PIONEER®

SILAGE ZONE® MANUAL

FOURTH EDITION

Plant
Grow
Harvest
Store
Feed
The Silage Zone®

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PLANT

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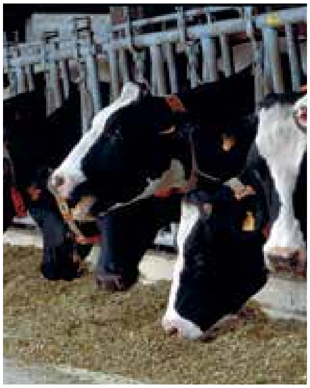
INTRODUCTION

Ensiled forage and cereal crops, utilized in the feeding of livestock, have long been a fundamental link in the food chain. The ensiling of forage and grains allows for year-round availability of nutritious and palatable feed while utilizing a smaller land base than grazing. By their conversion into milk and meat products, ensiled feeds contribute to the nourishment of mankind.






With proper management, many different crops can be ensiled as livestock feed. However, when analyzed individually, various crops have differing potential to satisfy livestock nutritional requirements. For example, ensiled cereal grains like high-moisture corn are an excellent source of energy, while alfalfa is utilized primarily as a fiber and protein source.

Feed cost represents the largest single expenditure on most livestock operations. The production of high quality silages can help reduce the cost associated with feeding concentrates and supplements. For dairy and beef producers, whole-plant corn, high-moisture corn, alfalfa, cereal, and a variety of grass species are the silages of most economic significance. This manual will focus primarily on corn silage, high-moisture corn and alfalfa silages.

The Silage Zone® Manual has been developed to provide a concise source of relevant information on the five most important aspects of silage production: **PLANT, GROW, HARVEST, STORE** and **FEED**. A profitable silage program hinges on the success and interaction of each of these unique and important functions.

PLANT

CORN

Corn silage is increasingly becoming the forage of choice for many livestock producers due to factors such as high yields of a high energy (starch) crop, a single harvest period, and the ability to utilize relatively high amounts of waste water/manure. Matching the product selection for each acre based on a grower's tillage practices, drought potential, soil fertility, disease, pest prevalence and harvest capacity are critical to the total success of a corn growing program.

SILAGE HYBRID SELECTION

The five most important considerations when choosing a hybrid for silage or high-moisture corn has to be:

1) hybrid maturity,
2) desired technology traits (e.g. herbicide resistance, corn borer, corn rootworm, black cutworm and western bean cutworm),
3) agronomic stability (e.g. stress emergence, drought tolerance),
4) inherent genetic resistance to yield robbing diseases such as leaf diseases (e.g. gray leaf spot, northern and southern leaf blight, common and southern rust) and ear rots (e.g. fusarium, gibberella, diplodia) and proven yield potential (e.g. tonnage and starch).
5) proven yield potential (e.g. tonnage and starch)

It is recommended to select silage hybrids that are 5-10 days longer than would be grown for grain because the heat units are not needed to mature the crop to typical grain (combining) maturities. This approach will help maximize silage yield and starch content. If maturity is too long for the growing zone, starch levels and total yield may be compromised by a frost incident.

Corn hybrid maturity ratings help growers select and compare hybrids, manage agronomic risk, and spread harvest timing. What is often misunderstood by growers is there is no industry standard for these ratings, so comparing hybrids across companies can be challenging.

Hybrids within each individual seed company are typically rated for CRM (Comparative Relative Maturity) or RM (Minnesota Relative Maturity) and in the U.S., this is reported in calendar days (e.g. 105-day hybrid). In Canada, hybrid maturity is reported as CHU or Corn Heat Units (e.g. 3100 CHU). Multiplying the CRM of a U.S. hybrid by 30 will approximate the CHU rating (e.g. 100-day CRM ~ 3000 CHU hybrid). Europeans use the Food and Agriculture Organization (FAO) method of crop maturity.

The most important word in the CRM acronym is "relative" because the values are based on comparisons within each seed company's own hybrids, not necessarily against competitive hybrids. The most common approach to assigning a new grain CRM is to compare grain harvest maturity (20-22% kernel moisture) to other current commercial hybrids in the company lineup. This overall grain CRM is a function of when the plant reaches physiological maturity (black layer or zero kernel milkline) and the dry down characteristics of the hybrid. With this approach, growers have a "relative" idea of how hybrids from the same company will advance through the various reproductive stages but it does not represent actual days from planting or emergence to harvest moisture. Some companies also report silage CRM based either on comparing whole-plant moistures to known silage check hybrids or regressing grain data to a silage kernel maturity standard such as 50% milk line.

Seed companies may conduct research trials comparing their approach to assigning maturity to competitors and make subtle adjustments to how they are reporting hybrid maturities. For example, if a seed company observes a disadvantage in harvested grain moisture levels, they will want to be sure they are aligning their maturity ratings as closely as possible to key competitors.

It is important to read individual seed company footnotes to clearly understand the rating definitions. A grain hybrid will typically be given an overall CRM, a silking CRM and physiological CRM (black layer or zero milkline). Physiological CRM can be particularly important for growers harvesting high-moisture corn or snaplage. Hybrids within the same genetic family, but containing different technology traits, will often be assigned the same maturity. However, depending upon level of insect infestation, these hybrids may differ by 2-3 days in maturity. For example, a hybrid with corn borer and rootworm resistance traits will likely be healthier under heavy insect infestation compared to the same base genetics lacking these technology traits.

Most seed companies also report average GDUs (growing degree units, also known as Growing Degree Days or Heat Units) to silking and GDUs to physiological maturity (kernels 30-34% moisture). There are different methods of calculating GDU heat unit accumulation, but the most common is the Base 50 Method. This method is based on the use of minimum (50ºF) and maximum (86ºF) temperatures for corn growth and development. GDUs can be used to predict crop development by totaling accumulated GDUs for a specific time period. Canada uses a different system called CHU (corn heat unit) to track accumulated heat units and define the maturity of corn hybrids. Just like relative maturity ratings, GDUs are also difficult to compare across seed companies. This can be due to the use of different formulas or the use of formulas not accounting for the length of time maximum or minimum temperatures were held, or the location of research stations used to generate GDU values.

Longer-season hybrids generally have more yield potential than shorter-season hybrids. GDU to physiological maturity (black layer) is probably the best overall indicator to determine if a hybrid can mature for grain harvest based on comparisons with long-term GDU accumulation records for that particular geography. The length of time for the grain to dry down to 20-22% harvest moisture can also vary by hybrid drydown rate (also typically given a relative score in most seed catalogs).

Some growers like to reduce risk by spreading the pollination period between hybrids. However, planting hybrids with different CRM ratings (e.g. 105 day) may not always provide the desired effect because they could both have similar GDU to silking. It is best to consult GDU to silk ratings to see the relative difference in timing of pollen shed and silk emergence. Remember that it is difficult to compare GDU to silk across companies. To help determine if a new hybrid will adapt to local conditions, compare the silk rating

GROWING DEGREE UNIT REQUIREMENTS FOR GROWTH STAGES OF A 2700 GDU HYBRID

GROWTH STAGE	PLANT CHARACTERISTICS	GDU
	Planting	0
Vegetative	Two leaves fully emerged	200
	Four leaves fully emerged	345
	Six leaves fully emerged (growing point above soil)	476
	Eight leaves fully emerged (tassel beginning to develop)	610
	Ten leaves fully emerged	740
	Twelve leaves fully emerged (ear formation)	870
	Fourteen leaves fully emerged (silks developing on ear)	1000
	Sixteen leaves fully emerged (tip of tassel emerging)	1135
Reproductive	Silks emerging/pollen shedding (plant at full height)	1400
	Kernels in blister stage	1660
	Kernels in dough stage	1925
	Kernel denting	2190
	Kernels dented	2450
	Physiological maturity	2700

Adapted from the National Corn Handbook

GDU (Growing Degree Unit) CALCULATION

GDU Base 50 = [(daily maximum temp in degrees Fahrenheit + daily minimum temp in degrees Fahrenheit)/2] – 50

If the minimum temperature is below 50°F, then 50 is used as the minimum temperature. Similarly, the upper limit is 86°F. If maximum temperature exceeds 86°F, then 86 is used as the maximum temperature.

Example: when daily high = 86°F and daily low = 65°F; then GDU = (86 + 65/2) – 50 = 25.5

CHU (Corn Heat Unit) CALCULATION

CHU = [1.8 (daily minimum temperature in °C – 4.4) + 3.3 (daily maximum temperature in °C – 10) – 0.084 (daily maximum temperature in °C – 10) °] / 2

As with GDU, this calculation assumes no corn growth with night temperatures below 4.4°C or daytime temperatures below 10°C and an upper threshold of 30°C

An approximate conversion between the two systems is to multiply the CRM day length of a hybrid by 30 to approximate maturity in terms of CHU.

Example: a 100-day CRM hybrid is approximately a 3,000 CHU hybrid

CORN RELATIVE MATURITY RATING SYSTEMS: RM, GDUs, OCHUs, and FAO.

MINNESOTA RELATIVE MATURITY (days)	U.S. GROWING DEGREE DAYS (GDUs)	ONTARIO CORN HEAT UNITS (OCHUs)	FAO (units)
70	1650	2100	100
75	1750	2300	
80	1850	2500	200
85	1950	2600	
90	2050	2700	300
95	2150	2800	
100	2250	2900	400
105	2350	3200	
110	2450	3400	500
115	2550	3500	
120	2650	3700	600
125	2750	3900	
130	2850	4100	700
135	2950	4300	
140	3050	4500	800

Source: Handbook of Maize: Genetics and Genomics. 2010, ISBN-10 1441926690

to a well-known hybrid (from the same company). Research shows that earlier silking hybrids generally move north of their adapted zone and more readily adapt to higher elevations. If moved too far north or in elevation, late silking hybrids may not reach physiological maturity before first frost, or may have reduced grain yield potential if abnormally late silking exposes the crop to cooler temperatures during grain fill.

The best source of information on hybrid maturity is the local Pioneer sales professional or agronomist. They will certainly know their hybrid lineup and have likely seen competitor's in various plots to help put company differences in perspective.

For silage producers, a focus on the three important traits of agronomic stability (over diverse growing seasons), yield and starch content will help in sorting through the reams of silage hybrid data. University of Wisconsin research shows that silage tonnage (dry matter yield) is primarily a function of:

1) harvest timing,
2) hybrid genetics (plant height and starch yield) and
3) planting date.

Harvest timing is important because grain (starch) typically contributes about half of the dry matter yield (and 65% of the energy) and given the value of grain, must factor heavily in silage hybrid decisions.

Neutral detergent fiber digestibility (NDFD) tends to be the measurement of most interest, especially among nutritionists. However, while small NDFD differences do exist among conventional silage hybrids (2-3 percentage points), the biggest influence over NDFD is the growing environment that plants receive during the vegetative growth stage (see more in the GROW section). Pioneer researchers have concluded that growing environment is three-times more influential over fiber digestibility than genetics. This is why the seed industry has resorted to the use of Brown MidRib (BMR) genetics as the only practical approach to significantly improve NDFD. When evaluating NDFD, be sure you note the incubation time point (e.g. 24 vs. 30 vs. 48-hour) when comparing values from different laboratory reports.

Some growers also like to evaluate hybrids based on indexes such as Net Energy of Lactation (NE-L) or University of Wisconsin's "Milk per Ton" and "Milk per Acre." While they can be useful in ranking hybrids, it still makes sense to evaluate the absolute value of the traits (yield, starch, fiber digestibility) that influence these index values. Sharing the relative importance of key silage traits with seed representatives can help them better sort through their lineup to suggest a suitable hybrid rather than selecting a hybrid based on composite index values where input traits may be weighted differently than desired by an individual grower.

Traits like crude protein and oil content are less important simply because there are minimal genetic differences between these traits among commercial hybrids. Sugar is another trait found on some plot reports. Difference in sugar content is primarily due to maturity differences between hybrid entries. Sugar is translocated and deposited in the kernel as the plant matures, and those hybrids higher in sugar are typically less mature as evidenced by higher whole-plant moistures and lower starch content. Fiber values such as the quantity of acid detergent fiber (ADF), neutral detergent fiber (NDF) and undigested neutral detergent fiber (uNDF) are important in total ration formulation. However, their importance in evaluating hybrid genetics is minimal because their absolute values are impacted from dilution by starch and sugar.

Some nutritionists also request ruminal starch digestibility values on silage plot reports. Most university and seed company silage hybrid testing programs do not provide starch digestibility values. This is understandable given the fact that starch digestibility, as influenced by the amount of hard or vitreous starch in the kernel, is a trait also lacking in significant variation among commercially available hybrids. While differences clearly exist in the amount of vitreous starch among hybrids harvested at grain (combining) maturity as evidenced by differences in test weights, there are minimal differences in the amount of vitreous starch among corn silage hybrids harvested when kernels are pre-blacklayer maturity (e.g. 1/2-3/4 milk line). Furthermore, the length of time silage kernels are exposed to the fermentation environment influences ruminal starch digestibility. While starch digestibility is an important measurement for nutritionists switching from long-stored corn silage to new-crop silage, it is not a trait that should be given consideration when selecting silage hybrid genetics.

Research by corn breeders suggests that to be 95% confident in selecting the best hybrid for silage yield or nutritional traits, a minimum of 20 direct, side-by-side comparisons (in the same plot) are recommended. Hybrids should also be compared within the same maturity, seed treatment, technology segment, planting population and chop height. It is also desirable to compare hybrids in multiple environments and growing seasons to better understand hybrid stability when exposed to extremes in growing conditions. Data from a single plot, while certainly of interest to growers wanting to know how a hybrid may perform on their farm, is essentially meaningless from a statistical perspective. This is due to the variability caused by soil compaction, previous crop history, fertility/manure history, soil type, water availability, tillage, and insect damage. To overcome the possibility of a "one-year wonder," some university silage programs also show multiple year data if the hybrid was entered in their plots more than one year.

Most university silage plot programs offer statistical parameters to help evaluate the robustness of the comparison data. Typically this is in the form of an average (mean) value for the trait and a Least Significant Difference (LSD) which is used to determine if the hybrids are statistically (rather than just numerically) different. If the difference between the two hybrid values are equal to or greater than the LSD value (at the 10% level), then 90% of the time, the hybrids are statistically different for that particular trait.

It is best to secure as much information as possible on the performance of a silage hybrid. Do not be satisfied with catalog scores (e.g. 1-9). Seed companies serious about silage will be able to provide absolute values for important silage traits compared against their own hybrids as well as competitors. Finally, be cautious about putting too much credence in "beauty-pageant" forage contests where yield is not considered and there is no way to ensure that all entries were chopped at the same height.

Corn Traits and Technology (as of August 2020)

Efficacy levels based on Corteva Agriscience™ and/or independent university entomologist results against susceptible insect populations. Product responses can vary by location, pest population, environmental conditions, and agricultural practices.

Various factors, including pest pressure, reduced susceptibility, and insect resistance in some pest populations may affect efficacy of certain corn technology products in some regions. To help extend durability of these technologies, Corteva Agriscience recommends you implement Integrated Pest Management (IPM) practices such as crop rotation, cultural and biological control tactics (including rotating sources of Bt-protected corn traits), pest scouting, and appropriate use of pest thresholds when employing management practices such as insecticide application.

You must also plant the required refuge when using these technologies. Please contact your sales professional or consult with your local university extension for more information regarding insect resistance management guidelines, best management practices and to understand whether there has been a shift in susceptibility or insect resistance with certain pests documented in your area.

* Western bean cutworm has been removed from the Corteva Agriscience product use statement for several corn products that contain Herculex I (Cry1F) but lack another mode of action for western bean cutworm due to a wide-spread decrease in susceptibility indicating the possibility of field-evolved resistance to Cry1F in most geographies.

C = Controlled S = Suppressed
Blank = Not Labeled

All scores of integrated refuge products are based upon the major component.

CORN TECHNOLOGY TRAITS
INTEGRATED REFUGE PRODUCTS
Optimum® AcreMax® (Corn Borer)
Optimum® AcreMax® Leptra® (Corn Borer/Corn Earworm)
PowerCore® Refuge Advanced® (Corn Borer)
Optimum® AcreMax® TRIsect® (Corn Borer/Rootworm)
Optimum® AcreMax® Xtra (Corn Borer/Rootworm)
Optimum® AcreMax® XTreme (Corn Borer/Rootworm)
Qrome® (Corn Borer/Rootworm)
SmartStax® Refuge Advanced® (Corn Borer/Rootworm)
Optimum® AcreMax® RW (Corn Rootworm)
STRUCTURED REFUGE PRODUCTS
Herculex® I (Corn Borer)
PowerCore® (Corn Borer)
PowerCore® Enlist™ (Corn Borer)
Optimum® Intrasect® (Corn Borer)
Optimum® Leptra® (Corn Borer/Corn Earworm)
Herculex® XTRA (Corn Borer/Rootworm)
Optimum® TRIsect® (Corn Borer/Rootworm)
Optimum® Intrasect® Xtra (Corn Borer/Rootworm)
Optimum® Intrasect® TRIsect (Corn Borer/Rootworm)
Optimum® Intrasect® XTreme (Corn Borer/Rootworm)
Optimum® AcreMax® 1 (Corn Borer/Rootworm)
SmartStax® (Corn Borer/Rootworm)
SmartStax® Enlist™ (Corn Borer/Rootworm)

	INSECT EFFICACY LEVELS												
	European Corn Borer	Corn Earworm #	Western Bean Cutworm *	Fall Armyworm #	Black Cutworm	Southwestern Corn Borer #	Lesser Cornstalk Borer	Sugarcane Borer	Southern Cornstalk Borer	Stalk Borer (Common)	Western Corn Rootworm #	Northern Corn Rootworm	Mexican Corn Rootworm
	C	S		C	C	C	C	C	C	S			
	C	C	C	C	C	C	C	C	C	C			
	C	S		C	C	C	C	C	C	S			
	C	S		C	C	C	C	C	C	S	C	C	C
	C	S		C	C	C	C	C	C	S	C	C	C
	C	S		C	C	C	C	C	C	S	C	C	C
	C	S		C	C	C	C	C	C	S	C	C	C
	C	S		C	C	C	C	C	C	S	C	C	C
											C	C	C
	C	S		C	C	C	C	C	C				
	C	S		C	C	C	C	C	C	S	C	C	C
	C	S		C	C	C	C	C	C	S	C	C	C
	C	S		C	C	C	C	C	C	S	C	C	C
	C	C	C	C	C	C	C	C	C	C			
	C	S		C	C	C	C	C	C		C	C	C
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	C	S		C	C	C	C	C	C	S	C	C	C
	C	S		C	C	C	C	C	C		C	C	C
	C	S		C	C	C	C	C	C	S	C	C	C
	C	S		C	C	C	C	C	C	S	C	C	C

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 products may exhibit reduced yield under water and heat stress. Individual results may vary.

TECHNOLOGY SEGMENT: AM1 - 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. **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 corn borer refuge must be planted with Optimum AcreMax products. **AMT** - Optimum® AcreMax® TRIsect® insect protection system with RW,YGCB,HX1,LL,RR2. Contains a single-bag refuge solution for above- and below-ground insects. The major component contains the Agrisure® RW trait, the Bt trait, and the Herculex® I gene. In EPA-designated cotton-growing counties, a 20% separate corn borer refuge must be planted with Optimum AcreMax TRIsect 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 corn borer refuge must be planted with Optimum AcreMax Xtra products. **AMXT** (Optimum® AcreMax® XTreme) - Contains a single-bag integrated refuge solution for above- and below-ground insects. The major component contains the Agrisure® RW trait, the Bt trait and the Herculex® XTRA gene. In EPA-designated cotton-growing counties, a 20% separate corn borer refuge must be planted with Optimum AcreMax XTreme products. **Q** (Qrome®) - Contains a single-bag integrated refuge solution for above- and below-ground insects. The major component contains the Agrisure® RW trait, the Bt trait, and the Herculex® XTRA gene. In EPA-designated cotton-growing counties, a 20% separate corn borer refuge must be planted with Qrome products. Qrome products are approved for cultivation in the U.S. and Canada. They have also received approval in a number of importing countries, most recently China. For additional information about the status of regulatory authorizations, visit http://www.biotradestatus.com/. **YGCB,HX1,LL,RR2** (Optimum® Intrasect®) - Contains the Bt trait and Herculex® I gene for resistance to corn borer. **YGCB,HXX,LL,RR2** (Optimum® Intrasect® Xtra) - Contains the Bt trait and the Herculex® XTRA gene for resistance to corn borer and corn rootworm. **RW,HX1,LL,RR2** (Optimum® TRIsect®) - Contains the Herculex® I gene for above-ground pests and the Agrisure® RW trait for resistance to corn rootworm. **AML** - Optimum® AcreMax® Leptra® products with AVBL, YGCB, HX1, LL, RR2. Contains a single-bag integrated refuge solution for above-ground insects. In EPA-designated cotton-growing counties, a 20% separate corn borer refuge must be planted with Optimum AcreMax Leptra products. **AVBL,YGCB,HX1,LL,RR2** (Optimum® Leptra®) - Contains the Agrisure Viptera® trait, the Bt trait, the Herculex® I gene, the LibertyLink® gene and the Roundup Ready® Corn 2 trait. **HX1** - Contains the Herculex® I insect protection gene which provides protection against European corn borer, southwestern corn borer, black cutworm, fall armyworm, 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 gene. **YGCB** - The Bt trait 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. **LL** - Contains the LibertyLink® gene for resistance to Liberty® herbicide. **RR2** - Contains the Roundup Ready® Corn 2 trait that provides crop safety for over-the-top applications of labeled glyphosate herbicides when applied according to label directions.

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Liberty®, LibertyLink® and the Water Droplet Design are registered trademarks of BASF.

Agrisure® and Agrisure Viptera® are registered trademarks 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.

