fixation by some amount, even up to the total quantity of N applied, thus resulting in a zero net gain in available N to soybean.

N Fixation Reduced by Soil Nitrate - Research on N fixation in the presence of soil nitrate is consistent: N fixation by soybean is inhibited in the presence of elevated levels of soil nitrate (NO_3^-). This means that when N fertilizer is applied, soybean simply fixes less N. From a physiological perspective, this makes sense because the process of initiating the symbiotic relationship with rhizobia is energy-demanding. If soybean can avoid the additional "expense" of fixing N by obtaining inorganic N already present in the soil, it will forego, or at least postpone, N fixation. Because all N fertilizers ultimately change to the nitrate form in the soil, this limitation applies to all N-containing fertilizers.

How might N fertilizer be applied to soybean without adversely affecting N fixation? An approach taken in a Nebraska study was to apply slow release N fertilizer (polymer coated) eight inches below the soil surface midway between the rows (Salvagiotti et al., 2009). The placement was intended to avoid or minimize the reduction of N fixation by putting the N fertilizer below the zone where most N fixation occurs. Results showed that this treatment was successful in not reducing the amount of N fixed by the soybean.

Conclusions

Research studies have not consistently identified the conditions for yield increases from supplemental N applications. However, the N budget shown in Figure 1, which was derived from a summary of over 100 research studies, may represent the best estimate of N supply from soil and N-fixation sources and resulting sufficiency or need in soybean production. The budget indicates that a yield-limiting N deficit may exist as yields increase above 60 to 80 bu/acre.

Nitrogen needs that are unmet by the combination of N mineralization by the soil and N fixation by the plant can be supplied by other sources, such as N fertilizer or manure. These supplemental N amounts to meet crop demands are shown below for various soybean yield levels.[1,2] These are based on the potential N deficit (difference between N supply and crop needs) shown in Figure 1 for soybean yields above 60 bu/acre.

Nitrogen Needs[1,2] of Soybean Based on N Budget Shown in Figure 1

50 to 60 bu/acre soybean yields - Additional N is likely not needed, except perhaps in soils with very low inherent N mineralization.[1,2]

60 to 80 bu/acre soybean yields - 0 to 30 lbs/acre additional N may be needed to reach this yield level.[1,2] In soils with high mineralization capability, N may be sufficient.

80 to 100 bu/acre soybean yields - 30 to 60 lbs/acre additional N may be needed to reach this yield level.[1,2]

100 bu/acre and higher soybean yields - More than 60 lbs/acre additional N may be needed to reach this yield level.[1,2]

[1] These N needs are only approximations based on the N budget shown in Figure 1. Soybean fields are subject to a wide variety of environmental effects, including climatic, disease and insect pressures. Mineralization of N by soils and soybean N fixation is affected by soil moisture, temperature and other factors that vary within season and from season to season. Consequently, soybean needs for fertilizer sources of N are variable and difficult to predict. Individual results may vary.

[2] In soils with low mineralization capacity (soils with low organic matter), an additional 20 lbs N/acre may be needed.

Even if soybean needs for supplemental N are identified, the question of cost-effectiveness of applications remains. That question will only be answered over time with broad-based research studies and side-by-side comparisons in growers' fields. With that in mind, the best approach to determine if supplemental N is required for your high-yielding soybean field may be to simply try a low rate of N in alternate strips on a few acres and adjust future trial rates based on year-to-year results.

Authored by John P. Schmidt, DuPont Pioneer Research Scientist, Soybean Production. Champaign, Illinois.

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White Mold of Soybean

White mold is a fungal disease that can attack hundreds of plant species. Also known as Sclerotinia stem rot, it has become an annual threat to soybeans in northern growing areas throughout North America. When wet, cool conditions prevail during flowering, the disease can be found in central states as well. When severe infestations occur, primarily due to sustained wet weather conditions, losses may be substantial. The spread of white mold in recent years is likely due to cultural practices that have accelerated canopy development, including earlier planting and narrow row spacings.

Disease Description and Life Cycle

Sclerotia on stem.

White mold persists in soybean fields over time by production of survival structures called sclerotia. These dark, irregularly shaped bodies about ½-inch long are formed within the white, cottony growth both inside and outside the stem during the fall. These sclerotia contain food reserves and function much like seeds, surviving for years in the soil and eventually germinating, producing millions of spores beneath the soybean canopy.

White mold spores are not able to invade plants directly but must colonize dead plant tissue before moving into the plant. Senescing flowers provide a ready source of dead tissue for preliminary colonization. From these flowers in the branch axils or stuck to developing pods, the fungus spreads to healthy tissue. Stem lesions develop and may eventually be overgrown with white mold. The disease can then spread directly from plant to plant by contact with this moldy tissue. Sclerotia are formed within the moldy growth and inside the stem to complete the disease cycle.

Wet, cool conditions are required throughout the white mold disease cycle, including germination of the sclerotia in the soil, spore release, infection of soybean flowers by spores and spread of white mold from plant to plant. As the disease progresses, tissue rots and sclerotia form inside the stem, often leading to rapid wilting and death of the entire plant.

Management of White Mold[1]

White mold is often a disease of high yield potential soybeans, but abandoning high yield management practices to control the disease may be counter-productive. Rather, a systems approach that includes avoiding disease spread, selecting tolerant varieties, adjusting cropping systems, and applying specific fungicides or herbicides can reduce soybean damage during white mold outbreak years.