Do not export Pioneer® brand alfalfa seed or crops containing Roundup Ready® technology including hay or hay products to China pending import approval. In addition, due to the unique cropping practices, do not plant this product in Imperial County, California. Purchase and use of HarvXtra® alfalfa with Roundup Ready® technology is subject to a Seed and Feed Use Agreement. **Always Read and Follow Pesticide Label Directions.** Alfalfa with the Roundup Ready® technology provides crop safety for over-the-top applications of labeled glyphosate herbicides when applied according to label directions. Glyphosate agricultural herbicides will kill crops that are not tolerant to glyphosate. **ACCIDENTAL APPLICATION OF INCOMPATIBLE HERBICIDES TO THIS VARIETY COULD RESULT IN TOTAL CROP LOSS.** HarvXtra® is a registered trademark of Forage Genetics International, LLC. HarvXtra® alfalfa with Roundup Ready® technology is enabled with Technology from Nobel Research Foundation Institute, LLC. Roundup Ready® is a registered trademark of Bayer Group, used under license.

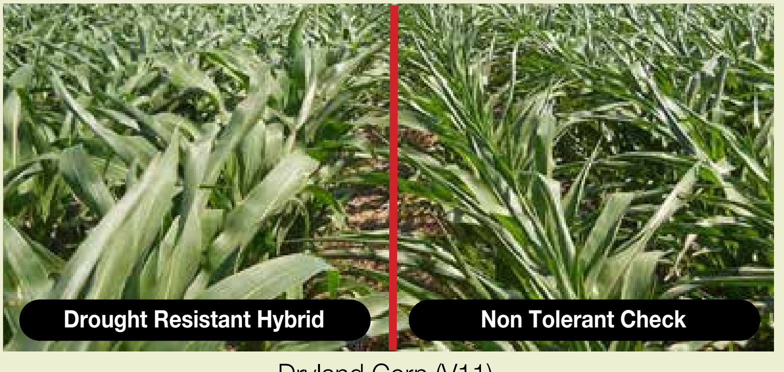
DROUGHT-TOLERANT HYBRIDS

The seed industry has recently introduced transgenic and conventionally-bred hybrids that exhibit increased tolerance to the lack of water. Drought tolerance is a complex trait involving multiple genes acting at different times of plant development. The approach to improving drought tolerance has been by reducing the size of the plant's leaf surface pores (stomata) to reduce leaf rolling, improving the efficiency of root systems and improving synchronization of pollination and silking even under high heat or water stress conditions. Modern corn hybrid genetics have improved corn grain yield from 3 bushels per acre per inch of water in the early 1900s to 10 bushels per acre per inch of water in the 1990s. Drought-tolerant hybrids have made even greater gains, yielding 5 to 7 percent better than other leading hybrids in water-limited environments. These newer drought-tolerant hybrids have also been shown to perform equally well in normal growing conditions so there is no yield penalty for planting these hybrids in fields that may only occasionally experience water stress. Planting drought-tolerant hybrids for silage typically results in higher biomass and starch yields.

DROUGHT-TOLERANT PHENOTYPES

MINIMAL LEAF FIRING

MINIMAL LEAF ROLLING



Dryland Corn (V11)

Source: Soderlund, S., F. N. Owens and C. Fagan. 2013. Field experience with drought-tolerant corn. Presentation at the Joint Annual Meeting of the American Dairy Science Association (ADSA) and American Society of Animal Science (ASAS), Indianapolis, Indiana, July 2013.

BROWN MIDRIB CORN HYBRIDS

Brown MidRib (BMR) corn silage hybrids have been on the market for nearly two decades. BMR mutants were first discovered in 1924 at the University of Minnesota and BMR genes have been introduced into sorghum, sudangrass, millet and corn. BMR derives the name from plants displaying reddish-orange coloration on the underside of the leaf mid-vein (MidRib) starting at the 4-6 leaf stage. BMR hybrids will exhibit lower lignin and improved NDFD but the reduced lignin content makes standability an issue for BMR hybrids relegating their use for silage only. Early BMR hybrids were plagued with agronomic and drought-tolerance issues and had reduced silage yield (10-30%) compared to non-BMR silage hybrids. Modern

BMR hybrids have much improved agronomics and disease resistance and often produce yields of total dry matter and starch very comparable to non-BMR silage hybrids.

BMR corn typically has 20-30% less lignin and reduced cross-linkages with other cell wall carbohydrates. Lignin is an indigestible component of fiber. Each gram of acid detergent lignin (ADL) binds with 1.4 grams of fiber (hemicellulose) and renders the complex indigestible by mammalian enzymes. There are four BMR mutants and being a single gene recessive trait, they must be in both parents. The bm1 and bm3 genes are most common in the industry. In the pathway in which plants convert phenylalanine to lignin, there are slight differences in how the two genes down-regulate enzymes involved in lignification. The bm3 gene confers reduced COMT (caffeic o-methyl tranferase) activity and the bm1 gene confers reduced CAD (cinnamyl alcohol dehydrogenase) activity. In a 2015 trial conducted by Miner Institute, there were no statistical differences in lignin content or NDFD between two different hybrids containing bm1 and bm3 genes.

The reduced lignin in BMR silage results in a 4-10 point higher NDFD-24 hour value. In the lab, the BMR sample cannot escape the analysis vessel. But in the cow, the net effect is a faster rate of NDF digestion with the more fragile BMR fiber exiting the rumen much quicker than non-BMR corn silage. This typically results in higher intakes of the entire diet (especially important in transition and early-lactation cows) which usually drives higher milk yields. The improved rate of digestion and feed passage allows for higher forage diets, improved rumen health and the potential to remove some supplemental energy or protein (from higher rumen microbial production) from the diet. The higher starch content in certain BMR hybrids will also act to dilute undigestible NDF (uNDF) levels in the corn silage and in the diet. Lower levels of uNDF have also been associated with improved intake potential of forages.

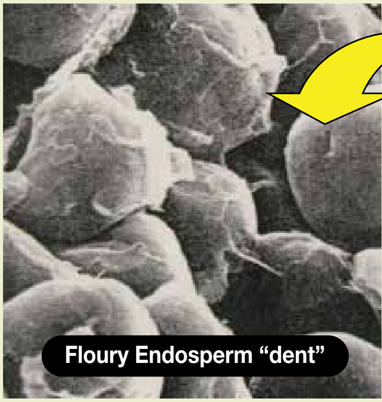
The majority of BMR is grown in separate, high fertility fields (often with fungicide application) to minimize agronomic risks. BMR needs to be managed and harvested similar to conventional hybrids, ideally when the kernels are at a ½ to ¾ milk line maturity. BMR hybrids are subject to the same effects of growing environment as conventional hybrids and can vary significantly in NDFD from year to year (or field to field) depending upon the unique growing environment. As with non-BMR hybrids, attention to kernel damage during harvest is critical to assure maximum ruminal starch availability. BMR silage also tends to be more prone to aerobic stability problems (heating) due to extremely high levels of sucrose in the stalk. This tendency for heating at feedout can be significantly reduced with the use of inoculants containing *Lactobacillus buchneri*.

FLOURY VERSUS VITREOUS ENDOSPERM HYBRIDS

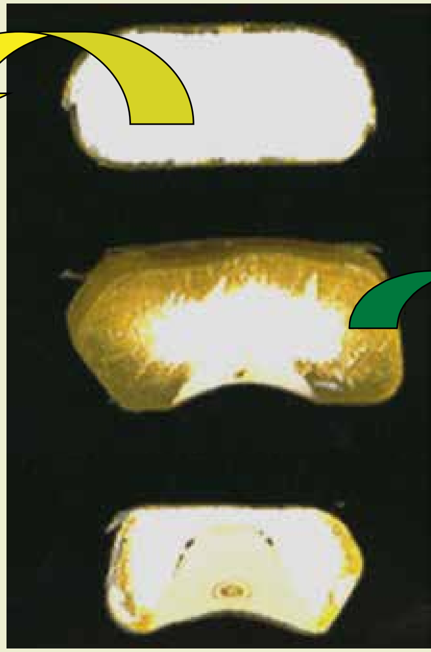
There has been an explosion of interest among silage growers about the differences in the type of kernel starch found in hybrids due to some seed companies suggesting higher starch digestion among floury endosperm genetics. This is referencing the amount of floury (also called soft or dent) endosperm versus vitreous (also called glassy, hard or flinty) endosperm found in the kernel. In fact, flint hybrids can be found in Europe and South America where growing conditions favor their early plant vigor but they are not grown in North America because of their poor yield compared to dent hybrids.

Floury endosperm contains the white-colored starch granules found in the center of kernels grown in North America. Floury endosperm is more loosely bound in a starch: zein protein (prolamin) matrix. Dent corn derives its name because this softer starch “dents in” at the top of the kernel as it matures. Vitreous starch is the higher-density, yellowish-colored starch granules found on the outer edges of a mature kernel which are more tightly bound in a starch: protein matrix. Popcorn or Indian corn would be considered nearly 100 percent vitreous starch. Vitreous starch in dent kernels becomes more prominent as the kernel approaches dry grain harvest maturity (post black layer) and contributes to test weight. Hybrids with more floury starch generally have lower test weight due to kernel reduced density (more air space between starch granules). However, only about 40 percent of the variation in grain density can be attributed to test weight. The remainder is due to the influences of kernel size, shape, maturity, germ content, and pericarp slickness. Most

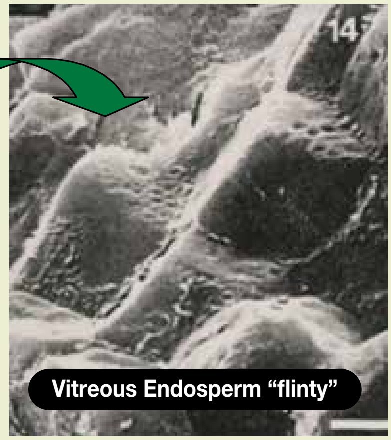
CORN KERNEL PHYSIOLOGY



Starch granules are surrounded by hydrophobic proteins (prolamin or zein) which repel water to prevent premature starch hydration that could interfere with germination.



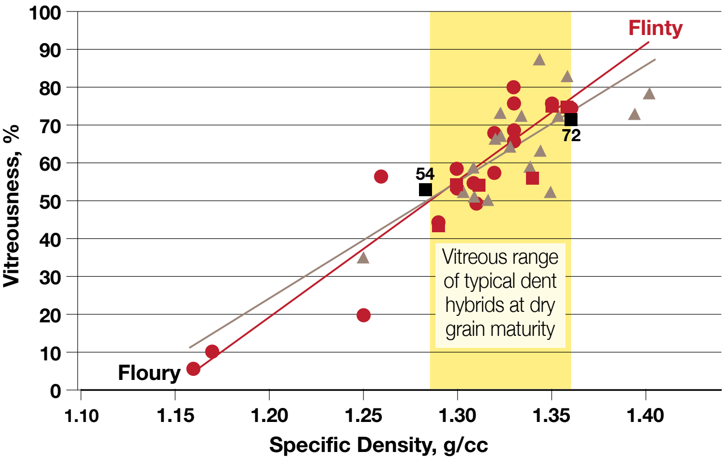
This is a post-blacklayer (combining maturity) kernel. This is NOT what the kernel looks like at silage or HMC maturity.



More mature kernels tend to have more prolamin (zein)

Higher test weight kernels at combining maturity have more prolamin

CORN DENSITY AND STARCH VITREOUS COMPARED



Source: Mestres et al. 1995 and F.N. Owens, Pioneer Senior Research Scientist

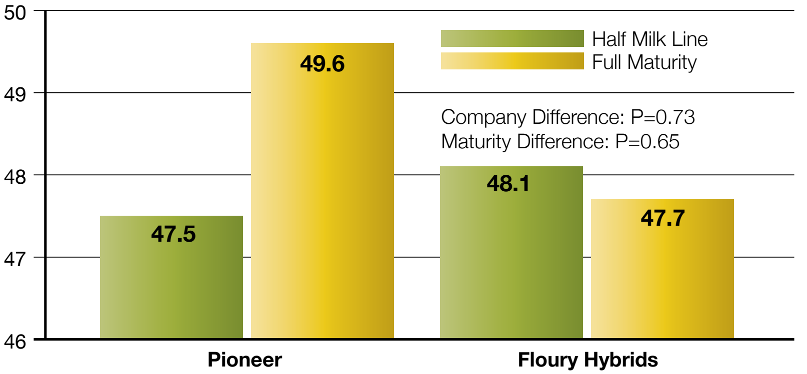
hybrids grown in North America range between 54-72% vitreous starch. That is at full physiological, combining maturity (post black layer). The range would be much narrower among kernels at silage harvest maturity (R5).

Research comparing the starch digestibility of floury genetics versus flinty hybrids has certainly furthered the understanding of the mechanisms of starch digestion. However, caution is needed when extrapolating these "bookend" comparisons to what producers will observe from high-yielding, commercially-available hybrids. According to Ohio State researchers, the level of kernel vitreousness between hybrids has little, if any, impact on the digestibility of starch in (R5) kernels when fed as fermented corn silage or high-moisture corn.

Furthermore, much of the claims of companies promoting floury endosperm neglect to present yield data and also focus only on ruminal digestion, when total tract (ruminal and intestinal) starch digestibility typically exceeds 96 percent for adequately processed and fermented corn silage or high-moisture corn.

It is well proven that while starch digestibility differences between hybrids at silage maturity do not exist, the ruminal starch digestibility in all ensiled hybrids does increase over time in fermented storage. Microbial activity during fermentation and the chemical action of various fermentation end-products (acids, yeast-generated alcohol) alter the kernel storage proteins, removing most of the negative effects of zeins (prolamins) on starch digestibility. This is evidenced by a strong positive relationship between the level of soluble protein (or ammonia nitrogen) from the degraded kernel proteins in corn grain and the improved ruminal starch digestibility of corn grain over time in fermented storage. Typically about 70% of the starch will be ruminally degraded in corn silage and will increase by about 2% units per month, stabilizing after about 6 months of fermented storage. If properly processed, what is not digested in the rumen will be digested in the intestines. Validation of the extent of starch digestion can be further accomplished by collecting

IN VITRO RUMEN STARCH DIGESTIBILITY AT 7 HOURS



fecal samples from 10-12 cows and submitting to a lab for fecal starch analysis. The goal is to have less than 3-5% starch in feces and most herds are below this level despite growing hybrids that are not advertised as floury.

If corn kernels are fed fully mature and not fermented, as in the case of dry corn grain, research from France with true flinty hybrids indicates that fine-grinding can remove the negative impact of vitreous endosperm on total tract starch digestibility. This is something nutritionists have learned simply by watching cows (and manure) and is the reason for feeding fine-ground dry corn (600 to 1,000 microns) rather than rolled or cracked corn to high-producing cows.

Pioneer has conducted several studies investigating the ruminal digestion of Pioneer® brand hybrids grown in the same plot as hybrids from companies claiming higher starch digestion due to floury endosperm. When averaged across hybrids, no statistical difference in 7-hour *in vitro* ruminal starch digestibility was detected between kernels from five Pioneer® brand hybrids and two floury hybrids harvested at either half-milk (R 5.5, silage) maturity or black layer (full kernel maturity).

In another Pioneer field study, five Pioneer® brand commercial dent hybrids were harvested at three stages of maturity (1/2 milk line to black layer maturity). In contrast with some previously published research:

1) prolamin content did not increase as kernels matured,
2) prolamin and prolamin/starch ratio were only weakly correlated with 7- hour in vitro ruminal starch digestion (R^2 = 0.22-0.30) and
3) prolamin content increased as field nitrogen fertility and kernel protein content increased (R^2 > 0.60).

For corn fed as fermented corn silage or high-moisture corn, more vitreous hybrids with large kernels (reduced pericarp: endosperm ratio) appear preferable. This is because they typically have higher grain yields, and the process of fermentation (protein matrix solubilization and acid hydrolysis) will minimize most of the adverse effects of vitreousness.

It appears counterproductive to recommend any hybrid selection pressure for floury endosperm given these facts:

1) seed companies typically do not have data on the level of vitreousness at silage or high-moisture grain harvest maturity and data from combine-maturity corn is not valid,
2) vitreousness of grain harvested at silage maturity is considerably lower than for dry grain,
3) adverse effects of vitreousness in dry, unfermented corn can be largely alleviated by fine-grinding,
4) fermentation significantly reduces the impact of vitreousness,
5) selecting hybrids for reduced vitreousness likely depresses grain yields and possibly causes more ear molds.

Rather, it seems more prudent to select silage hybrids for traits where there are significant genetic differences such as agronomic stability, tonnage, grain (starch) yield, and trait packages necessary to protect yield against specific pest and weed challenges.

HYBRID MIXING

The concept of planting a mix of hybrids with differing maturity in the same field has been proposed as an approach to extend pollination periods and reduce inbreeding depression resulting in higher grain (starch) and grain protein yields. Most of this research has been done with alternating strips of two hybrids, though some trials blended a small percentage of a second hybrid in the seed hopper so there were plants of that hybrid scattered throughout the field. However, the positive results seen in "within row" or in narrow "side-by-side" strips has not proven repeatable in numerous university studies conducted at an entire field level. While the use of multiple hybrids across an entire farm is recommended to spread agronomic risk, there appears to be no justification, given current knowledge, for mixing hybrids in the same field. As technology advances, with planters capable of changing hybrids on the go, there will likely be potential for the concept of planting different hybrids in a single field; if that field contains distinctly different soil types or fertility levels.

Mixing two or more hybrids in a field is not the same as planting a "silage blend." Most silage blends are a mix of several unnamed hybrids, often ones that the seed company for one reason or another chose not to sell as individual hybrids. Most silage blends don't state the names of the individual hybrids comprising the blend. How good a silage blend performs depends on the hybrids in the blend. The fact is that seed companies can (and often do) change the makeup of hybrids in the blend from year to year. Just because a silage blend did well one year doesn't mean it will be the same hybrids in the blend the next year even if labeled as the same maturity sold by the same seed company. Despite the fact that many silage blends are usually less expensive, relying on a silage blend does have inherent risks.

There has also been recent interest in mixing Brown MidRib (BMR) and non-BMR hybrids in the same field. This idea has been tried as an approach to improve standability of BMR in the case of strong wind events. However, the idea has not been embraced by most agronomists due to the complexity of matching pollination/silking dates. Furthermore, diluting the higher NDFD and lower uNDF advantage BMR with a non-BMR hybrid may not make the best use of BMR genetics, particularly when further diluted with other dietary ingredients. By the time the cow consumes the mixed silage diet, intakes among fresh and high-production cows may not reach levels typical of 100% BMR-based diets.

PLANTING DATE

Corn growers are typically aggressive in pushing planting dates given the growing number of acres that need to be planted and the desire to boost yields with today's longer season hybrids. Ideal planting dates vary considerably across North America but USDA statistics indicate that average planting dates are about a week earlier than in the 1990s. Research does support that yields are less affected by planting too early rather than planting too late.

Timing of planting has the biggest impact on stand establishment. Soil temperature, seedbed condition (moisture) and weather following planting are also key elements in the successful emergence of any hybrid. Early plantings have a better chance of success in well-drained soils with limited residue cover. Selecting hybrids with high stress emergence ratings and using premium seed treatments can provide critical protection in stressful environments. Cool, wet soils are most conducive to seedling disease development and also delay emergence and plant development. These delays keep seedlings from outgrowing damage by soil borne diseases that attack seeds and seedlings. Seed treatments are extremely beneficial, but are generally limited to about two weeks of protection. If cool, wet conditions persist longer than two to three weeks, crop stands are at risk.

Growers should choose hybrids based on the local growing season and specific field environment. Cool temperatures restrict root growth and nutrient uptake. Banding fertilizer can help increase nutrient availability and early growth. Shallow planting may provide a warmer environment for seeds when planting early, but always plant at least 1.5 inches deep for normal plant development.

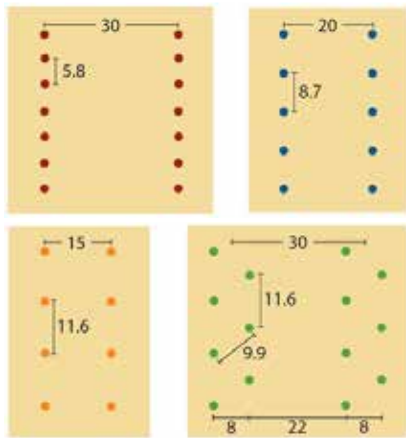
The yield of a particular corn hybrid is greatly influenced by stand density and uniformity. Planter maintenance and effectiveness are certainly important (particularly proper depth and trench closure) but so are seedbed conditions (e.g. minimal compaction which inhibits root growth) and the genetic potential of the hybrid to emerge from cold, wet soils. The trend towards reduced tillage and the accompanying higher infield residues often results in slower seedbed drying and colder soil temperatures. This can cause seed emergence stress even in Southern and Western corn growing regions. The guideline for planting corn is to wait until soil temperatures are at least 50°F. Corn is a warm season plant with over 85°F as the optimal temperature for emergence. It is not unusual for early planted corn to take three weeks or longer to emerge if planted into 50° to 55°F soil temperatures compared to less than a week if planted into 70°F soils.

University of Wisconsin research conducted in 2003-2012 with full-season hybrids (104-108 RM) indicates that the planting date window for silage is slightly longer than the same hybrid planted for grain and should planting be delayed, growers can stick with full-season hybrids longer than if corn will be used for silage rather than grain. While the number of leaves, the size of the stalk, shank and husk is largely genetically controlled, silage starch content does tend to decrease with later planting dates which can reduce milk per acre (quality + yield). Digestibility of stover does not seem to be significantly affected by planting date. Earlier research at the University of Wisconsin showed that corn silage planted in Wisconsin between April 18 and May 25 produced about 18,000 lbs of milk per acre. This started to decline significantly after May 15 and by June 1, 279 lbs of milk per acre was lost with each day of delayed planting.

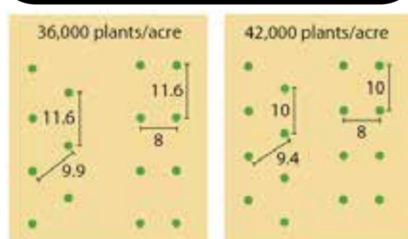
ROW SPACING

Corn planted in narrow rows has more equidistant plant spacing, down and across the row, decreasing plant competition for available water, nutrients and light. In 2015, estimates are that about 92% of the North American corn crop was planted on 30-inch rows or wider. Only about 4% of the crop was planted on 15- or 20-inch rows. Research showing significant grain or silage yield response (3-10% increase) to narrow rows occurs primarily in the northern Corn Belt which is limited in solar radiation and may be lacking in fertility or soil moisture.