Disease Avoidance - White mold spreads either by movement of spores or sclerotia from field to field. There is little known about stopping the spread of spores. Sclerotia move from field to field in harvest equipment or in contaminated seed. Harvest equipment should be thoroughly cleaned when moving from infected to non-infected fields. Harvesting infected fields last provides additional safety. DuPont Pioneer avoids growing seed beans in fields with a history of white mold. Seed is also thoroughly cleaned and inspected to ensure that it is disease-free. Seed cleaning with a gravity table or centrifugal tower is essential to remove sclerotia. Fungicide seed treatments can help ensure that no disease is transmitted by mycelia present on seed.

White Mold Development: Long-Term Risk Factors

The North Central Plant Health Initiative has developed the following list of risk factors for white mold:[a]

Field/Cropping History - Pathogen level will gradually increase if:

- Other host crops are grown in rotation with soybean.
- Only 1- to 2-year intervals occur between soybean crops.
- White mold susceptible varieties are grown.

Weed Management Systems - Inoculum will increase if control of broadleaf weeds is ineffective. Some herbicides used in rotation systems may be suppressive to white mold.

Topography of Field - Pockets of poor air drainage, tree lines and other natural barriers that impede air movement will create a favorable micro-environment for white mold development.

Pathogen Introduction:

- Contaminated and infected seed
- Movement of infested soil with equipment
- Wind-borne spores from apothecia in areas outside fields

[a] Adapted from: North Central Soybean Research Program, Plant Health Initiative. http://www.planthealth.info/whitemold_basics.htm

Variety Selection - At this time, there is no complete genetic resistance to white mold – all varieties can develop white mold symptoms under severe infestations. But varieties do differ, and DuPont Pioneer researchers assign each Pioneer® brand soybean variety a 1 to 9 rating based on these differences. These scores reflect varietal differences in the rate at which the infection develops and the extent of damage it causes. Growers can use this rating to help choose the best variety for their field (higher scores indicate more tolerance). However, because there is no complete genetic resistance available at this time, white mold may sometimes occur even with above-average tolerance scores. Your local Pioneer sales professional can suggest white mold tolerant varieties with a complete package of traits needed for top soybean production in your area.

Pioneer researchers have targeted improvement of varieties for white mold tolerance as a key research objective. To accomplish this goal, soybean breeders use new lab and field techniques as well as conventional selection in white mold environments. These scientists also continue to screen novel, exotic and alternative germplasm sources with native tolerance to white mold. Future possibilities include transgenic approaches – transferring resistance genes from other crops or organisms into soybeans.

Cropping Systems

Tillage - Sclerotia germinate from the top two inches of soil. Below that depth, they can remain dormant for up to 10 years. Because of its longevity in the soil, it is difficult to devise a strategy to control white mold with tillage. Deep tillage buries sclerotia from the soil surface but may also bring prior sclerotia into their zone of germination. If the disease is new to a field and a severe outbreak has occurred, a deep tillage followed by no-till or shallow tillage for many years may be beneficial. Research studies have shown that no-till is generally superior to other tillage systems in limiting white mold development.

Rotation - Rotation with a non-host crop is an effective means of reducing disease pressure in a field. Non-host crops include corn, sorghum and small grains. Susceptible crops to avoid in a rotation include alfalfa, clover, sunflower, canola, edible beans, potato and others. Depending on soybean tolerance, field history and other factors, more than one year away from soybeans may be required. Because sclerotia survive for up to 10 years in the soil, rotation is only a partial solution.

Chemical Application[2]

DuPont™ Acapela® - In 45 field trials conducted in Ontario, Quebec and Manitoba in 2012, there was an average 2 bu/acre yield increase, with one application of DuPont™ Acapela®, compared to an untreated check. The Acapela label specifies that two applications are required for white mould control. Please refer to the product label for complete application directions including timing, rates and water volume. Coverage is critical to achieve optimum efficacy. Ensure spray volume and spray pressure are optimized to achieve thorough coverage.

Production Practices

It is well-established that many current practices that increase soybean yields also increase white mold. Whether growers should abandon their yield-enhancing practices to help control white mold is debatable. In areas with lower white mold levels or drier climate, production practices that increase yield but also increase white mold levels may still be highest yielding. However, in areas with higher white mold levels and a cool, wet climate, some change in production practices may be necessary to limit early, dense canopy development.

Row Width - A review of soybean row-spacing studies published within the past 10 years generally confirms previous results comparing 30-inch rows and drilled narrow rows. In 5 studies, drilled soybeans outyielded 30-inch row soybeans by an average of 4.1 bu/acre. Six studies that compared 30-inch rows and 15-inch rows found that 15-inch rows increased yield by 3.6 bu/acre. Yields were similar between 15-inch row and drilled narrow-row soybeans in these studies.

A 6-year research study in Wisconsin measured yield and white mold incidence in 7-inch (drilled) vs. 30-inch rows (Grau, 2001). Though white mold mortality was much higher in drilled beans, the yields were nevertheless equal or higher for drilled vs. 30-inch rows when averaged across years.

These results suggest that narrow-row planting systems should not necessarily be abandoned simply to help control white mold. In fact, narrow-row systems generally increase yields each year, and white mold does not develop every year. However, because research studies have shown that 15-inch rows often yield as well as 7-inch rows, many growers in white mold areas have chosen the 15-inch row width.

Planting Date - Later planted soybeans are generally shorter and less branched and therefore, later to canopy closure. Some planting date studies show that later planting results in less incidence of white mold. However, yields are generally reduced when planting is delayed past mid-May in northern states. The trade off between less yield reduction due to white mold but more yield reduction due to late planting may not be favorable, especially in years of low disease pressure.

Plant Population - Soybean yields generally increase with increased plant population within a range. Studies have demonstrated higher white mold incidence with higher plant population, but yields were not reduced. However, part of the expected increase from higher seeding rates was likely offset by losses from the disease. In fields with high risk of white mold, seeding rates should be sufficient for uniform stand establishment but should not be aggressively high. Actual rates will vary depending on planting date, seedbed conditions, row width and seed quality.

Weed Control - White mold has over 400 plant hosts, including many broadleaf weeds. Host weeds that are also common weed species throughout soybean growing areas include lambsquarters, ragweed, pigweed and velvetleaf. In addition to acting as host to the disease, weeds can also increase canopy density, which favors disease spread.

[1] Many factors including weather influence white mold levels and crop damage from year to year. Your results may vary.

[2] This article is not intended as a substitute for the product label for the products referenced herein. Product labels for the above products contain important precautions, directions for use and product warranty and liability limitations that must be read before using the product. Always read and follow all label directions and precautions for use when using any pesticide. Mention of a product in this article does not imply an endorsement.

RESEARCH UPDATE

Planting Timing and Variety Maturity Effects on Soybean Yield 2012-2013

Objective

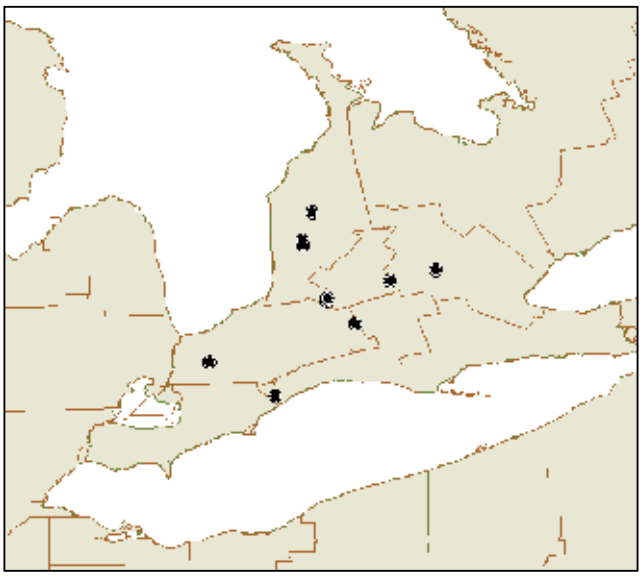
- Compare yield of adapted maturity and later maturity soybean varieties at early and late planting timings in Ontario.

Study Description

Plot Layout: Field-length strips
Replicates: 1-2 per location
Locations: 5 locations in 2012 and 5 in 2013
Factors:
Planting Timing: Early (before May 10)
Late (10-14 days after early planting)
Variety Maturity: Adapted maturity vs. later maturity

Pioneer® Brand Soybean Varieties:

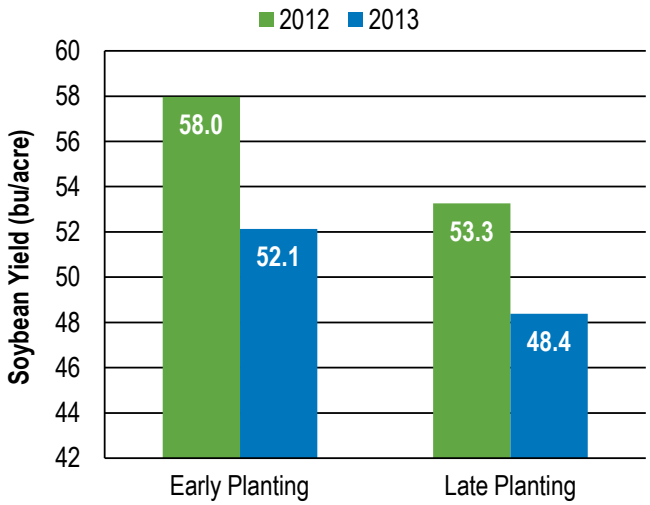
90Y90 (RR) and 91Y61 (RR) – 1 location
91M01 (RR) and 91Y61 (RR) – 4 locations
91Y61 (RR) and 92Y12 (RR) – 4 locations
92Y55 (RR) and 93Y05 (RR) – 2 locations

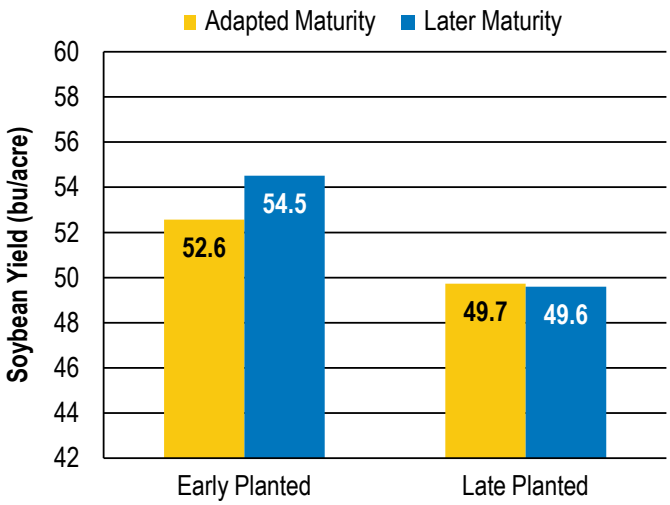


Locations of the trials in 2012 and 2013 in Ontario.