Across- and within-row spacing (in inches) in various row configurations at 36,000 plants/acre.



Distances (inches) between plants in alternating and parallel twin rows at 36,000 and 42,000 plants/acre.



Twin rows accounted for less than 0.2% of the 2009 corn crop, yet the practice is gaining interest as a way to potentially increase yields without the machinery cost associated with switching to narrow row production. Pioneer twin row research conducted in 2010 on 179 paired comparisons across 31 locations showed no overall grain yield advantage to twin rows over 30-inch rows. This supports the accumulated body of University and industry research concluding that a transition from 30-inch rows to twin rows would not provide a wide-scale yield benefit across the majority of the Corn Belt. There is also a lack of evidence that new hybrids and higher plant populations will broadly favor twin row production in the near future.

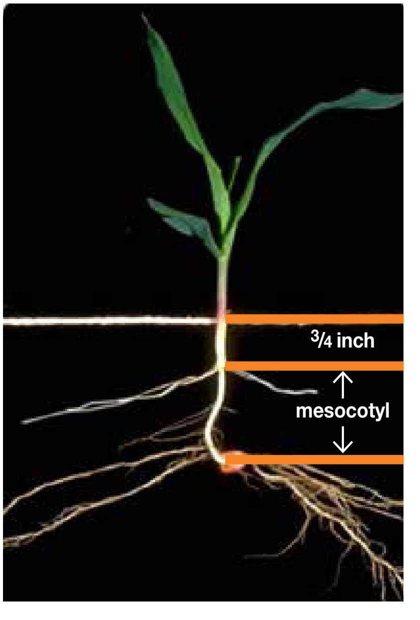
Yield environment does not appear to affect twin row yield response, although research data from low yield environments are limited. The most promising applications for twin row corn appear to be where narrow rows have been most successful, such as the northern Corn Belt, in silage production, and in southern wide row systems.

PLANTING DEPTH AND SPACINGS

Planting corn to a depth of 1½-2 inches is optimal for nodal root development. Two inches is best under normal conditions; 1½ inches may be favorable when planting early into cool soils but never plant corn shallower than 1½ inches. Planting depth can easily be determined after seedling emergence. The nodal root area (crown or growing point) typically develops about ¾ of an inch beneath the soil surface regardless of the seed depth. Measure the mesocotyl length (the area between the seed and crown or growing point), then add ¾ inch to determine the planting depth.

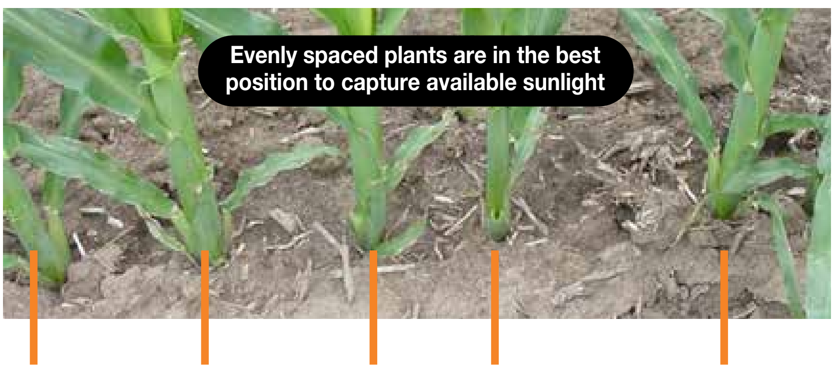
Symptoms of irregular planting depth include uneven emergence, non-uniform mesocotyl length and varying plant height. It is recommended to set the planting depth in the field, while the planter is at full operating speed to check for good seed-to-soil contact. Slowing the planting speed can help improve uniform planting depths. Pioneer research studies have shown that grain yields, averaged across multiple locations and hybrids, were 13% greater for 1.5 inch plantings than the 0.5-inch planting depth. Much of the yield decrease was attributed to a reduced final stand count from more "runts" in the shallow planted plots.

Corn planted too shallow is unable to uptake water and nutrients through the roots. They also can develop a condition called "rootless or floppy corn syndrome" where the root tip desiccates prior to reaching soil moisture. The aboveground appearance of the corn plant may appear fairly normal until a windy day when plants fall over due to the lack of



nodal root development in the dry soil. Shallow planting can also expose corn seedlings to salt injury from fertilizer and herbicide residues increasing the potential for herbicide injury.

Uniform plant spacing helps maximizes yield. Pioneer studies show that individual plant yield reaches a maximum level when plants are within 2-3 inches of perfect equidistant spacing. Types of non-uniform plant spacing include misplaced plants (definitely reduces yield), skips (yield of adjacent plants will increase, but not enough to compensate for the missing plant) and doubles (may increase yield slightly if stand is below optimum). Yield of doubled plants as well as adjacent plants will decrease, but the yield of the extra plant will generally compensate for this reduction.



EMERGENCE ISSUES

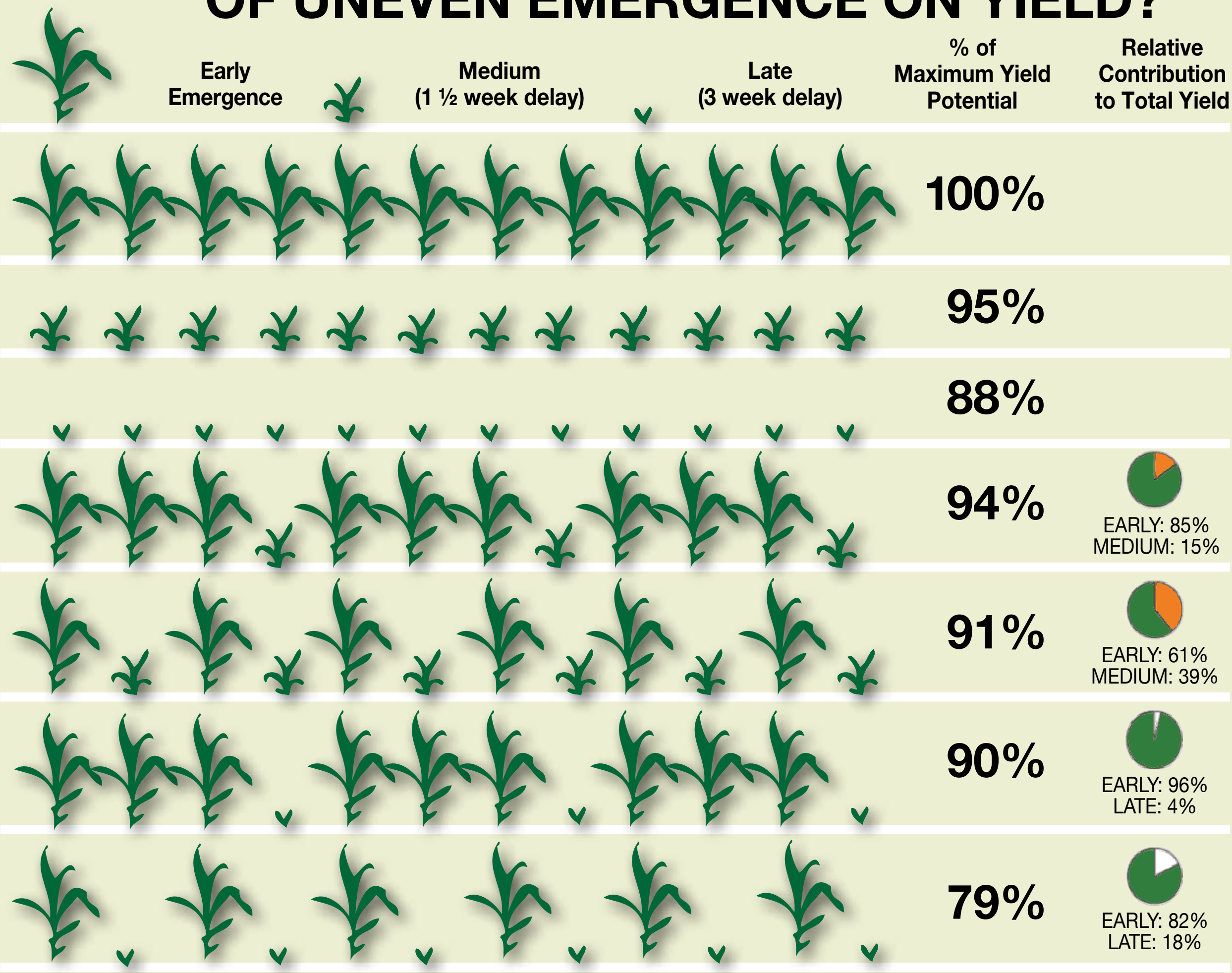
Corn is a warm season crop. Optimal temperature for emergence is 85º-90ºF, so it is almost always under some degree of cold stress. Corn will germinate at 46ºF but the common thumb-rule is to delay planting until soil temperatures reach 50°F because prolonged exposure to soil temperatures below this promotes seed deterioration and seedling disease. Once planted, corn seeds need a 48-hour window when the soil temperature at planting depth does not drop much below 50ºF. Below 50ºF., potential exists for chilling injury to affect seed germination and seedling growth. Soil temperature decreases after this time are less likely to affect seed germination. Cold imbibition causes physical damage making seeds more prone to attack by insects and disease. Extended cold delays emergence and further damages seeds, and the surviving seedlings are likely to produce runts.

It takes a coordinated effort for proper emergence to occur so that the coleoptile (pointed protective sheath covering the emerging shoot) is pushed above the soil surface allowing the first leaf to unfurl. This sequence of events can be compromised if the seed absorbs (imbibes) water less than 50° to 55°F. This is termed imbibitional chilling damage where brittle cell membranes can rupture causing abnormalities such as corkscrew or fused coleoptiles. This is further aggravated by leaked cell contents inviting pathogen invasion.

The potential for cold water damage falls as seedlings emerge and if initial imbibition occurred above 50°F. This partially explains why early planted corn, followed by warm weather, tends to emerge better than later planted corn emerging into cold weather or snow cover. Emergence damage caused by cold, wet soils is generally irreversible and difficult to detect as the problems with stand density/uniformity take several weeks to become visible.

Seed companies routinely test experimental hybrids for stress emergence by planting them into a wide range of stressful (cold, no-till, corn-on-corn) environments. Some companies also employ proprietary laboratory assays for hybrid advancement decisions and to support marker-assisted breeding efforts to improve

WHAT IS THE IMPACT OF UNEVEN EMERGENCE ON YIELD?



Data from Carter, P.R., E.D. Nafziger, and J.G. Lauer, Uneven emergence in corn, North Central Regional Extension Publication No. 344

tolerance to emergence stress. Stress emergence and high-residue suitability ratings found in seed catalogs reflect genetic variability for tolerance to environmental stresses. They are not a rating for specific disease resistance. However, injury to emerging seedlings can promote seedling disease, especially in growing environments with heavy disease pressure.

Planting into warmer soils typically favors seedling growth and reduces potential for soil pathogens, such as Fusarium and Pythium. The use of seed treatments (fungicides, insecticides, biological) are extremely popular and provide protection against target organisms for 10 to 14 days after planting during which the seed has a high vulnerability to infection. To optimize seed emergence, avoid planting ahead of a cold event, plant into moist well-drained, low residue fields first, use the right seed treatment and choose hybrids with good stress emergence scores suited to high residue.

PLANT POPULATION

It is important to target plant population based on individual hybrid recommendations. Typical seed corn germination is about 95%. Overplanting by at least 5% can help reduce the effects of germination-induced skips and for expected reductions due to insects and soil conditions.

Summarizing corn population research is difficult because varying maturities across diverse growing environments make it difficult to draw sweeping conclusions. However, over the last 25 years the average U.S. corn planting population has risen from 23,000 plants per acre (PPA) to about 30,000 PPA. High-yielding environments allow for increasing populations to 36-38,000 PPA depending upon individual hybrid genetics. Higher population increases competition among plants for water, sunlight and soil nutrients. Pioneer has conducted studies comparing hybrids sold during previous decades. There is modest improvement in grain yield production due to higher leaf area index, efficiency of leaf photosynthesis, number of kernels per ear and weight of each kernel. However, the genetic selection of corn hybrids for stress tolerance has accounted for the vast majority of the 1-1.5 bushels/year grain yield increase over the past 80 years. This is a result of higher population increasing the number of ears per acre. More precise soil fertility practices and technology traits which improve resistance to insect and weed pressure have also significantly improved average yields. Further driving yield is that the average grower is planting about two weeks earlier than in the past, somewhat the result of improvements in seed treatment options.

Growers should be cautioned not to rely on ear flex scores when considering planting populations. Ear flex refers to the ability of a plant to extend ear size as plant density is reduced or as growing conditions improve. Many seed companies have abandoned evaluating ear flex and advise growers to rely on actual population recommendations from research trials planted at upwards of 70,000 PPA. Ear flex scores have their primary utility in deciding if a hybrid has the ability to deliver higher yields under possible replant situations such as emergence problems or hail which reduces populations to less than 12,000 PPA.

It is important to differentiate between grain and silage production when discussing plant populations. In low grain yielding environments (<130 bushels/acre), response to plant population is more significant although grain yields tend to drop off gradually with higher populations. This is contrasted to drastic drops encountered among hybrids of 30 years ago which were more prone to barrenness under high plant densities. This presumably makes variable rate seeding more beneficial in lower yield environments. With improved hybrid stress tolerance, many seed companies are routinely evaluating hybrids at plant populations as high as 42,000 PPA. There also appears to be slight differences in ideal plant populations by maturity (CRM). Shorter-season hybrids (<100 CRM) tend to show a greater grain response to higher populations followed by 101-113 CRM hybrids and finally longer-season hybrids (>113 CRM). Researchers theorize that higher populations overcome some of the disadvantages of smaller stature and lower leaf area index exhibited by shorter-season hybrids. Pioneer provides a planting rate calculator on their website (www.pioneer.com) to determine economic grain planting rates based on hybrid genetics, yield environment, seed cost and grain price.

Silage is a more complex situation. Traditional recommendations have been to increase plant populations in hybrids destined for silage by 10-20% per acre. However, with the increasing value of starch, newer recommendations suggest planting silage at no more than 2,000-3,000 PPA above the recommended planting population for that hybrid if planted for grain. Higher populations might provide more yield of stover but reduce yields of starch (grain). Higher plant populations tend to decrease stalk diameter and increase potential for lodging. This is much less of a concern for silage than for grain corn harvested at a much later maturity. Research has consistently demonstrated that higher populations (upwards of 40-42,000 PPA) increase silage yield while decreasing quality only slightly. The decrease in quality is caused by increased stover yield diluting the grain (starch) portion of the plant causing slightly higher fiber levels.

Some earlier research suggests the smaller diameter stalk found in higher populations altered the rind: pith ratio causing slightly lower fiber digestibility. More recent research conducted in 2008 and 2009 by Cornell University with conventional, leafy and BMR hybrids planted at populations ranging from 25-40,000 PPA showed no significant effect of increasing population on fiber digestibility. There are some silage growers who prefer to plant at lower populations, more optimal to grain yield, in an attempt to increase the starch content of silage in response to increasing supplemental grain prices. A healthy corn crop can deposit as much as 0.5 to 1.0% units additional starch per day from 1/3 milkline to physiological maturity (black layer). Newer hybrids containing technology traits deliver excellent late-season plant health so delaying harvest until 3/4 milkline (or later) will result in higher starch corn silage without a significant decline in fiber digestibility. If the crop is stressed or diseased, there is increased tendency to have a lower fiber digestibility from delaying harvest to these later stages.

STAND EVALUATION

Many different stress factors are capable of reducing corn stands, such as cold or wet soils, insect feeding or unfavorable weather conditions. To determine stand counts, determine the number of live plants from 1/1,000th of an acre taken from several representative locations in the field. Multiply the number of plants by 1,000 to obtain an estimate of plants per acre. It is best to wait a few days to perform a stand assessment after a frost or hail event occurs, allowing for a better plant health determination.

Corn yield is influenced by stand density as well as stand uniformity. Variation in plant size can have a negative impact on yield, and uneven emergence timing leads to uneven plant size. Late emerging plants are at a competitive disadvantage with larger plants in the stand and will have reduced leaf area, biomass, and yield. Several factors can lead to uneven emergence including variation in soil moisture, poor seed to soil contact due to working or planting into wet soil, variation in soil temperature caused by uneven crop residue distribution, soil crusting and insects or disease.

Three key management factors have emerged from Pioneer field studies that hold promise to positively influence starch content and fiber digestibility in corn silage:

1) Plant emergence – plants that emerge from 12-72 hours later are significantly lower in starch and digestible fiber.
2) Nitrogen deficiency – stalk cannibalization during ear fill which can lower fiber digestibility.
3) Disease resistance – plant health deterioration due to disease pressure can reduce fiber digestibility by as much as one % point of NDFD per day during the pre-harvest window.

LENGTH OF ROW EQUATING TO 1/1000TH OF AN ACRE AT VARIOUS ROW WIDTHS

ROW WIDTH	LENGTH OF ROW
38 Inches	13 ft 9 in
36 Inches	14 ft 6 in
30 Inches	17 ft 5 in
22 Inches	23 ft 9 in
20 Inches	26 ft 2 in
15 Inches	34 ft 10 in

REPLANT CONSIDERATIONS

The factors to consider in deciding if replanting corn is economical include: plant density, uniformity and health of the current stand, date of the original planting and potential replanting, costs associated with replanting and crop insurance provisions. In situations such as flood damage, only a portion of the field may need to be considered for replant. Frost or hail can damage a wide area so plant density and health should be assessed across the entire field.

In severe cases of stand reduction, growers will need to determine if replanting will be more profitable than keeping the current crop. The first step in a replant decision is assessing the current stand by evaluating the number of lost or weak/injured plants. For hail or spring-frost events, it is best to wait a few days to assess the stand to allow time to see how plants recover because the growing point of corn will be about 3/4 of an inch below the soil surface until the V5-V6 growth stage. Symptoms of early frost will show up 1-2 days after a frost with leaves that turn brown, but new green leaves should emerge within 3-4 days. If new leaves not appearing, check the growing point for any color variation from the normal creamy white to light yellow coloration indicating the growing point has been killed. In general, frost damage in early vegetative stages exerts very little impact on yield. Research from Wisconsin indicates that even if all the leaves were killed in a V2 stage plant, yet the growing point still alive, the loss in grain yield would only be 8%.

In cases of early-season flooding, corn prior to the V5-V6 growth stage can also survive for two to four days in saturated soils. Warm temperatures can shorten this survival time to only 24 hours. Check the growing point of corn plants to determine if they are soft and discolored or firm and healthy. Flooding depletes soils of oxygen and increases disease infections and nitrogen losses. Weather conditions following flooding are important to plant survival. Cool, wet conditions favor disease development. Very hot, windy conditions may dry soils too quickly, causing crusting and restricted plant growth.

Also look for stand uniformity such as frequent long gaps in the rows. An uneven stand will yield less than a relatively even stand with the same number of plants. Stand counts should be taken randomly across the entire area being considered for replant. The accuracy of stand estimates logically improve with the number of locations sampled. When plant populations are lower than optimum, and will no longer produce a maximum yield, be sure to compare the lower yield due to late planting of a short-season hybrid with the yield potential of the reduced stand. Another factor to consider is the

Soft translucent tissue near the growing point indicates this plant will not recover.

Growth of green tissue near the growing point indicates this plant would have recovered.

	PLANT POPULATION (1,000 plants/acre)						
	10	15	20	25	30	35	40
MIDWEST PLANTING DATE	% MAXIMUM GRAIN YIELD						
APRIL 25	57	70	81	91	97	100	100
APRIL 30	57	70	80	90	96	99	99
MAY 5	57	69	79	89	94	97	96
MAY 10	56	68	77	86	92	94	93
MAY 15	54	66	75	84	89	91	90
MAY 20	52	64	73	81	86	88	87
MAY 25	51	63	71	79	84	86	84
MAY 30	49	61	69	77	82	83	81
JUNE 4	45	56	64	72	76	77	75
JUNE 9	40	51	59	66	70	71	69
JUNE 14	36	47	54	61	64	65	63
JUNE 19	32	42	49	56	59	59	57

uncertainty of obtaining a good stand with a late planting and the possibility of a reduction in yield due to moisture stress at silking time. Flex-ear hybrids will increase the size of the ear (both kernel number and kernel size), and sometimes the number of ears per plant, when the plant population drops below the optimum.

Once the surviving plant stand has been determined, check the health of the plants. Plants that are severely injured or defoliated will have reduced photosynthetic capability and lower yield. Check if the plant tissue at the growing point is a healthy white or cream color with normal texture. For evaluating frost damage to corn plants 6” or less in height, use a knife to cut some frosted plants off about an inch above the soil. If the plant is still alive you will see the new growth in a matter of hours, certainly within one day. The center of the cut plant grows fastest, so you will observe a pyramid shape where just hours before there was a flat cut surface.

Weed control is typically improved with later plantings due to tillage effects on germinated weeds and improved seedling vigor due to warmer soils. However, later plantings may incur more feeding from second-generation corn borers and silk feeding by rootworm beetles.

Once a stand has been evaluated, the expected yield can be compared to expected replant yield. In general, Midwest corn yield potential increases with increased stand up to the optimum of 35,000 plants/acre, and declines with planting dates later than April 20 and earlier than April 10.

Other factors such as fuel, labor, equipment, previous weed control applications, seed cost, insurance compensation, average first frost dates and availability/cost of feed alternatives need to be factored into whether replanting will result in an economically sound decision. If replanting is delayed past a reasonable time for corn to mature, it may be more economical to consider soybeans (e.g. after June 1 in Wisconsin) or forage sorghum, sudan-grass or sorghum-sudan crosses which can be planted into July. Corn is still one of the best options where total biomass production is the primary goal to meet emergency forage needs. As with all cropping decisions, working with your seed sales professional or consulting agronomist will help seal the replant decision.

GROW

CORN SILAGE

Corn growth and development is typically categorized by assigning a developmental stage. The most commonly used staging system divides plant development into vegetative (V) and reproductive (R) stages. Subdivisions of the V stages are designated numerically as V1, V2, V3, through Vn, where "n" simply represents the last leaf stage before tasseling. The first V stage is designated as VE, for emergence, and the last V stage is VT, for tasseling. The final leaf stage, Vn, varies by hybrid and/or environmental influences.

Corn is a monoecious plant, which means it produces separate male and female flowers on the same plant. The tassel (male flower) produces pollen,

VEGETATIVE STAGES (V)

- Stages before ear development
- Vn represents the last leaf stage before tasseling for the particular hybrid grown and often varies by hybrid and/or environmental influences.

REPRODUCTIVE STAGES (R)

- Ear development stages
- Starch development occurs
- Silage harvest usually occurs during R5

VEGETATIVE STAGES	
VE	Emergence
V1-Vn	Leaf Stages
VT	Tassel

REPRODUCTIVE STAGES	
R1	Silk
R2	Blister
R3	Milk
R4	Dough
R5	Dent
R6	Black Layer

WHAT IS CORN SILAGE?

HIGH MOISTURE CORN

ATTACHED TO A HIGHLY DIGESTIBLE GRASS...

Source of energy contribution in corn silage

- 65% grain
- 10% cell contents
- 25% NDF (fiber)

Increased grain (starch) is responsible for most of the nutritional value over the growth of the corn plant

Fiber influences energy density dry matter intake and rumen health (mat development and stimulation of cud-chewing to buffer the rumen) while the ear (female flower) produces ovules that become the seed. There is a vertical separation of about three to four feet between the flowers, which can add to the challenge of successful pollination.

The tassel can produce more than 1,000,000 pollen grains, and the ear can produce more than 1,000 silks. Consequently, there are approximately 1,000 to 1,500 times as many pollen grains as silks produced. In theory, 20 to 30 plants could fertilize all the silks in one acre, but not all the pollen shed by a plant lands on a silk.

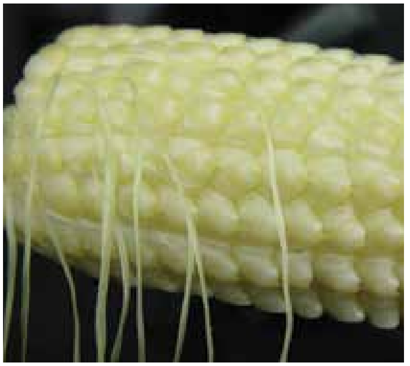
Pollen shed occurs discontinuously for a period of approximately five to eight days, and only sheds when temperature and moisture conditions are favorable. Pollen shed in a field can last up to 2 weeks. The peak time for pollen to shed is mid-to-late morning. The average life span of a pollen grain is approximately 20 minutes after it is shed, and most of the pollen that is shed by a plant falls within 20 to 50 feet of that plant. However, pollen can be transported much greater distances by the wind. It has been estimated that roughly 97 percent of kernels produced are fertilized with pollen from another plant.

Silks emerge from the husk over a period of three to five days, starting with those silks attached at the lower middle portion of the ear and progressing toward the ear tip. Depending on the environment, an individual silk continues to grow for about seven days or until the silk intercepts pollen grains. Research studies have shown that typically, a minimum of five pollen grains must land on each silk and start pollen tube growth to ensure that genetic material from one of these pollen grains successfully fertilizes the ovule.

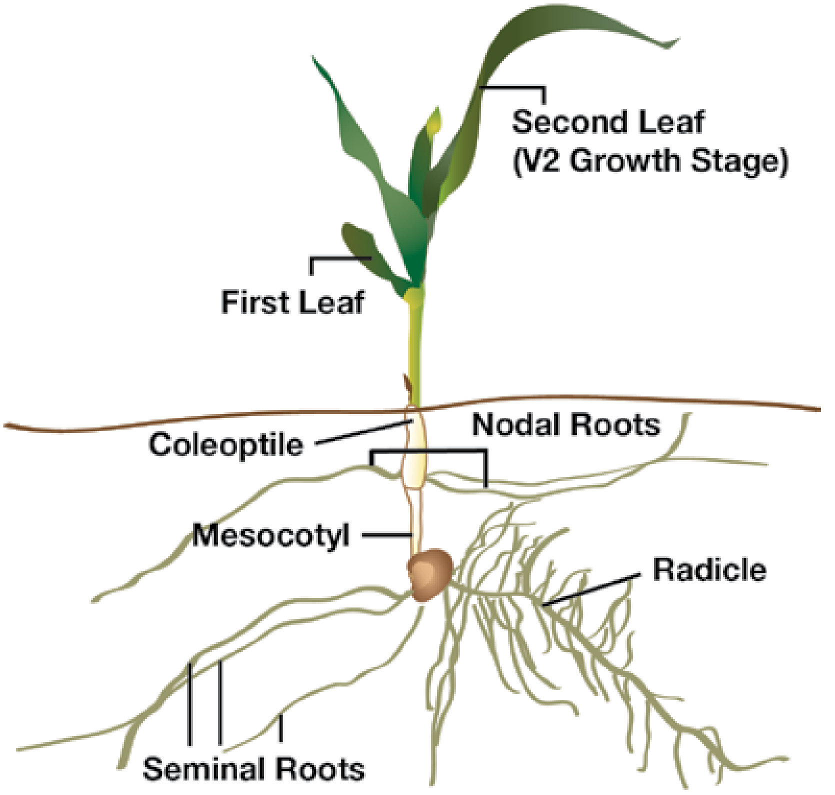
Immediately after fertilization, the ovule creates an abscission layer at the base of the silk that restricts entry of genetic material from other pollen grains. The silk then detaches from the developing kernel, begins to desiccate, and turns brown. If the ovule is not successfully fertilized within this seven day window, the silk dies, the unfertilized ovule eventually disappears, and the portion of the cob to which this ovule is attached becomes barren.

Kernel set (actively growing kernels after pollination) can be checked two or three days after pollen shed stops by carefully removing the husks from an ear and then gently shaking the ear to see if the silks are detached. Silks drop off ovules that have been successfully fertilized (kernels), but any ovule that retains a silk has not been fertilized and no kernel will develop.

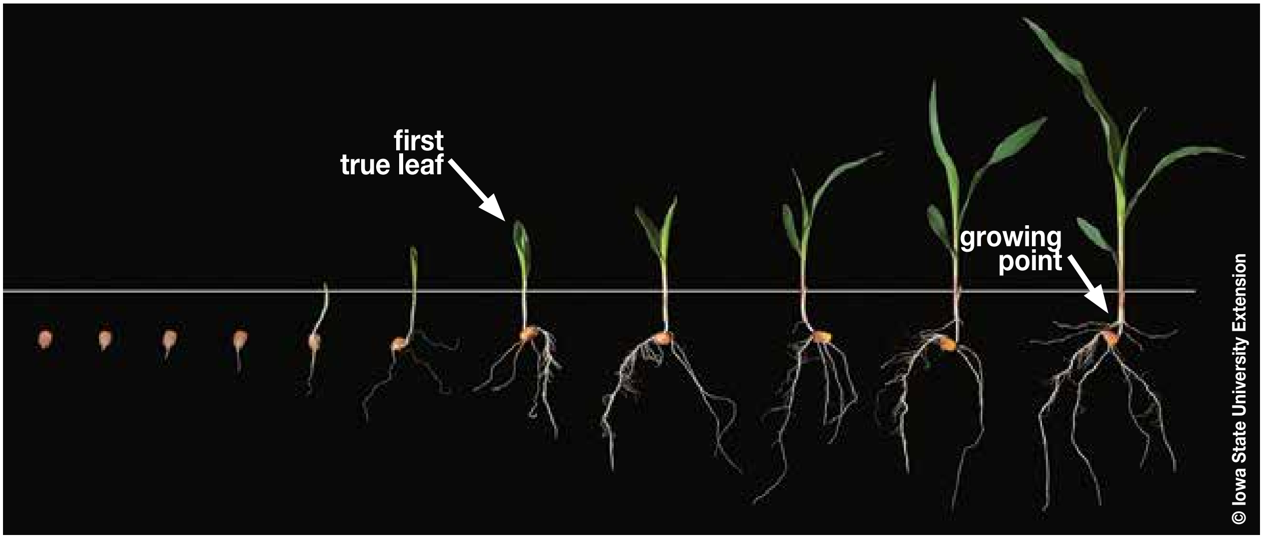
It is important that pollen shed and silk emergence happen concurrently to ensure successful pollination, which is called "nick." However, with today's modern hybrids, it is not unusual to see silks emerging from the husks one or two days before full tassel emergence occurs. This is a large change from hybrids of a few decades ago, and has resulted in a greatly improved pollination process and higher yields.



Corn ear at R1 with husk removed, showing attached silks where ovules were not pollinated.



CORN SEEDLING DEVELOPMENT FROM GERMINATION THROUGH V2



KEY GROWTH PERIODS

Once planted, corn seeds absorb water from the soil and begin to grow. Corn seed needs to take up 30% of its weight in water to germinate. VE (emergence) occurs when the coleoptile (spike) pushes through the soil surface. Corn plants can emerge within five days in ideal heat and moisture conditions. But in practice, due to early planting under seasonably cool conditions, at least two weeks are normally required from planting to emergence. With below average spring temperatures, corn seeds may be in the ground for three weeks or more before seedlings emerge (reinforcing the value of seed treatments). The growing point (stem apex) is 1 to 1.5 inches below the surface. The seminal root system is growing from the seed. The seminal roots do much of the early work, but growth slows after VE as nodal roots begin to grow.

Approximately 90-120 GDUs are required for a corn seedling to emerge following planting, but the exact number required may be affected by planting depth, solar radiation, moisture, tillage, or other factors. Although air temperature is monitored and reported, the speed of germination, seedling emergence, and subsequent growth while the growing point is below the soil surface is governed by soil temperature (soil GDUs) at the seed zone. Soil GDUs play a dominant role as the corn seed germinates and a progressively diminishing role as the seedling grows through V stages until about V6. Air temperature inserts its dominant influence on the rate of corn growth after the growing point rises above the soil surface.

Purple corn

Most of the corn grown in the United States contains five of eight genes required to produce purple color. The other three genes are present only in certain hybrids and some of these genes are cold sensitive. When exposed to cool temperatures, they induce purpling in young plants. Purpling can be triggered when daytime temperatures are above 60º F followed by nighttime air temperature below 50º F. Testing of corn plants that exhibit genetic purpling at the seedling stage has shown no evidence of adverse effects on metabolism, growth, chlorophyll production, or yield. The cold temperature stress which induces purpling, however, does affect early plant growth. Regardless of whether the corn is purple or green, cool temperatures slow growth. Researchers studying purple corn have observed no difference between cold-stress effects associated with purple seedlings compared to green seedlings. Hybrids that develop the purple pigment when exposed to cold temperatures have been found to contain as much chlorophyll (the green pigment) as hybrids that remain green when grown under the same cool conditions.

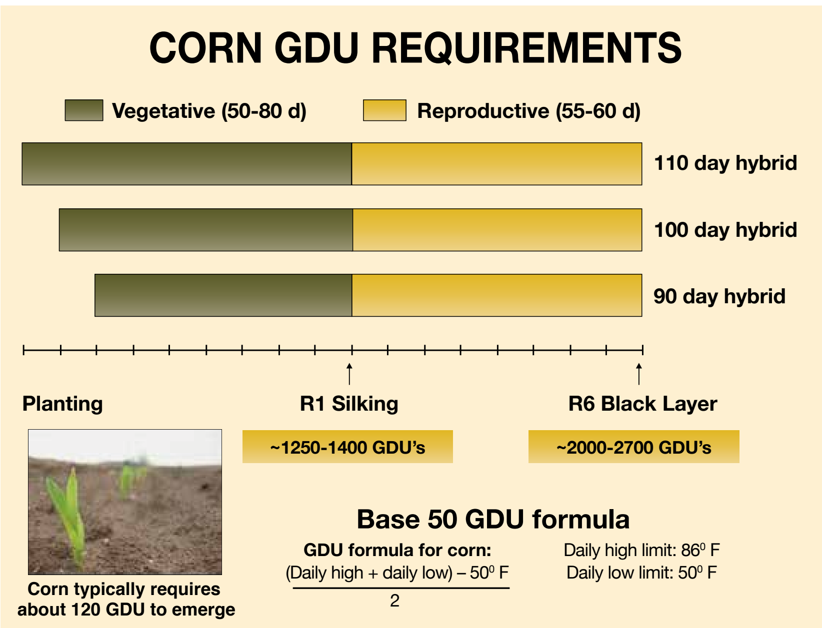
During early vegetative stages (V1-V5), there is minimal stalk (internode) elongation, which is somewhat dependent on soil temperature. Corn is a rather hardy plant when it comes to recovering from early season stress such as frost damage because prior to V5 the growing point is still below the ground and protected from low air temperatures. A shoot initiates at each node (axil of each leaf) from the first leaf (below ground) to approximately the 13th leaf (above ground). Shoots that develop at above ground nodes may differentiate into reproductive tissue (ears or cobs), and shoots that develop below ground may differentiate into vegetative tissue (tillers or suckers). Permanent roots develop at five nodes below the surface, one at the soil surface, and potentially one or more nodes above the soil surface. Roots above the soil surface are commonly referred to as "brace" or "anchor" roots and may support the stalk and take up water and nutrients if they penetrate the soil. The uppermost roots may not reach the soil because the plant stops growing when it switches from vegetative to reproductive development. The development of this stage is dependent on genetics and the environment.

Starting at about the V5-V6 stage of growth, a corn plant will begin to determine yield potential. It is during this period when the number of kernels around the ear, or ear girth, is determined. For this reason, minimal stress at this time is essential for plants to maximize ear girth potential.

V6 to VT represents the rapid growth period when the plant will be utilizing nutrients from the soil at the maximum rate. Corn plants develop leaves based on their relative maturity and growing environment. Locally adapted hybrids in the United States Central Corn Belt (Iowa, Illinois, Indiana, and Ohio) typically develop 20-21 leaves. Early maturing hybrids may have as few as 11-12 leaves at full maturity, and the latest maturing hybrids in tropical environments may develop 30 or more leaves. Between VE and V14, each new collared leaf will appear after the accumulation of approximately 66 to 84 GDUs, depending on the hybrid. Between V15 and VT, leaf development happens faster with each new collared leaf appearing after the accumulation of approximately 48 to 56 GDUs, depending on the hybrid.

During the mid-vegetative stages (V6-V12) the corn plant begin a period of very rapid internode elongation. The growing point moves above the soil surface around V6, and the plant is now susceptible to environmental or mechanical injuries that may damage the growing point. As a result of this rapid growth, the lower three or four leaves, including the first true leaf, may become detached from the stalk and decompose.

Rapid growth syndrome occurs when corn leaves fail to unfurl properly and the whorl becomes tightly wrapped and twisted. It most commonly occurs at the V5-V6 growth stage, but can be observed as late as V12. It is generally associated with an abrupt transition from cool temperatures to warmer conditions, resulting in a sharp acceleration in plant growth rate. The rapidly growing new leaves are unable to emerge and will cause the whorl to bend and twist as they try to force their way out. As with many weather-related stress effects, it is common for some hybrids to be more prone to rapid growth syndrome than others. Twisted whorls can also have other causes, most notably herbicide injury. Growth regulators and acetamides are the herbicides most commonly associated with twisted whorls or "buggywhipping." Other herbicides may also interfere with leaf unfurling in rare cases. Leaves of affected plants usually unfurl after a few days. Newly emerged leaves will often be yellow as a result of being twisted up inside the whorl, but will green up quickly once exposed to sunlight. Affected leaves may be wrinkled near the base and will remain that way throughout the growing season. Development of individual plants may be slightly delayed due to rapid growth syndrome however yield is unlikely to be reduced.



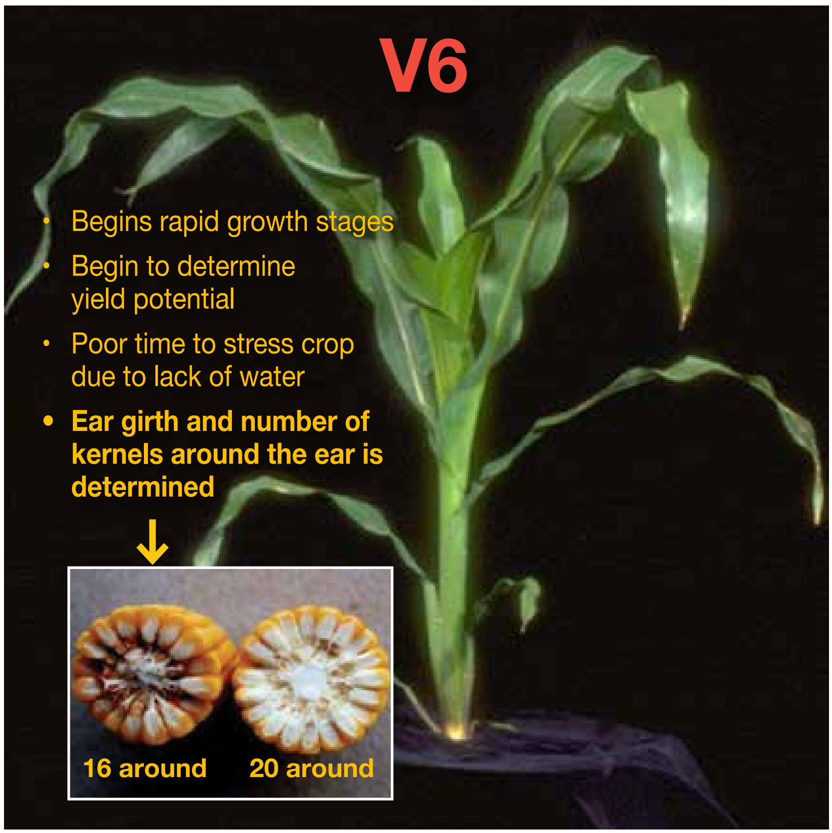
Corn typically requires about 120 GDU to emerge

Corn plants in rapid growth phase showing wrapping of leaves

In the central Corn Belt of the United States, the number of rows of kernels around the cob is established at about V7 stage at which time the ear shoots, and/or tillers and tassel are visible, as well as the tassel. For northern latitude hybrids this occurs earlier (V6), and for tropical hybrids it happens later. There will always be an even number of rows, as a result of cellular division. Most mid-maturity hybrids average 14, 16 or 18 rows of kernels. Lower row numbers are highly correlated to early maturity hybrids. The absolute number is strongly controlled by hybrid genetics and often consistent within a hybrid at a given location. Severe metabolic stresses during these stages, such as timing of some herbicide applications, may reduce the number of kernel rows produced.

Soon after tasseling (VT), the plant begins the “reproductive” stages of growth. The transition from vegetative development to reproductive development (VT to R1) is a crucial period for grain yield determination. At this point, the upper ear shoot becomes dominant. VT occurs when the last tassel branch has emerged and is extended outward. VT overlaps with R1 when visible silks appear before the tassel is fully emerged. Vegetative development is now complete and maximum plant height is nearly achieved. Stalk cells will continue to lignify to improve stalk strength as the plant transitions to reproductive development (R1).

R1 officially starts when silks are visible outside the husks and typically occurs a couple of days after tasseling. Once a pollen grain lands on a silk (pollination), a pollen tube forms and

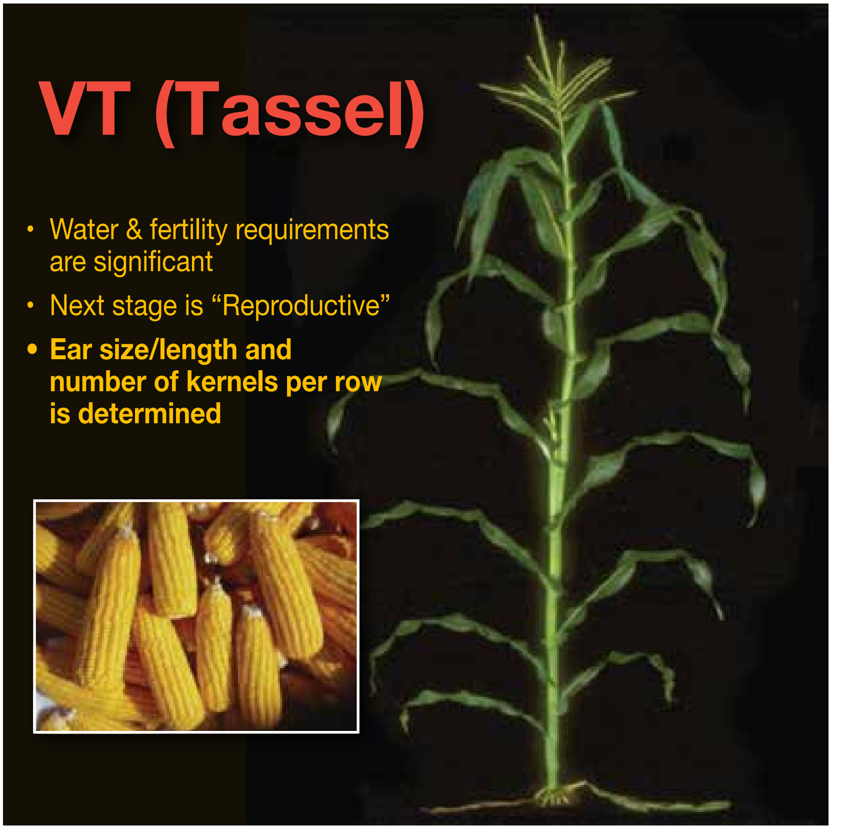


takes about 24 hours to go down the silk to the ovule. Silage growers should note the date when corn plants silk (R1) and count ahead about seven weeks to begin checking fields for kernel maturity. The old thumb rule that corn will reach silage maturity in 35-45 days (900 GDUs) after silking was based around silage being harvested at 70% moisture (30% dry matter). Modern hybrids have improved late-season plant health so to avoid effluent and also significantly increase starch deposition, it is now recommended to delay harvest of healthy plants until the kernels are closer to ¾ milk line. Most of the difference between hybrids of different relative maturities is between emergence and silking, not from silking to the 62-68% whole-plant moisture (38-32% DM) that is considered ideal for corn silage.