Results

- Soybean yield was significantly affected (p=0.0003) by planting timing. Early planting resulted in an average yield increase of 4.2 bu/acre compared to late planting over the last two years.
- Soybean yield did not significantly differ between adapted maturity and later maturity varieties at either planting timing.





RR - Contains the Roundup Ready® gene. Roundup Ready® is a registered trademark used under license from Monsanto Company. PIONEER® brand products are provided subject to the terms and conditions of purchase which are part of the labeling and purchase documents. 2013 data are based on average of all comparisons made in 5 locations through November 5, 2013. Multi-year and multi-location is a better predictor of future performance. Do not use these or any other data from a limited number of trials as a significant factor in product selection. Product responses are variable and subject to a variety of environmental, disease, and pest pressures. Individual results may vary.

RESEARCH UPDATE

Acapela® Fungicide Application & Planting Rate Effects on Soybean Yield 2013

Objective

- On-farm trials were conducted in Ontario and Quebec to determine yield response of soybeans treated with Acapela® fungicide compared to untreated soybeans when planted at current grower-selected planting rates (normal) and 50,000 seeds/acre over current planting rates (normal + 50,000).

Study Description

Plot Layout: Field-length strips

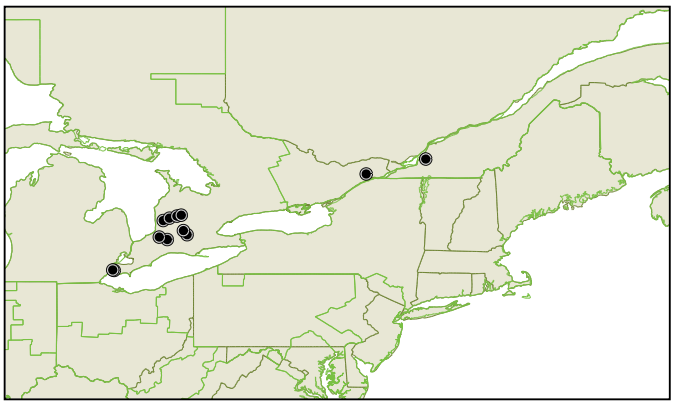
Replicates: 1-2 per location

Locations: 10 locations in Ontario & Quebec

Factors:

Fungicide: Acapela, Nontreated

Seeding Rates: Normal, Normal + 50,000



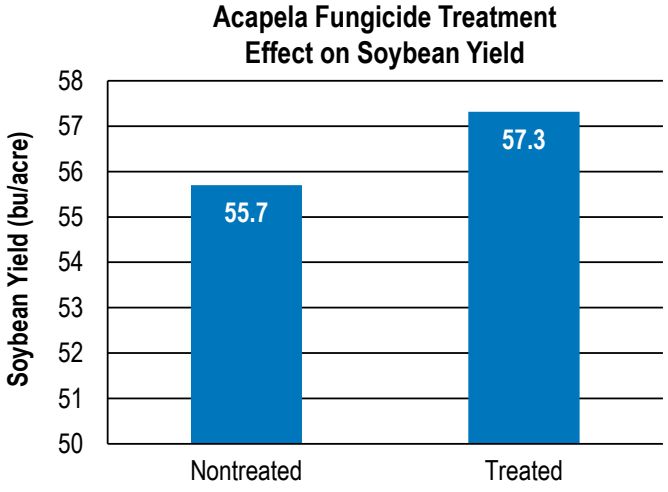
Acapela fungicide on-farm trial locations in 2013.

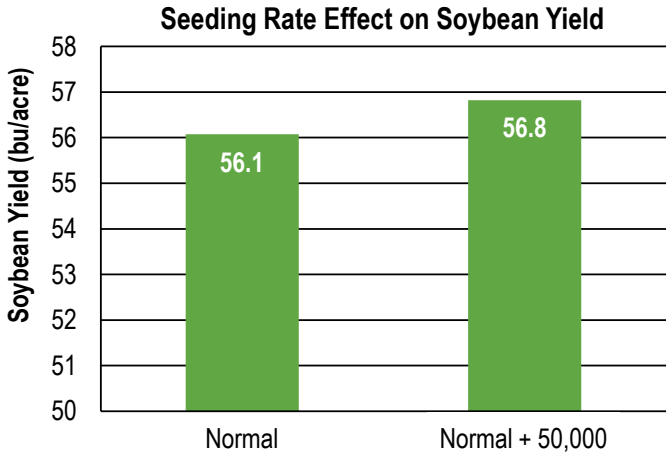
Study Details

- Treatments were compared on the same soybean variety within a location.
- Soybean maturities ranged from group 00 to 3.