Corn grain yield can be thought of as a 2-step process. The first step is to establish the maximum potential yield or the maximum number of fertilized ovules that can be produced. The second step is to convert the maximum number of fertilized ovules to harvestable kernels. During all stages of the corn life cycle, meristematic cells are extracting nutrients, water and energy from the corn plant. These cells must be properly fed every day. If the corn plant faces a stress in which it cannot supply all of these necessary nutrients, water, and energy, some of these meristematic cells die. For grain yield, stress factors become particularly important during pollination when the meristematic cells are the ovules and young, fertilized embryos, and during early grain fill when these young fertilized embryos are gaining size and weight. Approximately 85% of total grain yield is related to the total number of kernels produced per acre and approximately 15% of the total grain yield is related to the weights of these kernels.

The length of the ear (number of kernels per row) is determined the last few weeks prior to tasseling. Stress at this time may reduce the number of kernels produced in each row; however, the ultimate kernel number is determined during and after pollination. Water and fertility requirements are significant during these stages and shortages significantly reduce yield.

While number of kernel positions is



determined earlier in the corn plant's development, number of kernels actually set is largely determined near the time of pollination. Once pollination begins, maximum yield potential has been set within the plant and only environmental factors such as drought, late-season insects, disease, and environmental events (e.g. hail, high wind) negatively influence final harvestable yield. Reduction in kernel number may result from incomplete pollination due to asynchrony of pollen shed and silking ("silk delay"), ovary dysfunction due to low water potential, or abortion of the newly formed embryo due to insufficient carbohydrate availability from reduced plant photosynthesis (shading or disease).

From full canopy through the reproductive period, any shortage of sunlight is potentially limiting to starch yield. When stresses such as low light limit photosynthesis during kernel starch fill, corn plants remobilize stalk carbohydrates to the ear. This may result in stalk quality issues and lodging at harvest. Sensitive periods of crop development, such as flowering and early grain fill, are when plants are most susceptible to stresses, including insufficient light, water, and/or nutrients.

Corn originated in the central highlands of Mexico and adapted during its evolution to the predominant climatic conditions of this region, consisting of warm days and cool nights. Research has shown that above-average night temperatures during reproductive growth can reduce corn yield both through reduced kernel number and kernel weight. A 1983 University of Guelph study examined the effect of temperature on grain fill. After kernel number had already been set, plants were grown in outdoor pots and then moved into controlled-temperature growth chambers 18 days after silking. The lowest temperature regime (77°F day, 59°F night) resulted in the greatest grain yield per plant as well as the longest grain fill duration. Increasing night temperature to 77°F significantly reduced yield per plant. Increasing the day temperature to 95° F also resulted in lower yield per plant, regardless of night temperature.

Current research supports two hypotheses that may explain why higher night temperatures during the grain filling period reduce grain yield:

1) the rate of respiration in the corn plant increases, requiring more sugar for energy thus making less sugar available for deposition as starch in the kernel and
2) higher temperature accelerates the phenological development of the corn plant so the corn plant matures sooner.

Although higher night temperatures undoubtedly increase the rate of respiration in corn, research generally suggests that accelerated phenological development is likely the primary mechanism affecting corn yield.

Blister stage (R2) occurs 10 to 14 days after silking. Developing kernels are about 85 percent moisture, resemble a blister, and the endosperm and the inner fluid are clear. Stress-related kernel abortion may occur during this time. Kernels fertilized last (near the tip) are often aborted first (nosing back). Kernel abortion risk is highest within the first 10-14 days after pollination or until the kernels reach R3. At this stage, maximum ear length is achieved. Silks from fertilized kernels dry and turn brown. Unfertilized silks may be visible among the brown silks.

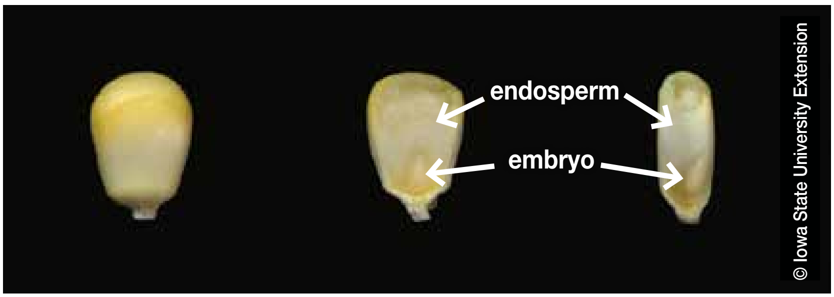
R3 occurs 18 to 22 days after silking when the kernels are about 80 percent moisture, inner fluid is milky white from accumulated starch (endosperm). The embryo and the endosperm are visually distinguishable upon dissection. Stress-related kernel abortion is still possible at this time.

Dough stage (R4) occurs 24 to 28 days after silking. Kernels are about 70 percent moisture and the inner fluid thickens to a pasty, dough-like consistency and they have attained around one-half of their mature dry weight. Hybrid specific cob color (white, pink, light or dark red) begins to develop. Husks begin to turn brown on the outer edges. Stress during this stage does not generally cause kernels to abort, but it can reduce the starch accumulation rate and average kernel weight.

Dent stage (R5) occurs 35 to 42 days after silking and accounts for nearly one half of the reproductive development time. Kernels are comprised of a hard starch outer layer surrounding a soft starch core. An indentation (dent) forms at the top of the kernel when the softer starch core begins to lose moisture and shrinks. The amount of denting that occurs is dependent on genetics and growing conditions. Flint hybrids grown in South America and Europe generally produce very little to no dent because the kernels contain primarily hard, vitreous starch and do not collapse. To optimize starch concentrations, corn silage will typically be harvested during late dent stage, but prior to black layer formation (R6).

Reduced kernel set (nosing back) due to drought stress near pollination

Primary ear at R2, with and without husks and silks.



Kernels from a R3 plant.

Monitoring kernel "milk" line is a practical approach to field evaluations for timing of silage harvest. The milk line forms as a visible separation between hard starch and soft starch. It forms at the crown of the kernel and progresses toward the base, or kernel tip. Milk line stages are generally referred to as ¼ milk line, ½ milk line, or ¾ milk line as it moves toward the cob. The total time for this movement is related to temperature, moisture availability, and hybrid genetics but typically there is about a week between each stage. At a ¼ milk line, kernels are about 55 percent moisture and have accumulated about 45 percent of their total dry matter, and about 90 percent of total dry matter by R5.5 (½ milk line). Healthy plants can accumulate from 0.6 to 1.0 percentage points of starch in corn silage every day until reaching black layer (R6). Harvesting corn silage at too early a milk line stage will severely reduce starch concentrations.

Kernel physiological maturity is achieved at the R6 (black layer) stage in about 60 to 65 days after silking. Kernel moisture is approximately 35 percent and kernels have reached their maximum dry weight. The milk line, or hard starch layer, has advanced to the kernel tip. Cells at the tip of the kernel lose their integrity and collapse causing a brown to black abscission layer to form, commonly referred to as "black layer". Black layer formation progresses from the tip of the ear to the base. If the corn plant dies prematurely from disease or a killing frost (prior to physiological maturity) the black layer still forms, but may take longer, and yield may be slightly reduced. The "premature" kernel black layer formation is related to the reduction or termination of sucrose (photosynthate) available to the developing kernels.

R6 is very near the ideal high-moisture corn (or snaplage) harvest kernel moisture of 30-34% to capture the most energy from the kernel and the cob.

Once the black layer forms, starch and moisture can no longer move in or out of the kernel, with the exception of moisture loss through evaporation. Drying rates are normally 0.4-0.8% moisture per day. Ideal combining harvest moisture for corn is 15-20%,

Progression of black abscission layer formation

R6 - Kernel abscission (black Layer)

How a corn plant develops:

Growth and development through the vegetative stages.

All corn follows a similar pattern of development with variations based on hybrids, seasons, planting dates and locations. This illustration shows the key phases of corn development through the vegetative (V) stages. Most of the information comes from "How a Corn Plant Develops," by Iowa State University and applies to a central Iowa corn hybrid (see www.extension.iastate.edu/hancock/info/corn.htm). A look at corn development from tasseling through harvest will appear in a future issue.

Germination and emergence (VE)
Once planted, corn seeds absorb water from the soil and begin to grow. VE (emergence) comes when the coleoptile (spike) pushes through the soil surface. Corn plants can emerge within five days in ideal heat and moisture conditions. But under cool and wet — or even under very dry conditions — they can take more than two weeks to emerge. The growing point (stem apex) is 1 to 1.5 inches below the surface. The seminal root system is growing from the seed. The seminal roots do much of the early work, but growth slows after VE as nodal roots begin to grow.

Tips: Longer-season hybrids generally have more yield potential than shorter-season hybrids. However, growers should choose hybrids based on the local growing season and specific field environment. Cool temperatures restrict nutrient absorption, slowing growth. Banding fertilizer can help early growth. Shallow planting may provide a warmer environment for seeds when planting early.

V3 Stage
At V3, the growing point is still below the surface. The stalk (stem) hasn't elongated much. Root hairs are growing from the nodal roots as seminal roots cease growing. All leaves and ear shoots the plant will ever produce form from V3 to about V5. A tiny tassel forms at the tip of the growing point. Above-ground plant height typically is about 8 inches.

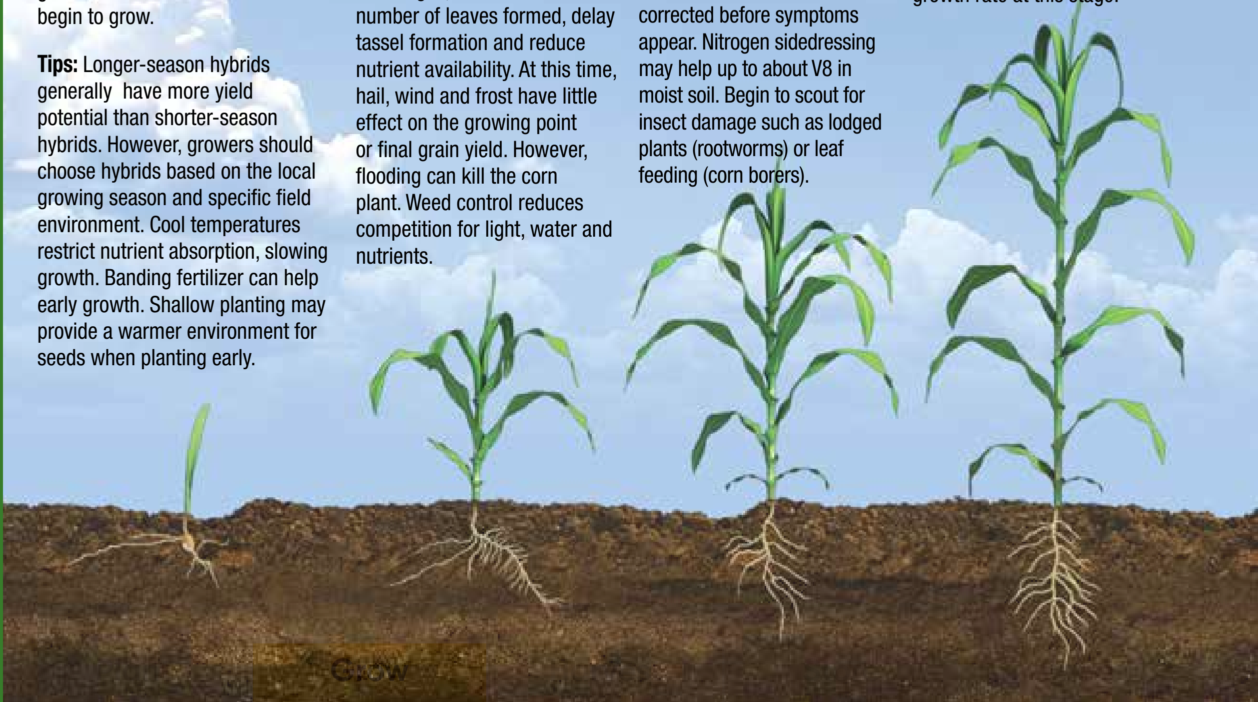
Tips: The growing point is greatly affected by soil temperatures. Cold soils may increase the time between leaf stages, increase the total number of leaves formed, delay tassel formation and reduce nutrient availability. At this time, hail, wind and frost have little effect on the growing point or final grain yield. However, flooding can kill the corn plant. Weed control reduces competition for light, water and nutrients.

V6 Stage
The growing point and tassel rise above the soil surface at about the V6 stage. The stalk begins to elongate. The nodal root system grows from the three to four lowest stalk nodes. Some ear shoots or tillers are visible. Tiller (or sucker) development depends on the specific hybrid, plant density, fertility and other conditions.

Tips: Precise fertilizer placement is less critical as roots spread. Watch for signs of nutrient deficiencies. Foliar or soil applications may help, but deficient soils are best corrected before symptoms appear. Nitrogen sidedressing may help up to about V8 in moist soil. Begin to scout for insect damage such as lodged plants (rootworms) or leaf feeding (corn borers).

V9 Stage
Dissection of a V9 plant shows many ear shoots (potential ears). These develop from every above-ground node except the last six to eight nodes below the tassel. Lower ear shoots grow fast at first, but only the upper one or two develop a harvestable ear. The tassel begins to develop rapidly. Stalks lengthen as the internodes grow. By V10, the time between new leaf stages shortens to about every two to three days.

Tips: At about V10, rapid increases in nutrient and dry weight accumulation begin. This continues into the reproductive stages. Soil nutrient and water requirements are very high. This is to meet greater demands due to the increased growth rate at this stage.



V12 Stage

The number of ovules (potential kernels) on each ear and the size of the ear are determined at the V12 stage. The number of kernels per row isn't determined until about a week before silking, at about V17. The top ear shoot is still smaller than the lower ear shoots, but many of the upper ears are close to the same size.

Tips: Moisture or nutrient deficiencies from V10 to V17 are critical. They can seriously reduce kernel numbers and ear size. Earlier-maturing hybrids progress through growth stages in less time and produce smaller ears than later-maturing hybrids. Thus early-maturing hybrids need high plant densities for maximum yields.

V15 Stage

This is the start of the most crucial period for determining grain yield. Upper ear shoot development overshadows lower ear shoot development. Every one to two days, a new leaf stage occurs. Silks begin to grow from the upper ears. By V17, the tips of upper ear shoots may be visible atop the leaf sheaths. The tip of the tassel also may be visible.

Tips: Water stress can cause yield reduction starting two weeks before silking until two weeks after silking. The closer to actual silking, the more yield reduction from stresses such as nutrient deficiencies, high temperatures or hail. When fields are dry avoid applications of fungicides, pesticides and the associated surfactants. (Read and follow label directions.) This is a critical period for irrigation.

V18 Stage

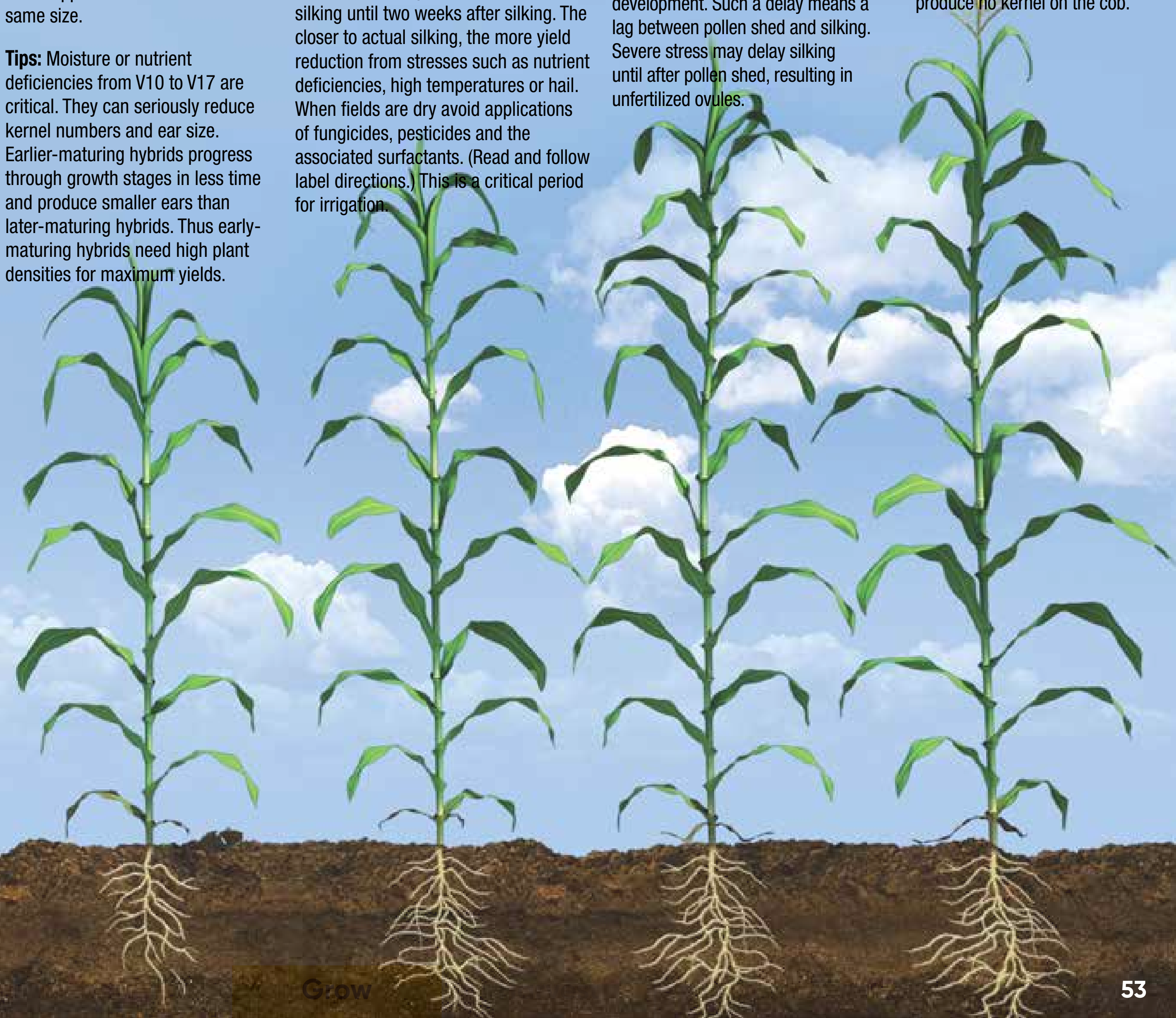
Silks from the basal ear ovules elongate first. Silks from the ear tip ovules follow. This illustration represents about eight to nine days of reproductive organ development. Brace roots (aerial nodal roots) grow from the nodes above the soil surface to help support the plant and take in water and nutrients during the reproductive stages.

Tips: The plant is about a week away from silking. Ear development is rapid. Stress can delay ear and ovule development more than tassel development. Such a delay means a lag between pollen shed and silking. Severe stress may delay silking until after pollen shed, resulting in unfertilized ovules.

VT Stage

The VT stage arrives when the last branch of the tassel is completely visible. VT begins about two to three days before silk emergence. The plant is nearly at its full height. Pollen shed begins, lasting one to two weeks. The time between VT and R1 can fluctuate considerably depending on the hybrid and the environment.

Tips: With the tassel and all leaves exposed, the plant is extremely vulnerable to hail from VT to reproductive phase 1 (R1). Total removal of leaves can devastate yield potential. If ovules aren't fertilized they produce no kernel on the cob.



How corn develops: Reproduction through maturity

R1 stage: Silking

The R1 stage begins when silk is visible outside the husks. Pollination occurs when these moist silks catch falling pollen grains. Pollen takes about 24 hours to move down the silk to the ovule where fertilization occurs. The ovule becomes a kernel. Generally, all silks on an ear are pollinated in two to three days. The silks grow 1.0 to 1.5 inches each day until fertilized. The R1 kernel is almost engulfed in cob materials and is white on the outside. The inner material is clear with little fluid present.

TIPS: The number of ovules fertilized is determined at this stage. Those not fertilized will degenerate. Environmental stress at this time can cause poor pollination and seed set. Moisture stress, in particular, affects the silks and pollen grains, which may result in a scatter-grained ear or an ear with a barren tip. Watch for corn rootworm beetles feeding on the silks and treat if necessary. At this point, potassium uptake is about complete. Nitrogen and phosphorus uptake is rapid. Nutrient content of the leaf correlates highly with final yield.

R2 stage: Blister
(10-14 days after silking)

R2 kernels are white on the outside and resemble a blister. The endosperm and its now-abundant inner fluid are clear. The embryo is still developing, but it now contains a developing miniature corn plant. Much of the kernel has grown out from the surrounding cob materials. The cob is close to full size. Silks are darkening and beginning to dry out. Starch has just begun to accumulate in the watery endosperm. Kernels are beginning to accumulate dry matter. Seed-fill is beginning.

TIPS: Nitrogen and phosphorus are accumulating rapidly and relocating from vegetative to reproductive parts of the plant. The kernels are about 85 percent moisture and will dry down from this point.

R3 stage: Milk
(18-22 days after silking)

The R3 kernel is yellow outside, while the inner fluid is now milky white due to accumulating starch. The embryo is growing rapidly. Most of the R3 kernel has grown out from the surrounding cob. Silks are brown and dry or becoming dry.

TIPS: The kernels, well into their rapid rate of dry matter accumulation, are about 80 percent moisture. Cell division within the endosperm is essentially complete, so growth is mostly due to cell expansion and starch-fill. Final yield depends on the number of kernels that develop and the final size or weight of the kernels. Stress can still impact yield by reducing both factors.

This illustration shows phases of corn development during the reproductive stages through maturity. Most of this information comes from a website feature, "How a Corn Plant Develops," by Iowa State University and applies to a central Iowa hybrid (see www.extension.iastate.edu/hancock/info/corn.htm). However, all corn follows a similar pattern with variations due to hybrids, seasons, planting dates and locations. Development from germination through the vegetative stages appears in Pioneer *GrowingPoint®* magazine, March 2010.

R4 stage: Dough
(24-28 days after silking)

Continued starch accumulation in the endosperm causes the milky inner fluid to thicken to a pasty consistency. Usually four embryonic leaves have formed as the embryo has grown dramatically from the R3 stage. The shelled cob is a light red to pink. Toward the middle of R4, the embryo will stretch across more than half of the width of the kernel side. Just before R5, kernels along the length of the ear begin to dent or dry. The fifth (last) embryonic leaf and the lateral seminal roots have formed. If this seed is planted, these five embryonic leaves will appear the following season after germination and VE.