Results

- Soybean yield was significantly affected by fungicide treatment (p=0.05) but not by seeding rate or the interaction of fungicide treatment and seeding rate.
- Treatment with Acapela fungicide increased soybean yield by an average of 1.6 bu/acre compared to nontreated soybean.
- Similar results were observed in a 2012 study, in which soybean yield was significantly increased (p=0.0007) by an average of 2 bu/acre with Acapela fungicide treatment across 45 on-farm trials in Ontario, Quebec and Manitoba.





2013 data are based on average of all comparisons made in 10 locations through November 4, 2013. Multi-year and multi-location is a better predictor of future performance. Do not use these or any other data from a limited number of trials as a significant factor in product selection. Product responses are variable and subject to a variety of environmental, disease, and pest pressures. Individual results may vary.

DuPont Pioneer Agronomy Sciences

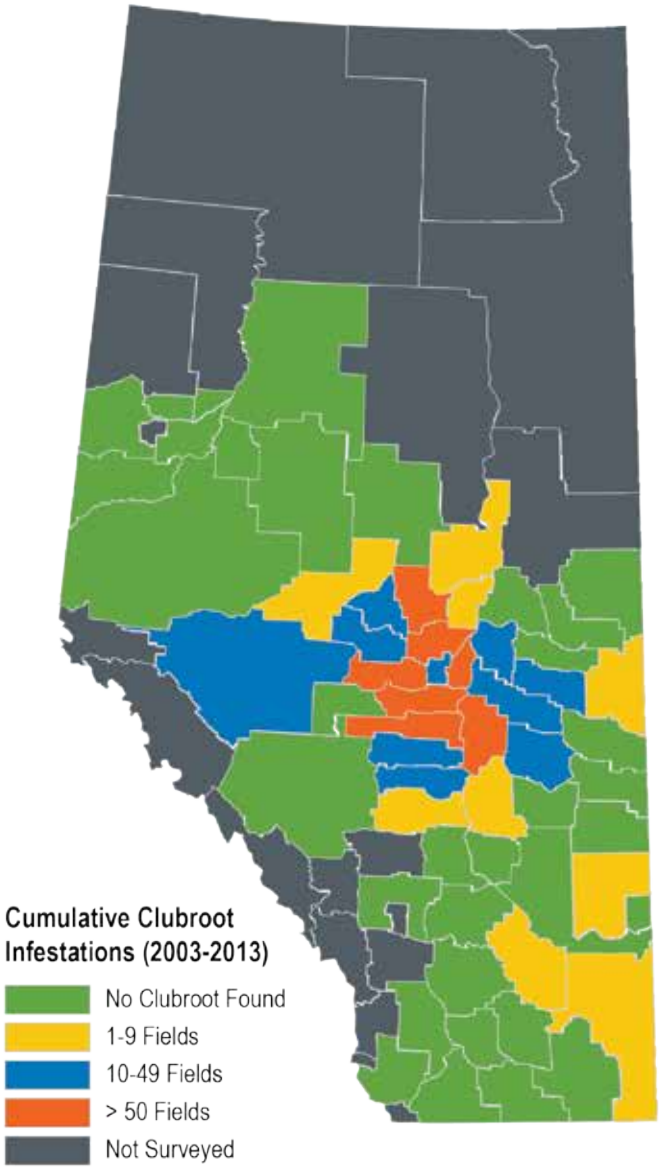
Clubroot Disease of Canola – Western Canada Update

Clubroot Infection and Spread

- Clubroot is a soil-borne disease of cruciferous crops and weeds and is caused by *Plasmodiophora brassicae*, a protist pathogen that induces gall formation on infected roots of susceptible plants.
- Infections occur when exudates from roots of host plants trigger germination of resting spores in the soil, producing zoospores. They swim in soil water to root hairs that they infect to start the formation of the root galls.
- The disease is favoured by warm soil (20-24° C), high soil moisture and low soil pH (< 6.5) but can still develop outside these optimum conditions.
- Clubroot is mainly spread through movement of soil containing the long-lived resting spores that are released into the soil when the galls decay.
- To estimate yield loss due to clubroot, take the percentage of infected plants in a field and divide by two (recognizing that losses > 50% can occur from extreme infestations). For example, if 50% of the plants are infected, a 25% yield loss would be estimated.

Clubroot in Western Canada

- Clubroot was first reported in western Canada in canola fields in the Edmonton area in 2003. Since 2003, additional canola fields in Alberta have been identified with clubroot every year.
- In 2013, 459 fields were surveyed in Alberta for clubroot. 418 new cases of clubroot were found, bringing the total number of fields in Alberta with confirmed clubroot to 1,483 (>235,000 acres) (Strelkov et al., 2013).
- In 2008, one canola field was identified in Saskatchewan with spore concentrations sufficient to produce clubroot symptoms in plants.
- Recently, confirmation of clubroot symptoms were found in two Manitoba canola fields and one Saskatchewan commercial canola field. What this means is that growers in all three Prairie Provinces need to be vigilant with their scouting program and have in place a management strategy for this disease.
- Effectively managing any plant disease requires an understanding of how it survives within fields and the conditions that allow the population to increase and spread.



The occurrence of clubroot on canola in Alberta in 2013 *(Adapted from Strelkov et al., 2013)*

Source: Canola Council of Canada

DuPont Pioneer Agronomy Sciences

What Can You Do To Protect Your Crop From Clubroot?

Early Identification

- Scout canola fields regularly from late rosette through podding, being sure to examine the roots of plants.
- High risk areas for clubroot include field entrances and low lying areas, but it could show up anywhere.

Clean Your Equipment

- Cleaning equipment helps avoid the movement of soil from infested to non-infested fields.
- If you do not have clubroot on your farm, the greatest risk of infestation comes from equipment that was previously used for tillage or excavation off-farm.
- If you have found clubroot in some of your fields, sanitation when leaving those fields is critical to reduce spread throughout the rest of the farm.

The roots and stalk of clubroot resistant hybrid (left) are healthy and unaffected compared to the clubroot susceptible hybrid which exhibits the characteristic galls (right).

Photo Courtesy: Michael Raine, Western Producer, 2009

Grow Clubroot-Resistant Canola Hybrids

- Pioneer Protector® Clubroot resistance, as found in Pioneer® hybrid 45H29 (RR), provides multi-race resistance and a high level of resistance to the most prevalent race in Alberta (Race 3) as well as races 2, 5, 6 and 8.
- This effectively reduces incidence and severity of gall formation in affected fields, protecting yield and reducing the number of resting spores re-introduced into the soil.

Rotate to Non-Host Crops

- Tight canola rotations do not cause clubroot but can increase the rate of spore build-up once the disease is present in a field.
- They can also increase selection pressure for breakdown of resistance deployed in infested fields.
- Good weed management of alternate hosts is essential to maximize reduction in viable spore numbers between canola crops.

Plan Your Strategy

- Clubroot can be managed effectively, but once it is present, it moves with soil regardless of the crop being grown.
- Manage infested patches separately to limit growth of host plants and equipment traffic, and develop a suitable rotation to maintain the effectiveness of available genetic resistance.

PIONEER PROTECTOR CLUBROOT

Strelkov et al., 2013. The Occurrence of Clubroot on Canola in Alberta in 2013. Internet: www.2020seedlabs.ca Accessed: December 6, 2013

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[3] **RR** - Contains the Roundup Ready® gene. Roundup Ready® is a registered trademark used under license from Monsanto Company.

DuPont™ Lumiderm™ – New Canola Insecticide Seed Treatment Technology

DuPont Pioneer has introduced a new addition to its premium canola seed treatment package – DuPont™ Lumiderm™ insecticide seed treatment. Lumiderm insecticide can now be added to the standard Helix® Vibrance™ seed treatment that is available on all Pioneer® brand canola seed.

Add Lumiderm insecticide to your Pioneer brand canola seed treatment package

Here's why:

- First canola seed treatment product that controls cutworms
- New class of chemistry (Group 28) for a resistance management strategy
- Improves consistency of flea beetle control when used with Helix Vibrance seed treatment
- Residual control – up to 35 days protection from cutworms and other insect pests through the critical stages of seedling growth
- Contributes to very good early season stand establishment & vigour

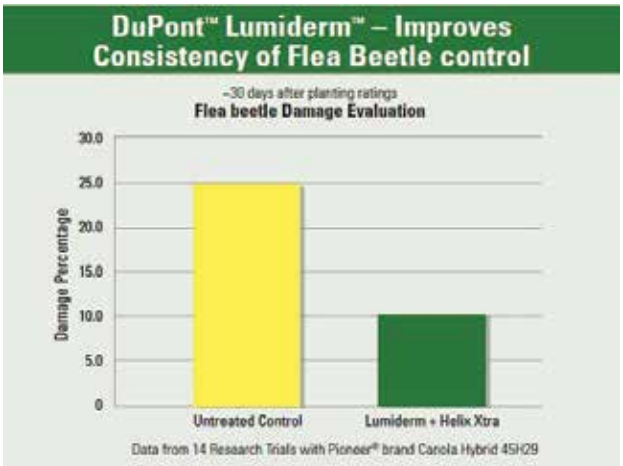
Enhanced Flea Beetle Control

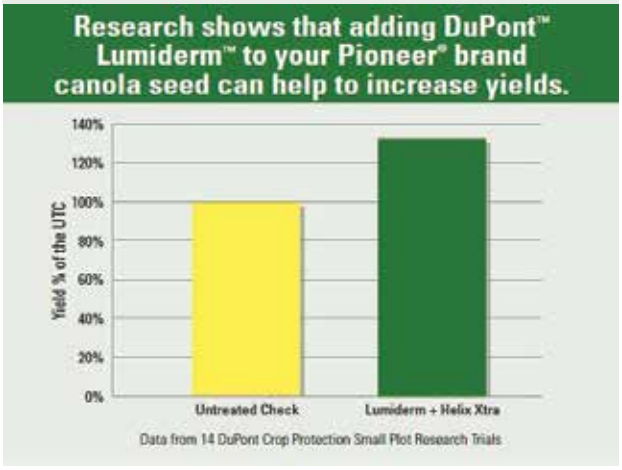
- Flea beetles are small, leaf-feeding insects with greatly enlarged hind femurs and have a habit of jumping when disturbed, which makes them difficult to see and even more difficult to scout.
- Flea beetles are the most chronically damaging insect pest of canola in Western Canada. Direct losses to oilseed production average 8-10% of the annual crop yield, and in outbreak years, flea beetles can cause hundreds of millions of dollars in damages.
- **Pioneer brand canola seed treated with a combination of Lumiderm and Helix Vibrance insecticide seed treatment outperforms untreated seed and provides more consistent, longer-lasting flea beetle control than conventional insecticide seed treatments.**