TIPS: The embryo continues to develop very rapidly. Kernels are about 70 percent moisture and have accumulated about half their mature dry weight.

R5 stage: Dent
(35-42 days after silking)

At R5, all or nearly all kernels are dented or denting. The shelled cob is dark red. The kernels are drying down from the top, where a small hard layer of starch is forming. This starch layer appears shortly after denting as a line across the back of the kernel (the non-embryo side). With maturity, the hard starch layer and line will advance toward the cob. Accumulated starch is hard above the line but still soft below the line.

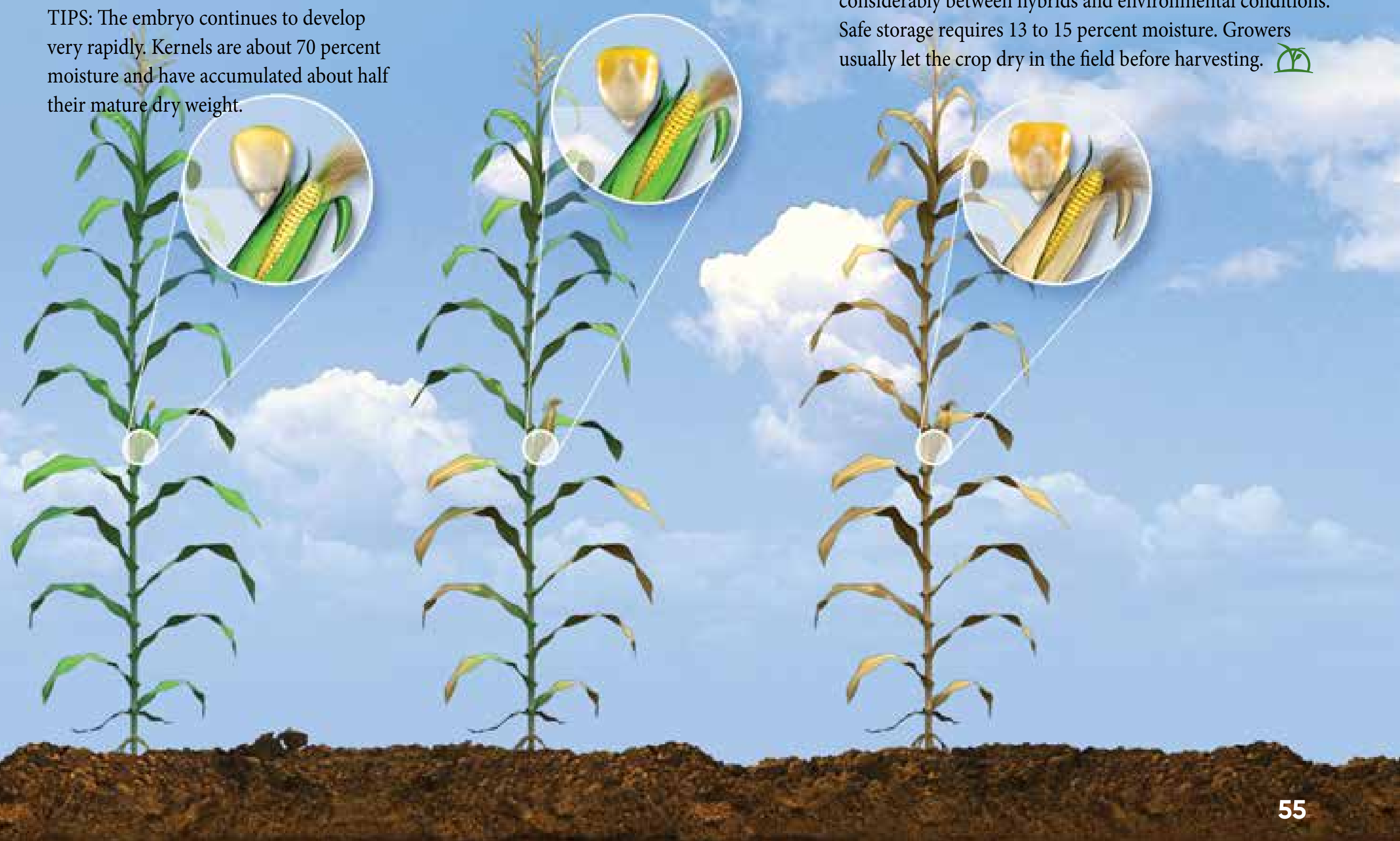
TIPS: Stress at this stage will reduce yields by reducing kernel weight. At the beginning of R5, kernels have about 55 percent moisture content.

R6 stage: Physiological maturity
(55-65 days after silking)

By the R6 stage, kernels have attained their maximum dry weight or dry matter accumulation. The hard starch layer has advanced completely to the cob. A black or brown abscission layer forms, moving progressively from the tip ear kernels to the basal kernels of the ear. It's a good indication of physiological maturity and signals the end of kernel growth. The husks and many leaves are no longer green, although the stalk may be.

TIPS: A hard early frost before the R6 stage may halt dry matter accumulation and cause premature black layer formation. This could reduce yields by causing delays in harvest (frost-damaged corn is slower to dry). To reduce potential frost problems, choose a hybrid that matures about three weeks before the average date of the first killing frost.

Kernel moisture averages 30 to 35 percent, but this can vary considerably between hybrids and environmental conditions. Safe storage requires 13 to 15 percent moisture. Growers usually let the crop dry in the field before harvesting.



which typically occurs 2 to 4 weeks after R6. The rate of field drying after R6 is highly dependent on air temperature, air movement, relative humidity, and grain moisture content. Drydown is also highly related to hybrid characteristics, such as ear orientation, plant density, tightness and length of husks, and kernel hardness. As a general rule, it requires 30 GDUs to remove one point of moisture from the grain early in the drying process (30 to 25 percent), and 45 GDUs to remove one point of moisture late in the drying process (25 to 20 percent). Grain drying rates will vary between hybrids and environments. For example, corn dries better on a 50°F (10°C) sunny day than on a 50°F (10°C) rainy or cloudy day. Both days have the same number of heat units, but the additional energy provided by the radiant energy on a sunny day dramatically improves the drying process.

STANDARD MEASUREMENTS

A typical ear of corn has 500 to 800 kernels, based on favorable environment and production practices.

Average kernel weight at 15.5 percent moisture is approximately 0.012 ounces (350 mg), with a range of 0.007 to 0.015 ounces (200 to 430 mg).

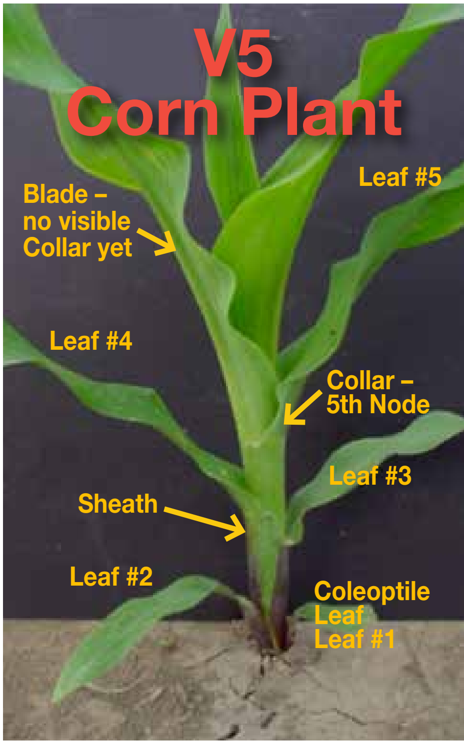
A standard bushel weighs 56 pounds (25.5 kg) and contains approximately 90,000 kernels, with a range of 59,000 to 127,000 kernels per bushel (2.3 to 5.0 million kernels per metric ton).

DETERMINING CORN LEAF STAGES

The "leaf collar" system developed at Iowa State University is the method most widely used by extension and seed company agronomists to determine leaf stages. With this method, each leaf stage is defined according to the uppermost leaf whose leaf collar is visible. This makes it easier to distinguish between stages, rather than using other indicator systems, such as plant height or exposed leaves. These other systems include the leaf tip number and the plant height systems (used by herbicide labels). The number of leaves exposed or plant height systems are not as accurate as the leaf collar system. Plants will respond to different environments/stresses and may be older than they appear if looking only at plant height. The leaf number system does not require collar formation to count, so it is open to interpretation, and may lead to less consistent staging.

The first part of the collar that is visible is the back, which appears as a discolored line between the leaf blade and the leaf sheath. The oval shaped first leaf, or "seed leaf," is the reference point for counting upward to the top visible leaf collar. The oval seed leaf is counted as the first leaf of a corn plant when staging vegetative growth. If a plant has four visible leaf collars, then it is defined as being at V4. Normally a plant at the V4 stage will have parts of the fifth and sixth leaves visible, but only four leaves with distinct collars.

To determine the plant stage in older plants, identify the sixth leaf. Find the node at the soil surface, and if the soil has not been disturbed (no cultivation), this will typically be the sixth node. Identify the leaf attached at the sixth node (leaf 6) and count successive collared leaves above that to determine the vegetative stage. A field is defined

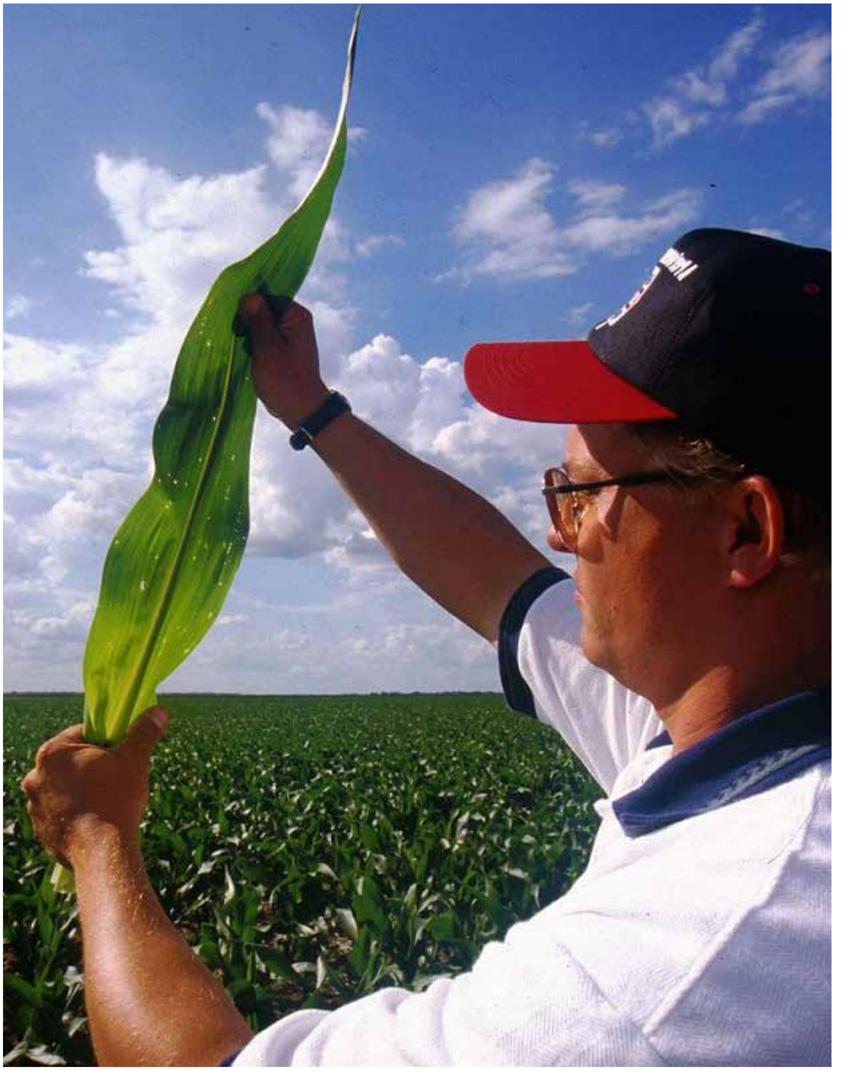


as being at a given growth stage when at least 50% of the plants show collars for that leaf number.

Another way to approximate plant maturity is to estimate leaf stage by GDD accumulation. Purdue University research indicates that from VE to V10 (10 leaf collars) leaf emergence occurs every 82 GDD. From V10 to tasseling (VT) leaf emergence occurs every 50 GDD. An example would be a field that had accumulated 785 GDD since planting. Assuming the plants emerge after about 120 GDD, that leaves 665 GDD (785-120) for leaf development. 665 divided by 82 GDD/leaf emergence equates to V8 (665/82=8.1) plant maturity.

SCOUTING FOR PROBLEMS

It should go without saying that walking fields and digging roots (e.g. monitoring corn rootworm) pays big dividends. Insects can cause standability issues, rob nutrients, and increase ear molds and premature plant death. The value of above- and below-ground pest management will be based on crop rotation, hybrid selection, class of insects that are of primary concern, available insecticide control methods and tillage systems. With all the options available, this area of management Is best discussed with consulting agronomists and seed or chemical company representatives.



Walking corn fields is important to monitor for yield-robbing pests and diseases. From emergence to V5, attention should be paid to seed placement and emergence issues along with looking for early insects (e.g. brown stink bugs, corn flea beetle, slugs), diseases (Goss's Wilt, Stewart's Wilt) or weed pressure that could affect early vigor of the plant. From V5 to tasseling, water stress, foliar diseases, and first generation insects are key factors that could limit yield. From tasseling to silage harvest maturity, second-generation insects, foliar diseases and mold issues are important to monitor.

COMMON CORN INSECTS


European Corn Borer


Japanese Beetles


Black Cutworm


Fall Armyworm


Wireworms


Southwestern Corn Borer


Western Bean Cutworm


Spider Mites


Corn Earworms


Corn Rootworm


White Grubs


Aphids

CORN FOLIAR DISEASE DIAGNOSIS AND MANAGEMENT TIPS

- Select resistant hybrids
- Manage residue properly
- Time planting
- Apply fungicide in high-risk fields

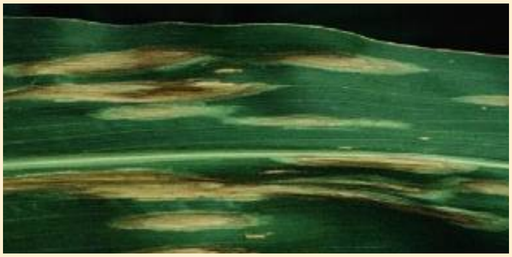
Eyespot Lesions

Northern Leaf Spot

Southern Leaf Blight

Gray Leaf Spot

Common Rust



Northern Leaf Blight

Southern Rust

Goss's Wilt

WIND/HAIL DAMAGE

Storm damage to the growing corn plant includes root lodging and stalk breakage from wind, along with leaf loss and stem bruising from hail. Yield potential of hail-damaged crops depends largely on the growth stage, remaining plant population and the type and severity of damage.

Recommendations from the University of Minnesota are to wait three to five days following a hail storm to allow time for regrowth for better evaluation of plant survivability given the growing point of corn will be about 3/4 of an inch below the soil surface until the V5-V6 growth stage. For hail damage in more mature plants, they will regrow if the growing point is still healthy. Plants with damaged growing points or stalks broke below the growing point will not recover. Locate the growing point by splitting a stalk down the center; a healthy growing point will be white to light green in color and firm in texture. If the growing point has been damaged, bacteria will often invade the plant and the growing point will be brown and soft and these plants will not recover. Bruising of stalks by hail limits the plant's ability to translocate water and nutrients and also reduces standability. Plants with stalk bruising should have their stalks split to determine the severity of the bruising. Plants with damage extending beyond the leaf sheaths and into the pith either will not recover or likely will have large reductions in yield. Fields with severe stalk bruising should be harvested early to avoid significant losses from stalk lodging.

Some plants that are severely damaged by hail may have difficulty regrowing. Plants with leaves loosely bound in the whorl usually grow or blow out and continue with normal development, but plants with leaves very tightly bound in the whorl usually don't grow out. These plants are often referred to as buggy whips or ties. The leaves remain so tightly wrapped that some of the uppermost leaves and the tassel are unable to emerge from the whorl. It is impossible to determine if these plants will recover or the degree to which they will recover. Although some of these tied plants might shoot an ear and produce some grain (tassel emergence is not necessary on each plant to allow pollination), they should not be counted as living plants when the population count is made. They are not likely to contribute significantly to grain yield.

When soils are saturated, strong winds can cause corn plants to lean over due to pulling of shallow roots. Within a few days, root-lodged plants will typically straighten upright and stalks will have a curved appearance. The impact of root lodging depends largely on the growth stage when it occurred. Most plants straightened upright within three days and yield loss was dependent on the growth stage when damaged. Research at the University of Wisconsin showed that grain yield was reduced by less than 5% when damaged at the V10 to V12 stage, by 5 to 15% when damaged at the V13 to V15 stage, and by up to 30% when damaged at V17 or later.

The initial step is to determine the viable plant population in the affected field. The length of row equivalent to one thousandth of an acre for various row spacing is provided in the PLANT section. Measure the distance for 1/1000th of an acre for your row spacing and count the number of live plants in that row section. Then multiply by 1000 to determine the number of healthy plants per acre. Several checks should be made throughout the field as scouting the entire field may identify areas of the field that do not need replanting.

The next step is to determine the amount of leaf loss. The amount of defoliation and the stage of development at the time of a hailstorm

EFFECT OF LEAF AREA DESTROYED ON CORN GRAIN YIELD

	PERCENT LEAF AREA DESTROYED				
LEAF STAGE*	**20**	**40**	**60**	**80**	**100**
	PERCENT YIELD LOSS				
7	0	1	4	6	9
8	0	1	5	7	11
9	0	2	6	9	13
10	0	4	8	11	16

*Leaf stage corresponds to number of leaves, which are arched over, and pointing downward.

Source: Hicks, D. The Corn Growers Field Guide For Evaluating Crop Damage And Replant Options will determine the effect on grain yield. Leaf loss early in the growing season, particularly major amounts of leaf loss, is thought to set back the corn plant or delay the maturity. However, research shows no appreciable delay in tassel emergence, silking date, or kernel moisture content at harvest resulting from partial or complete leaf removal for plants between leaf stages five and thirteen. Significantly shorter plants occur due to complete defoliation at these growth stages when the stalk is elongating. Plants can be as much as 8-10 inches shorter due to complete defoliation during this time. Corn will grow more slowly following leaf removal, depending upon the amount of leaf area lost and the weather that follows, but the shorter plants that grow after defoliation are not set back in maturity. Complete defoliation of young corn plants up to the 7-leaf stage will usually result in little or no reduction in yield. As the plant gets older, the loss of leaf area will increasingly affect yield. Leaves are sometimes torn or shredded due to high velocity winds or hail. Leaf tissue remaining on the plant, and green in color, continues to function and contribute to grain filling. Only leaf tissue completely removed, or brown in color, should be considered when determining the percentage of leaf area destroyed or removed.

Stalk breakage, often referred to as greensnap, may occur because of high velocity winds. Stalk breakage can occur any time after corn plants have reached knee high, but most frequently occur in the one-to two-week window prior to tasseling (V10-VT). Plants at that stage are growing rapidly such that stalks are brittle and very vulnerable to breaking when high velocity winds occur. Breakage early in the growing season when plants are knee-high causes a reduction in stand, and the calendar date may be such that replanting is not economically feasible. Plants that are not broken will compensate somewhat for reduced competition from adjacent plants, but grain yield will be lowered because of the lower plant population. Breakage is also common just before tasseling. Concerns about inadequate pollination arise when tassels are lost due to stalk breakage. However, individual tassels generally produce over two million pollen grains. Assuming 800 silks per ear, this corresponds to 2,500 pollen grains per silk, indicating great potential for adequate pollination of neighboring plants with lost tassels.

The effect of stalk breakage on grain yield will depend on a number of factors:

1) the percent of plants broken,
2) the distribution of broken plants,
3) the location of the break on the stalk, and
4) the growth stage of the crop.

Yields are affected least when the stalk breaks above the uppermost ear. Plants adjacent to broken plants will partially compensate and produce more grain weight per plant because of less competition, especially for sunlight. Yields are reduced more when the stalk is broken below the uppermost (top) ear compared with when the stalk is broken above the top ear. At the tassel stage, the potential size of the second ear has been determined with the plant expecting to fill kernels on the top ear and, under most situations, there usually is little or no grain produced on the second ear. At this stage, the plant cannot adjust the number of kernels that can be produced on the second ear.

FUNGICIDES

Keeping corn free of stresses caused by leaf diseases and stalk rots is important to achieving maximum yield. Diseases like Gray Leaf Spot, Northern & Southern Leaf Blight, Common & Southern Rust, Anthracnose and Eyespot can quickly reduce a crop's green leaf area, photosynthetic capacity and grain (starch) yield. In addition, reduced photosynthesis can cause depletion of stalk carbohydrates during ear fill, resulting in higher risk of stalk rots and lodging.

The goal of fungicide application is to protect yield by preventing infection on the ear leaf and above from these diseases as the plant enters the reproductive stage. Fungicides have various modes of action including electron blockers within the mitochondria or specific enzyme blockers which limit the fungal ability to metabolize nutrients to fuel their growth. The need for foliar fungicide applications for corn disease management has increased due to a number of factors, from the increase in continuous corn acres, and reduced tillage practices, to variable environmental conditions. Factors influencing hybrid yield response to foliar fungicide include: environmental conditions and weather patterns, disease pressure, previous crop and tillage, hybrid disease susceptibility, hybrid maturity and planting date.

There are strong opinions on both sides of the fungicide debate. Recommendations from the University of Wisconsin suggest that there is not a consistent economic return from fungicide usage and that growers should focus primarily on hybrid resistance to foliar diseases. Results of a three-year joint research study by the University of Tennessee and Pioneer further reinforces the need to focus on hybrid selection. The study showed that the probability of a positive economic return from using a fungicide was directly related to the susceptibility of a hybrid to the predominant leaf diseases in that growing environment. It is clear that corn grain and corn silage growers should fine-tune their hybrid selection process by assessing hybrid disease ratings for foliar diseases.

Contrast that with research from the University of Illinois that showed an average 7.6 bushel per acre yield advantage to fungicide treatment over the past three growing seasons and when the crop was under high disease pressure, anywhere from a 15-20 bushel per acre yield response. Consistent with the Illinois research, ten small-plot research locations harvested in 2009 by Pioneer showed fungicide yield responses varied from 0.6 bushel to 22.6 bushels per acre depending on disease pressure and hybrid susceptibility. Between 2007 and 2015, Pioneer researchers conducted 1,241 agronomy fungicide trials comparing yield and moisture of non-treated corn to corn treated with a foliar fungicide between tasseling and brown silk. Across these trials, the average yield response to fungicide application was an increase of 7.9 bushels/acre. While yield response varied from location to location and year to year due to different environmental conditions, a positive yield response due to fungicide application occurred in 82% of the trials.

There does seem to be agreement as to conditions which favor foliar fungicide applications. These include: 1) planting hybrids susceptible to foliar diseases, 2) fields with high residue, such as corn-following-corn, and no-till or strip-till, 3) extended warm, wet, humid growing conditions and 4) planting at very high populations. While no research data exists on narrow-row silage corn (15 inch rows), this may also contribute to a high-humidity, micro-environment more conducive to foliar diseases. Later planted fields and/or later maturing hybrids may also respond better to fungicide treatments because they are in the important grain filling period as foliar disease development peaks in late summer.

The use of fungicides does not eliminate the need for spending time walking the crop and scouting for diseases. This is especially true if considering early season fungicide applications (e.g. prior to the 5th leaf collar stage) which can be attractive by eliminating one application expense when mixing fungicide with a post-emergence herbicide. Plant pathologists suggest that fungicide application should be considered if infection has moved up through the leaf canopy such that over 5% of the ear leaf area contains lesions by tasseling and silking (VT-R1). This level of infection, at such an early growth stage, will likely increase in severity and reach the economic threshold of over 15% leaf area infection resulting in a significant decline in the ability of the plant to deposit starch throughout the reproductive stages. Some growers also apply fungicide at V5-V6 when side dressing nitrogen or applying herbicide, but unless scouting reveals early fungal infections, it may be best to wait until more leaf area is exposed (around tasseling, VT), given that most foliar diseases don't become entrenched until later in the growing season (after pollination) and that the average residual period is typically only 7-21 days.

There have been limited fungicide studies with corn silage, although benefits derived for grain corn should similarly benefit silage growers. A 2007 field trial conducted by University of Wisconsin extension specialists showed that fungicide treatment resulted in a 0.7 ton increase in silage dry matter yield, a 2% unit increase in starch content and reduced stalk lodging. There was also a 1.8% unit increase in NDFD. While these increases were not statistically significant, they do appear biologically and economically encouraging. This study also found no significant reduction in mold, yeast and mycotoxin levels, but it should be noted that even the untreated plots were essentially devoid of mold contamination. University of Illinois researchers have published several studies with corn silage plants treated with fungicides, in which yield was not significantly influenced, but where fiber changes in the plant improved feed conversion to milk production in cows fed the silage treated with fungicide. Researchers at the University of Wisconsin looked at fungicide application on the presence of deoxynivalenol (DON or vomitoxin) in 2017 small plot work with a BMR hybrid. Several of the commercial fungicides resulted in a significant reductions in

DON. In a subsequent trial in 2018, UW researchers added a second BMR hybrid and analyzed DON in both the stalk and the grain. Their findings were: 1) DON can accumulate in ears and stalks and appears to be hybrid dependent, 2) DON can accumulate in the stalk portion, independent of ear infection control by fungicide applied at R1 and 3) the recommended window of application was to begin at R1 (silking) and end around 10 days after the start of R1. The researchers suggested more work needs to be done to determine if earlier fungicide application (V6 stage) could reduce stalk DON accumulation. The ability of fungicides to reduce mold needs further research as they would not prevent spores infecting the ear by entering silk channels during pollination.

Silage growers have also questioned if fungicide application would have any negative effect on the anaerobic bacteria plant populations which are responsible for fermentation in silages that are not inoculated with a commercial product. The fact is that foliar fungicides inhibit aerobic fungi and do not have an effect on the anaerobic, natural (epiphytic) plant-borne bacteria that initiate silage fermentation.

Practical issues to discuss with an agronomist or chemical sales professional when selecting a fungicide include: 1) disease threshold considerations, 2) recommended timing of application(s), 3) any aerial application limitations in your State, 4) residual activity, 5) curative properties, 6) adjuvant recommendations, 7) redistribution capability to ensure coverage deep in the leaf canopy and 8) required time from application to harvest.

Research to date suggests that foliar fungicides do not consistently reduce disease or increase yield in hail-damaged corn. While there is still debate on the subject, University of Minnesota plant pathologists agree with studies at Iowa State University and the University of Illinois that there is no consistent increase in corn diseases due to hail damage, with the exception of common smut, Goss's leaf blight and wilt, and possibly stalk rots. None of these diseases are managed effectively with foliar fungicides. The most damaging diseases affecting corn after hail are bacterial and fungicides have no effect on these bacterial diseases.

Do not expect fungicides to always return a profit, nor to necessarily reduce mold and mycotoxin problems. However, there is data suggesting that fungicides can be a very effective tool for managing foliar diseases and deliver healthier plants with higher grain (starch) content. Modern fungicides should certainly be considered as a defensive or insurance-type management tool, especially in challenging, high-yield environments with hybrids susceptible to foliar disease.

FERTILITY

Soil nutrient tests prior to planting can inform growers of the various amounts of nutrients in the soil which are available to the crop. Soil nutrient credits can be subtracted, or credited from the total nutrient requirement to grow a corn silage crop based on yield goals. Credits can be taken for previous legume crop, manure application and N in irrigation water. Corn silage fertility programs must compensate for the large amount of nutrients removed with the whole plant. Soil fertility can improve the forage quality of corn silage primarily by enhancing grain yields.

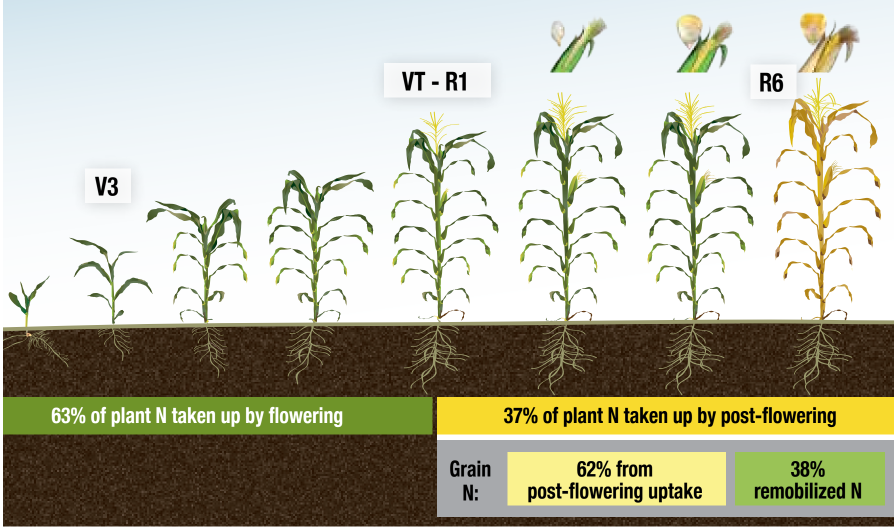
The starting point is proper soil sampling to establish the residual amounts of N, P, and K (nitrogen, phosphorus and potassium) and applying supplemental amounts according to the yield potential of the field. Soil nutrient testing, prior to planting, can inform growers of the various amounts of nutrients available to the crop. General thumb-rules of nutrient availability are that nutrient uptake begins before emergence, nutrient uptake is low early in the season, but nutrients surrounding the root must be high and nutrient deficiencies can be identified through plant symptoms.

Nutrients required for a corn silage crop are determined largely by expected yields. The table on the next page shows the nutrient amounts removed per ton of harvested silage. Crop availability of nutrients in the soil varies depending on factors such as soil pH, compaction and other various factors.

Phosphorus is removed at the rate of 35 lbs/10 tons of silage harvested. Maintaining soil plant-available phosphorus values at or near 20 ppm (Bray Test) or 16 ppm (Olsen Test) has been shown to optimize yield responses. Potassium soil test levels should be maintained at 100 to 150 ppm. At 150 bushels/acre yield, there are approximately 187 lbs of K_2O in the grain and stover or about 11 lbs of K_2O per ton of silage.

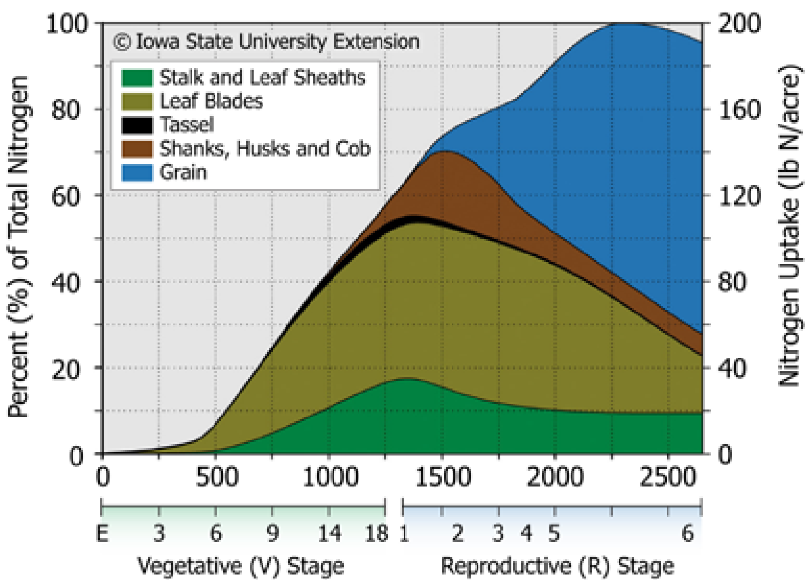
Corn grain removes approximately one pound of nitrogen per bushel harvested, and stover production requires a half-pound for each bushel of grain produced. Nitrogen rates should be increased by about 20 lbs/acre compared to grain requirements to help maximize nutrient yields of the corn silage crop. Only a portion of this amount needs to be supplied by N fertilizer; N is also supplied by the soil through mineralization of soil organic matter. On highly productive soils, N mineralization will often supply the majority of N needed by the crop.

Nitrogen for grain development originates from both remobilized N (from vegetative tissues) and continued N uptake from the soil. Ensuring a season-long N supply is critical for maximizing yield of starch. By silking maturity (R1), corn has taken up approximately 63% of its N requirement for the season. The remainder is taken up during the grain-fill period (R1 to R6). For high grain yield potential, 140 to 210 lbs N/acre is needed to support grain development. Approximately 38% of this demand is remobilized from vegetative tissue with the remainder supplied from continued uptake after flowering. In high yield environments, post-flowering N uptake can range from 85 to 130 lbs N/acre. Cannibalism of the corn stover to provide nutrients for ear development can have a negative impact on stover fiber digestibility.



NUTRIENT REQUIREMENTS PER TON OF SILAGE HARVESTED (30% DRY MATTER)

PLANT NUTRIENT	POUNDS REQUIRED PER TON
Nitrogen	8
Phosphate (P_2O_5)	4
Potassium (K_2O)	8
Sulfur	1
Zinc	.007



IN-SEASON NITROGEN FERTILITY

- One of the most important nutrients.
- Most prone to loss by leaching from:
    - High rainfall
    - Excessive irrigation
    - De-nitrification into the atmosphere

EFFICIENCY OF NITROGEN USE BY THE CROP (HIGHEST TO LOWEST)

1. Sprinkler applied during rapid growth phases (V6-VT)
2. Side-dress just before rapid growth phases
3. Post-plant incorporated
4. Pre-plant incorporated
5. Fall application for next years crop

IN-SEASON FERTILITY

- "Starter Fertilizer" near the root zone is beneficial to early plants
- Fertilizer should be placed in the "2 inch x 2 inch band" around the seed

2 inches to the side

2 inches to the side

2 inches below

- Fertilizer placed too close can cause salt damage to a young plant
- Roots are not attracted to the fertilizer, so it needs to be placed where roots will be

COMMON NUTRIENT DEFICIENCY SYMPTOMS IN CORN

NITROGEN

- Uptake continues until near maturity
- Can be translocated from plant parts to develop grain
- Nitrogen deficiency appears as a yellowish coloration in a "V" pattern progressing from leaf end to collar and from lower to upper leaves

POTASSIUM

- Need is completed soon after silking
- Can be translocated from plants to develop grain
- Potassium deficiency appears as yellow and brown coloration of the leaf margins which occurs first on the lower leaves and can progress to the upper leaves

PHOSPHORUS

- Uptake continues until near maturity
- Can be translocated from plant parts to develop grain
- Phosphorus deficiency appears as a purple coloration of the lower leaves

SULFUR

- Sulfur deficiency is a general yellowing similar to nitrogen deficiency, except the young upper leaves have more pronounced symptoms because sulfur is not mobile in the plant

ZINC

- Zinc deficiency can be induced by copper hoof treatment programs in wastewater from dairy operations
- Corn has high zinc requirements compared to other crops
- Zinc may be deficient in sandy soils, other low organic soils such as those with topsoil removed or soils with high pH
- Seedlings may show deficiencies during cool, wet weather
- Zinc deficiency appears on the upper leaves. The yellowing between the veins begins in the leaf middle and progresses outward

MANAGING WEEDS

Weeds compete with corn for light, nutrients and water, reduce silage feed quality at the later stages of growth and can harbor destructive insect pests. A vigorous well-growing crop is the best defense against weed infestations and competition. Studies show that the "critical period" for preventing yield-reducing weed interference in corn is from the V2 to V3 growth stage until V12 (approximately three weeks through eight weeks after planting).

A combination of cultural, mechanical, and chemical weed control procedures will typically give the best results. Cultural practices that keep fence lines, ditches and wasteland areas free of weeds will lower rates of weed infestations, as will thoroughly cleaning tillage and harvest equipment before entering or leaving a field. Cultivation will sever or bury weeds and is effective for herbicide-resistant weeds. Chemical control is effective when weed populations are high and cultivation is not economical or feasible.

Herbicides can provide cost-effective weed control while minimizing labor. However, improper herbicide use may result in crop injury, poor weed control, herbicide resistant weeds, environmental contamination, or health risks. Herbicides kill plants in different ways and must meet several requirements to be effective. It must come in contact with the target weed, be absorbed by the weed, move to the site of action in the weed, and accumulate sufficient levels at the site of action to kill or suppress the target plant. Herbicides may be classified according to selectivity (nonselective, grass control, broadleaf control, etc.), time of application (pre-plant incorporated, pre-emergence, or post-emergence), translocation in the plant (contact or systemic), persistence, or site of action. Understanding how herbicides work provides insight into how to use the chemicals and helps diagnose performance problems and related injury symptoms. The best source of information for herbicide use is the herbicide label. Always apply herbicides according to label directions.

Grain yield winners in the NCGA contest typically have more than one mode of action in their weed management program. Most included both pre- and post-emergence treatments. A pre-emergence followed by post-emergence herbicide program is likely to be the most reliable and effective under a wide range of growing environments.

IMPACT OF MOISTURE AND GROWING ENVIRONMENT

The influence of growing conditions (especially moisture) is a major source of the nutritional variability seen within hybrids across years and locations. Researchers at the University of Illinois attributes 19% of the grain yield performance to hybrid genetics, with the remaining influence being the result of weather (27%), nitrogen (26%), previous crop (10%), plant population (8%), tillage (6%) and growth regulators (4%).

A high-yielding corn crop requires between 20 to 24 inches of water in the Midwest and upwards of 28 to 30 inches in the more arid West. One inch of water per acre is about 27,000 gallons. A corn crop requiring 24 inches of moisture would need about 648,000 gallons of water. If that crop yielded a national average of 175 bushels per acre, each bushel would require about 3,700 gallons of water.

Crop water use, often referred to as evapotranspiration (ET) consists of soil evaporation (E) and crop transpiration (T). In practical terms, ET describes water in (or on) soils or plants converted to atmospheric water vapor. Corn plants extract water from the soil and transport it to small openings in the leaves (stomata) where it exits into the atmosphere. Transpiration cools corn plants to optimize photosynthesis and growth. The ratio of evaporation to transpiration changes as crops mature and shade more soil. When crops are young and leaf surface area is small, soil evaporation accounts for most of the moisture loss. As the corn plant matures and canopies the soil, transpiration becomes a significant cause of moisture loss.

The corn crop's need for water is an interaction between plant, soil and atmospheric factors. The amount of water available for corn plants from the soil is determined by soil texture, water holding capacity, infiltration rate and ease of giving up moisture. For example, the higher the salt concentration in the soil, the harder it is for the plant to extract water. Atmospheric factors include the amount of solar radiation, air temperature, humidity and wind speed. High solar radiation and air temperatures, low humidity, clear skies and high wind raise ET. Cloudy, cool and calm days reduce evapotranspiration.

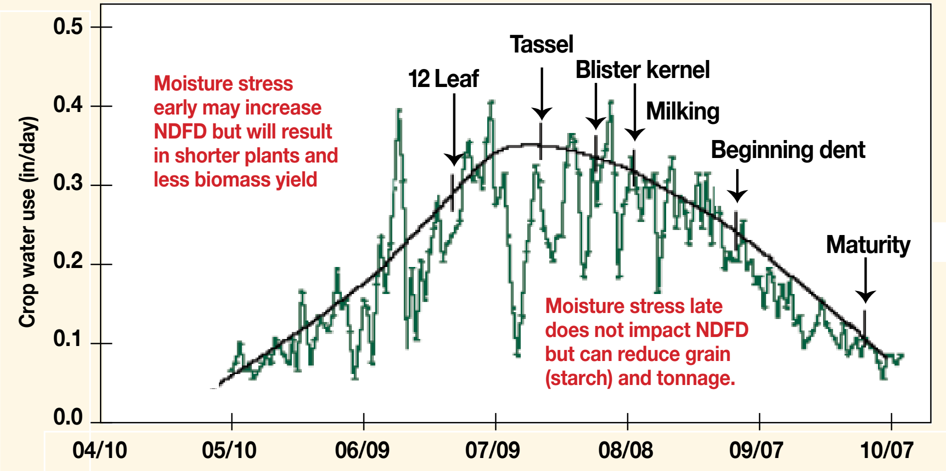
Crop factors such as stage of development, rooting depth, planting density and amount of crop residue all impact ET from the crop standpoint. Crop residue can have a significant effect on evaporation of water from the soil surface. A University of Nebraska study found that residue on the soil surface saved 3 to 4 inches of irrigation water compared to bare soil plots.

During the vegetative growth of the corn plant, it is relatively drought tolerant and can survive upwards of 60 percent soil water depletion in the root zones without a significant impact on grain yield. However, silage yields will be reduced due to shorter plants when corn is moisture-stressed during the vegetative growth stages. The corn plant needs the most moisture from about silking through the blister stage. After blister stage, the plant is again fairly immune to water deficiency and irrigation can be terminated when the kernel milk line is at about 50 percent (R5.5).

Drought can result in plants ranging from barren plants with no ears or starch content to varying levels of starch (grain) depending upon stress at pollination and subsequent kernel abortion. Energy will be partitioned

CORN WATER USE

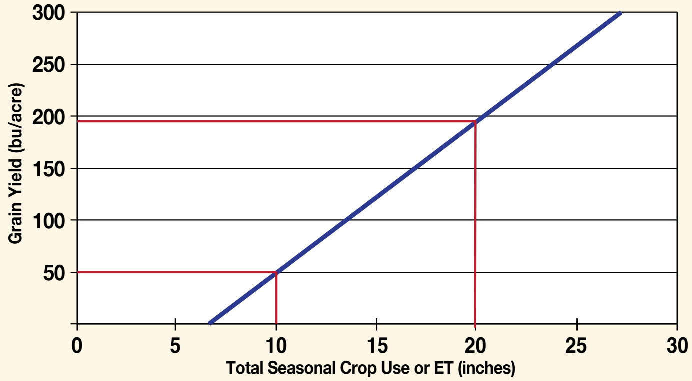
- Crop evapotranspiration (ET) is driven by the drying that the atmosphere exerts on soil/plant surfaces. For corn plants range is 0.1 to 0.4 inches/day.
  - ET is increased by high solar radiation and air temperatures, low humidity, clear skies and high wind.
  - ET is decreased by cloudy, cool and calm days.
- Seasonal ET also is affected by growth stage, growing season length, soil fertility, water availability and interactions of these factors
- Seasonal ET ranges from about 24 inches (~600 mm) in the humid area of eastern Nebraska to 28 inches (~700 mm) for the arid southwest US



Long-term daily average (black line) and individual year (green line) corn water use by growth stage from Kranz et al. (2008)

CORN YIELD RESPONSE TO WATER

- Under water-limited conditions, corn grain yields typically are associated positively with total seasonal water use
  - At 20 inches of available water (stored soil water + seasonal precipitation + irrigation), potential grain yield should be near 200 bu/acre
  - With only 10 inches, maximum of 50 bu/acre can be expected
- Water stress during critical reproductive growth (pollination) significantly lowers yield potential
- Understanding this relationship helps one make agronomic management decisions regarding hybrid selection, plant population, fertilization rate, and irrigation timing



Relationship of grain yield to total seasonal crop water use or evapotranspiration (ET) from Grassini et al (2009)

more into sugar and fiber in the stalk and leaves rather than to grain. Studies conducted by Michigan State University indicate that severely stressed corn (short plants with essentially no ears), still had a feeding value of approximately 70% of normal corn silage due to the highly digestible fiber and sugar content. Due to the potential variability, it is important to analyze droughty corn silage for dry matter, NDF, uNDF, NDFD, sugar, starch and nitrates (%NO3 or ppm NO3-N) and consider segregating storage based on fields that may have relatively lower nutritional value.