Source: Canola Council of Canada

Untreated

Lumiderm + Helix Vibrance





DuPont Pioneer Agronomy Sciences

Consistent Cutworm Control

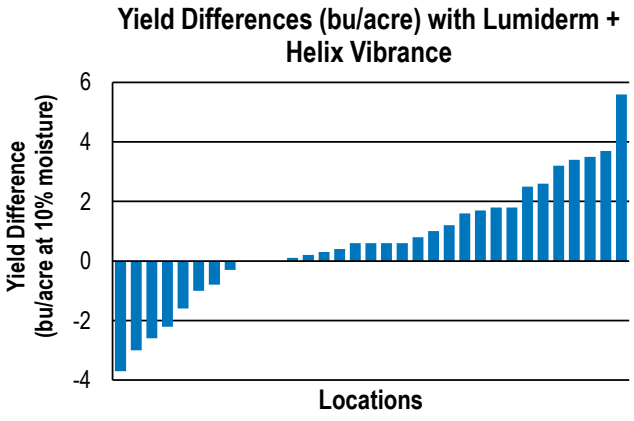
- Cutworms can be a significant pest of agricultural crops in Western Canada that can wipe out huge patches of your canola within a couple of days.
- Cutworms usually feed at night and then go under-ground during the day, making them very difficult to scout. Cutworm damage will often appear in patches and can cause severe damage before you are even aware they are actively feeding on your canola crop. They feed anywhere on the canola plant and can consume the entire plant.
- **DuPont™ Lumiderm™ is the first and only insecticide seed treatment to control cutworms in canola.**

Canola crop with a large patch wiped out due to cutworm damage.

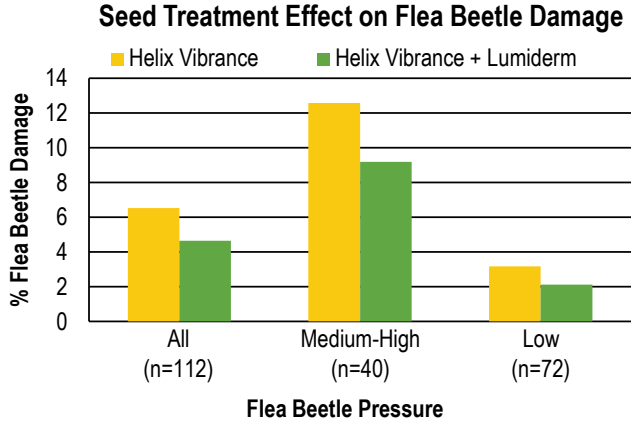
Non-Treated | Standard Treatment | Lumiderm Insecticide

2013 Seed Treatment Trials

- Trials were conducted across Western Canada in 2013 comparing two canola seed treatments: Helix® Vibrance™ and Helix Vibrance + Lumiderm. Treatments were applied on Pioneer® hybrid 45S52 canola.
- Over these sites in 2013, there was low to moderate pressure from flea beetle and low pressure from cutworm.
- The Helix Vibrance + Lumiderm seed treatment resulted in higher yields in 73% of the trials.



- 112 locations in Western Canada were evaluated to measure Lumiderm performance on flea beetle.
- 72 of the locations were in areas with low flea beetle pressure. In these locations, a 33% reduction in flea beetle damage to the canola was observed with the Helix Vibrance + Lumiderm seed treatment.
- 40 locations were conducted under medium to high flea beetle pressure; at these locations, a 27% reduction in flea beetle damage to the canola was observed with the Helix Vibrance + Lumiderm seed treatment.



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[2] Product responses are variable and subject to a variety of environmental, disease and pest pressures. Individual results may vary.

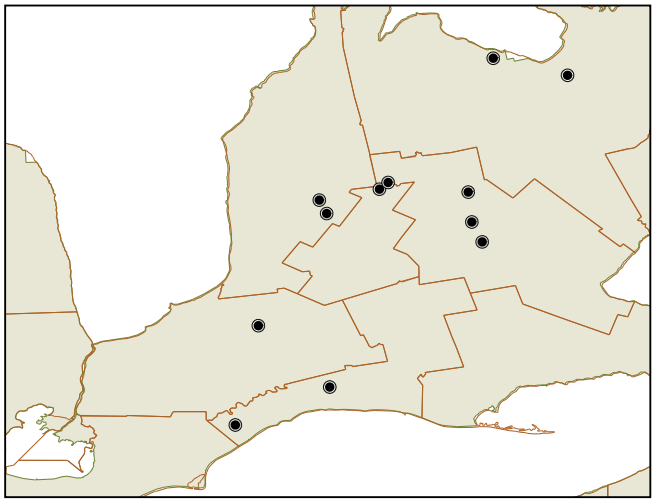
[3] All products are trademarks of their manufacturers. DuPont™ and Lumiderm™ are trademarks of DuPont.

RESEARCH UPDATE

Yield Response of Fungicide-Treated Wheat to Nitrogen Rate 2013

Objectives

- Previous research has shown evidence of a positive interaction between fungicide and nitrogen inputs in their effect on wheat yield.
  - Small plots trials conducted in 2008-2010 found a greater yield response to nitrogen fertilizer rate in fungicide-treated wheat than non-treated wheat.
- Field-scale on-farm trials were conducted in 2012 and 2013 to determine the yield response of wheat treated with fungicide to nitrogen fertilizer rate.



Locations of thirteen field-scale nitrogen rate trials conducted in southern Ontario in 2012 and 2013.

Study Description

Locations: 13 locations across southern Ontario from 2012 to 2013

Pioneer® Brand Varieties: 25R40 , 25R39 and 25R34

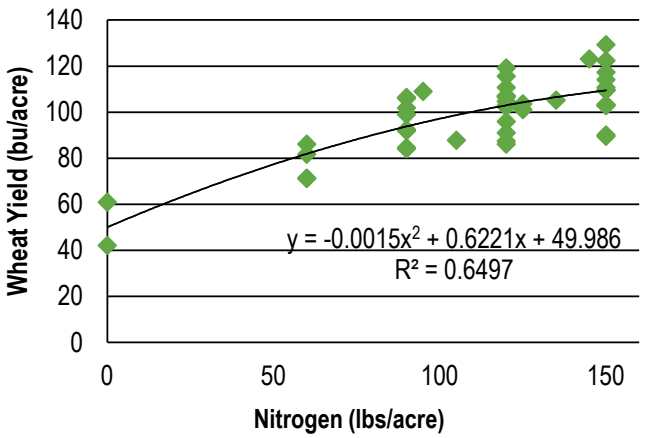
Nitrogen Rate: 60, 90, 120 and 150 lbs/acre

- Wheat varieties varied by location; each location included a single variety.
- Not all nitrogen rates were applied at all locations.

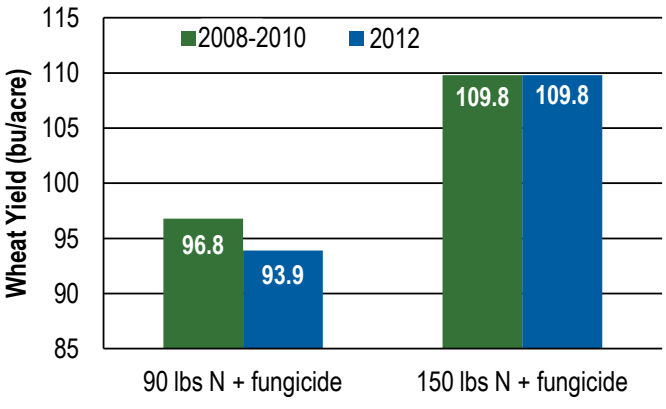
Results

- Average yield of wheat treated with a fungicide at T3 increased with nitrogen fertilizer rate up to the highest treatment rate of 150 lbs/acre.
- Average wheat yields with 90 and 150 lbs/acre of nitrogen were very similar to those observed in field-scale trials conducted by OMAFRA in 2008-2010.

2012-2013 Wheat Yield Response to Nitrogen Fertilizer



2008-2010 and 2012 Yield Response to Nitrogen Rates



Product performance in water-limited environments is variable and depends on many factors such as the severity and timing of moisture deficiency, heat stress, soil type, management practices, and environmental stress as well as disease and pest pressures. All hybrids may exhibit reduced yield under water and heat stress. Individual results may vary.

AMXT - Optimum® AcreMax® XTreme contains a single-bag integrated refuge solution for above- and below-ground insects. The major component contains the Agrisure® RW technology, the YieldGard® Corn Borer gene, and the Herculex® XTRA genes.

AM - Optimum® AcreMax® Insect Protection system with YGCB, HX1, LL, RR2. Contains a single-bag integrated refuge solution for above-ground insects. In EPA-designated cotton growing counties, a 20% separate refuge must be planted with Optimum AcreMax products.

AMX - Optimum® AcreMax® Xtra Insect Protection system with YGCB, HXX, LL, RR2. Contains a single-bag integrated refuge solution for above- and below-ground insects. In EPA-designated cotton growing counties, a 20% separate refuge must be planted with Optimum AcreMax Xtra products.

AM1 - Contains the Optimum® AcreMax® 1 Insect Protection System with an integrated corn rootworm refuge solution includes HXX, LL, RR2. Optimum AcreMax 1 products contain the LibertyLink® gene and can be sprayed with Liberty® herbicide. The required corn borer refuge can be planted up to half a mile away.

Agrisure® is a registered trademark of, and used under license from, a Syngenta Group Company. Agrisure® technology incorporated into these seeds is commercialized under a license from Syngenta Crop Protection AG.

LL - Contains the LibertyLink® gene for resistance to Liberty® herbicide. Liberty®, LibertyLink® and the Water Droplet Design are trademarks of Bayer.

RR2 - Contains the Roundup Ready® Corn 2 gene that provides crop safety for over-the-top applications of labeled glyphosate herbicides when applied according to label directions.

YGCB - The YieldGard® Corn Borer gene offers a high level of resistance to European corn borer, southwestern corn borer and southern cornstalk borer; moderate resistance to corn earworm and common stalk borer; and above average resistance to fall armyworm.

YieldGard®, the YieldGard Corn Borer design and Roundup Ready® are registered trademarks used under license from Monsanto Company.

HX1 - Contains the Herculex® I Insect Protection gene which provides protection against European corn borer, southwestern corn borer, black cutworm, fall armyworm, western bean cutworm, lesser corn stalk borer, southern corn stalk borer, and sugarcane borer; and suppresses corn earworm.

HXX - Herculex® XTRA contains the Herculex I and Herculex RW genes.

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