University of Wisconsin agronomists recommend the following practices if there is concern for drought conditions before planting:

1) plant deeper (2 to 3 inches) to ensure moisture for germination,

2) prevent water evaporation from the soil surface with residue on the soil surface,

3) minimize spring tillage and till at shallower depths,

4) work and plant fields as quickly as possible,

5) minimize anhydrous ammonium injury by applying at an angle and 8 to 10 inches deep,

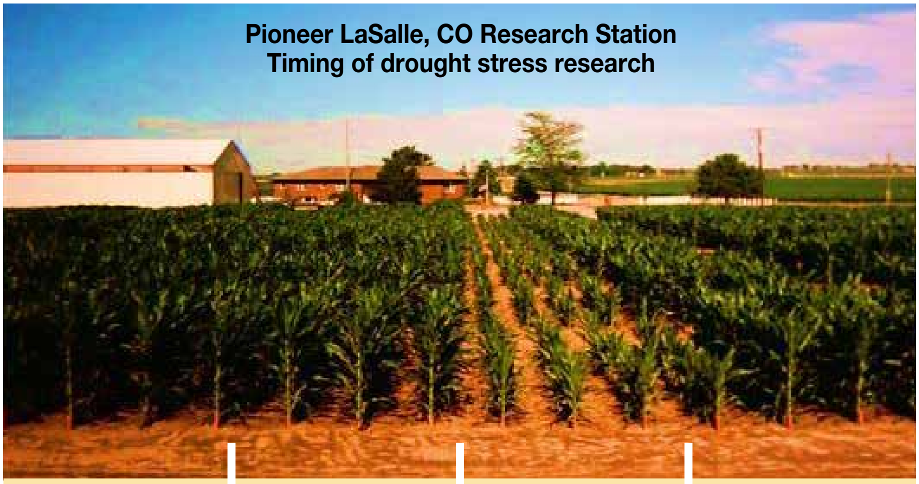
6) plant as early as possible so corn pollinates during less stressful times of the growing season and

7) weed control is essential because weeds compete with corn for moisture, and dry conditions reduces the effectiveness of most herbicides.

Research at Cornell University suggests that moderately cool and dry growing conditions improve corn silage nutritional quality and slight moisture stress stimulates seed (grain) production. Cool temperatures (especially at night) appear to inhibit secondary cell wall development which can negatively impact fiber digestibility.

The growing conditions before and after silking (R1) affects corn silage nutritive values in different ways. In general, dry (or limited irrigation) conditions during the vegetative stages of plant growth shortens plant stature, but enhances fiber digestibility (Neutral Detergent Fiber Digestibility, NDFD). Higher than normal temperatures tend to moderate the positive effect that low moisture has on improving NDFD. Wetter than normal conditions during vegetative growth, while improving whole-plant yield (taller plants), tends to reduce

EFFECTS OF MOISTURE STRESS

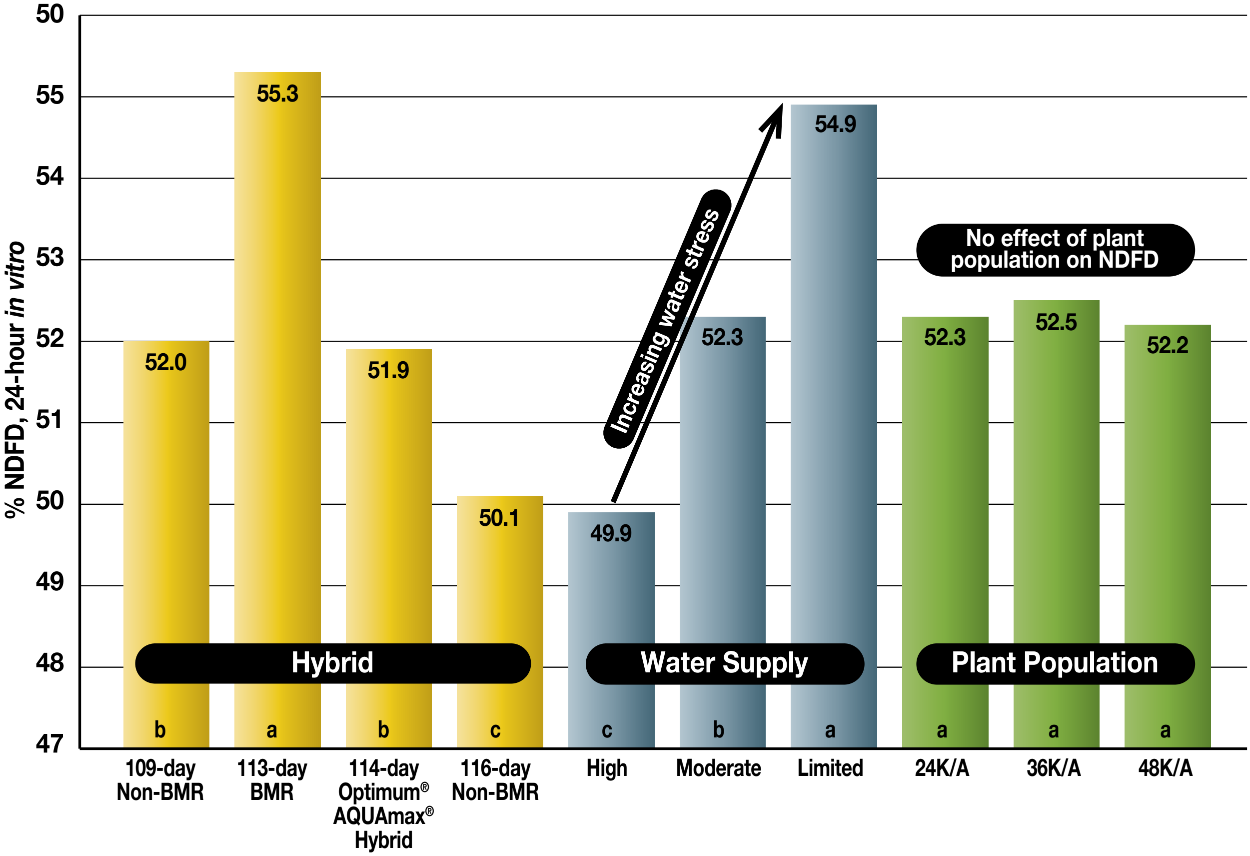


Grain Fill	Flowering	Vegetative	Full Water
Stress = normal plant height but lower starch driving less silage yield	**Stress** = normal plant height but lower starch driving less silage yield	**Stress** = shorter plants but reasonable starch yield	

127 bu/A	138 bu/A	164 bu/A	226 bu/A

Source: Soderlund, S., F. N. Owens and C. Fagan. 2013. Field experience with drought-tolerant corn. Presentation at the Joint Annual Meeting of the American Dairy Science Association (ADSA) and American Society of Animal Science (ASAS), Indianapolis, Indiana, July 2013.

EFFECT OF HYBRID TYPE, WATER LEVEL AND PLANT POPULATION ON 24-HOUR NDFD (PIONEER RESEARCH, LASALLE, CO 2011)



a,b,c Means within rows with different superscripts differ at P<.05

fiber digestibility.

Data from Michigan State University silage plots harvested in a relatively wet growing season (2006) compared to the same hybrids harvested from the same plot in a relatively dry growing season (2007). Hybrids averaged 6.5 points higher in 24-hour NDFD in the drought year. It was interesting to note that, as expected, the highest NDFD in both seasons was a Brown MidRib (BMR) hybrid (hybrid #10), but that nearly half of the conventional hybrids grown in the drought year were higher in NDFD than the BMR grown in the wet year. Even if the laboratory estimate of NDFD of the non-BMR hybrids look higher than the BMR hybrid, the BMR silage will tend to drive higher intakes among cattle because of the lower lignin and fragility of the BMR cell walls. It is not biologically valid to compare BMR to non-BMR hybrids with regards to NDFD alone. Perhaps a more biologically pertinent comparison would be to compare starch content (which dilutes the fiber) and amount of undigestible NDF (uNDF) which has been shown to be highly correlated with dry matter intake potential of the feedstuff.

During the reproductive growth stages, environmental growing conditions appear to exert little impact on NDFD, but does have considerable influence on kernel starch deposition (grain yield), starch: fiber ratios and ultimately total plant digestibility. University and seed company research shows

INFLUENCE OF MOISTURE STRESS AT VARIOUS GROWTH STAGES ON CORN GRAIN YIELD

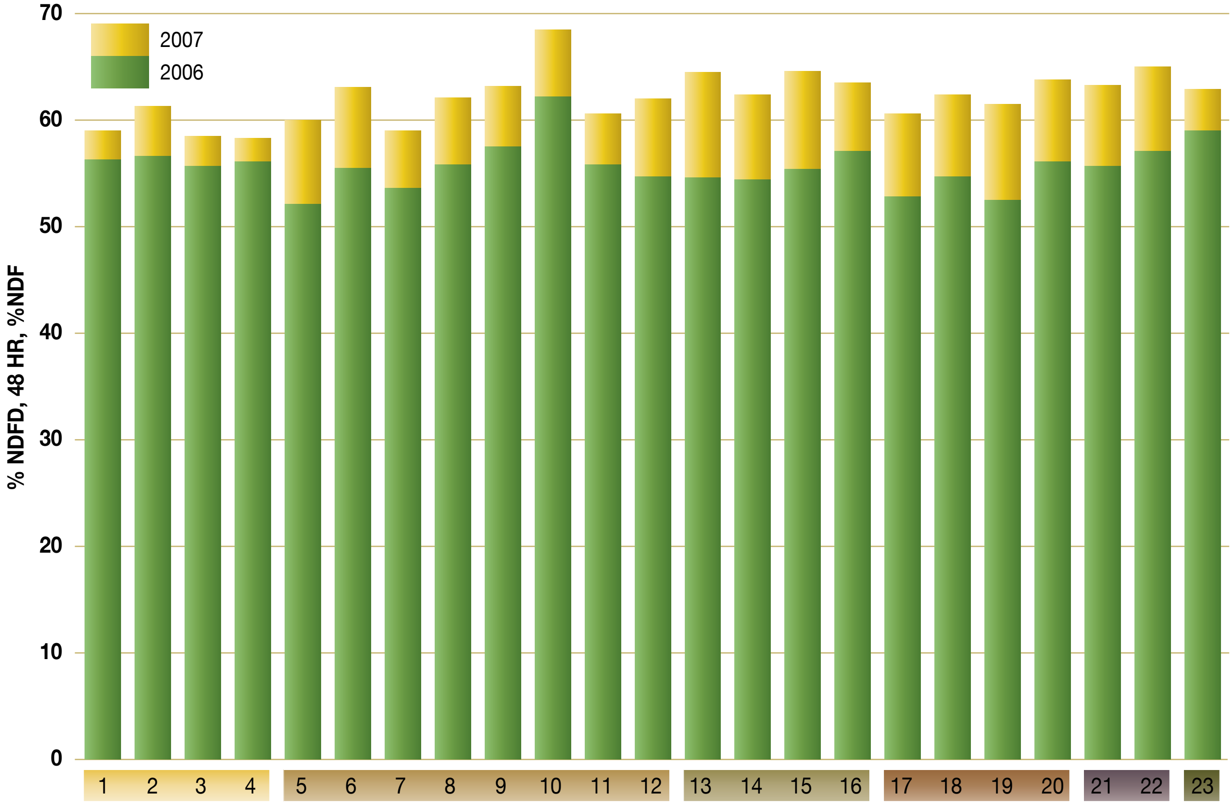
STAGE OF DEVELOPMENT	% YIELD REDUCTION
Early Vegetative	5 - 10%
Tassel Emergence	10 - 25%
Silk/Pollen Shed	40 - 50%
Blister Kernel	30 - 40%
Dough	20 - 30%

minimal genetic differences (3-4 percentage units) between non-BMR hybrids for NDFD. The large variation in NDFD observed from farm-to-farm and season-to-season are the result of environmental factors such as growing conditions and harvest timing. This is why corn silage growers in the Midwest and East, with fewer irrigated acres and more weather variability, struggle more with quantifying and managing corn silage digestibility.

It has been well established that growing environment is 3-times more influential on fiber digestibility than hybrid genetics and that moisture the plant receives is 7-times more important to fiber digestibility (or uNDF) than heat units.

Corn breeders are very interested in the interaction between genetics and environment (GxE). If GxE (in a statistical sense) is significant, it means hybrids grown in different environments could rank differently for any particular trait. Compare this to environmental

GROWING ENVIRONMENT EFFECT ON THE SAME HYBRIDS GROWN IN MSU SILAGE PLOTS IN 2006 (WET YEAR) VS. 2007 (DROUGHT YEAR)



Each block color indicates a different plot location where the same hybrid was grown in both years

CORN SILAGE SUMMARY

Corn silage yield and quality are determined by the interaction of G x E x M (Genetics, Environment, Management)

SILAGE YIELD

is primarily driven by biomass (plant height at the ear) and starch content.

- Starch (grain) typically contributes half of silage dry matter yield.
- Silage yield is influenced by: harvest timing (more mature kernels delivering higher tonnage), seed genetics and planting date in addition to the more obvious growing environment factors of weather, soil, and fertility.

FEED QUALITY

is primarily driven by starch content and secondly by fiber digestibility.

FIBER DIGESTIBILITY

is influenced 3-times more by growing conditions than genetics.

- Dry, cool weather, particularly during vegetative growth, tends to increase fiber digestibility.
- Hot, wet growing conditions tend to decrease fiber digestibility.
- BMR genetics were introduced to improve fiber digestibility because very little variation in fiber digestibility exists between non-BMR hybrids grown in the same environment and harvested at the same maturity.

STARCH CONTENT

is primarily driven by genetics and growing environment.

- Drought and/or disease during plant reproductive growth lowers starch content.
- High chopping increases starch concentration (and often improves fiber digestibility.

STARCH DIGESTIBILITY

refers to the amount of starch digested in the rumen and the intestines.

- Starch digestibility is influenced by kernel maturity and extent of kernel processing at the chopper.
- The ensiling process, in particular the length of time in storage, significantly increases starch digestibility.
- Very little difference in starch digestibility exists among dent hybrids grown in North America when harvested at similar kernel maturities. These small genetic differences are dwarfed by the influence of harvest maturity, processing, and storage effect.

SUMMARY:

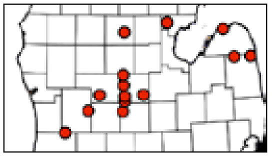
Silage growers should focus on **genetics** (G) with appropriate disease/trait package and yield stability for your growing environment. Choose genetics that deliver high biomass yield (taller plants) and high starch content. For the highest fiber digestibility, choose BMR genetics. Beyond that, the growing **environment** (E) (moisture, heat units, disease) is the primary driver of yield and quality. At harvest, **management** (M) around harvest timing (higher yield with more mature kernels), chop height and degree of kernel processing (biggest influence on starch digestibility) are the primary influencers.

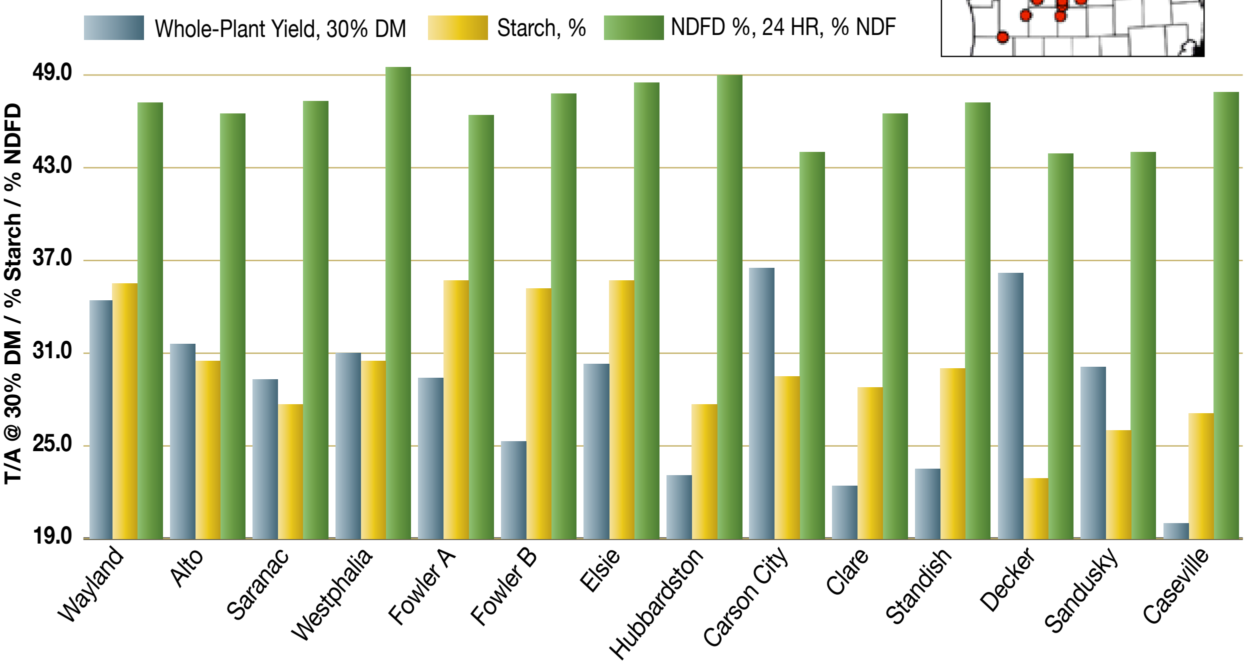
influence on genetics, meaning they will rank similar across environments, but the relative magnitude of difference will depend on the particular environment. It could also indicate the absolute values will change with no change in the relative hybrid differences between environments. The impact of GxE explains why seed companies do so much testing to determine the area of adaptation of hybrids. There is no indication that nutritional characteristics are any more susceptible to environmental interactions than either grain or whole-plant yield.

The figure below shows the relative silage yield, starch content and 24-hour NDFD of the same hybrid grown in 14 locations in Michigan in 2009. This clearly demonstrates why it is not valid to attribute hybrid genetics as the primary cause of nutritional differences when comparing hybrids grown on different farms. This is also why seed companies and university plots only compare hybrids grown in the same location (side-by-side).

Research by corn breeders suggest that to be 95% confident in selecting the best hybrid for silage yield or nutritional traits, approximately 20 direct, side-by-side comparisons (in the same plots), are required, preferably across multiple years to account for unique yearly environmental effects. Data from a single plot is almost meaningless due to variability caused by factors including soil compaction, previous crop history, fertility/manure history, soil type, water availability, tillage, and insect damage. To put a single plot in perspective, on average soil with 150 bushels/acre yield potential, a hybrid with a 2-ton per acre (30% DM) advantage has only a 60% chance of being the superior silage yielding hybrid. The odds of selecting the superior yielding silage hybrid increase to 95% with a 2-ton yield advantage demonstrated across 30 individual silage plots.

YIELD STARCH CONTENT AND 24-HOUR NDFD OF THE SAME HYBRID GROWN IN MULTIPLE MICHIGAN LOCATIONS IN 2009





Source: Dann Bolinger, M.S. – Pioneer Dairy Specialist, Michigan

HARVEST

GENERAL RECOMMENDATIONS

MATURITY AND MOISTURE

Recommendations vary with different silage crops and storage structures (e.g. drier in vertical stave/sealed silos to prevent excess effluent). Proper maturity assures adequate fermentable sugars for silage bacteria and maximum nutritional value for livestock. Maturity and/or wilting times also have a tremendous impact on moisture to help exclude oxygen and thus reduce porosity of the silage. For "dairy quality" forage, the "ideal" harvest maturity/moisture for healthy corn silage plants is 3/4 milk line (>62% moisture), alfalfa silage at mid-late bud (55-65% moisture) (reduced lignin varieties can be harvest more mature), grass silage when stems start elongating (55-65% moisture), cereal or sorghum silages at boot to soft-dough (55-65% moisture), high-moisture shelled corn (26-30% moisture), and snaplage/earlage (right at kernel blacklayer when kernels are about 34-36% moisture).

LENGTH OF CUT

It is difficult to offer generalized chop length recommendations because proper length depends on several factors including: 1) the need for physically effective fiber (peNDF) levels in the ration, 2) particle size of the other dietary ingredients, 3) the type of storage structure, and 4) silage compaction capabilities and unloading methods (e.g. silo unloaders, bunker facers). Other factors affecting chop length include the need to chop finer to damage corn kernels if on-chopper processing is not available or if chopping longer to compensate for particle reduction from bagging or feed mixing.

In general, shorter chop tends to improve compaction in the storage structure and also increases surface area of fiber (or kernels) to improve rate of digestion by rumen bacteria or intestinal enzymes. Longer chop increases the peNDF of the feed; however, excessive length can contribute to sorting by cattle in the feed bunk. It is best to work with the harvesting crew and nutritionist to decide on the proper compromise; recognizing that particle length in the final ration is what is most important. Start at the feed bunk and work backwards as to the amount of each feedstuff in the ration and how much peNDF each one of those feeds need to contribute to the entire diet.

CORN SILAGE

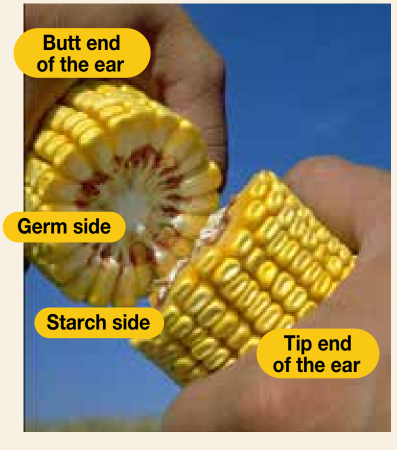
Silage growers should note the date when corn plants silk (R1) and count ahead about seven weeks to begin checking fields for kernel maturity. The old thumb rule that corn will reach silage maturity in 35-45 days (900 GDUs) after silking was based around silage being harvested at 70% moisture (30% dry matter). Modern hybrids have improved late-season plant health so to avoid effluent and also significantly increase starch deposition, it is now recommended to delay harvest of healthy plants until the kernels are closer to ¾ milk line. Most of the difference between hybrids of different relative maturities is between emergence and silking, not from silking to the 62-68% whole-plant moisture (38-32%DM) that is considered ideal for corn silage.

Modern corn genetics with vastly improved late-season plant health, coupled with technologies such as foliar fungicides, allow for a plant that retains fiber digestibility much later into the growing season. Late-season plant health is also advantageous in growing seasons lagging in heat units. Fiber digestibility will be maintained longer into the fall even as harvest is delayed to allow the plant to deposit additional starch. Harvesting corn silage at the ideal stage requires coordination between the days required to plant, the days required to harvest and the maturity of the hybrids planted.

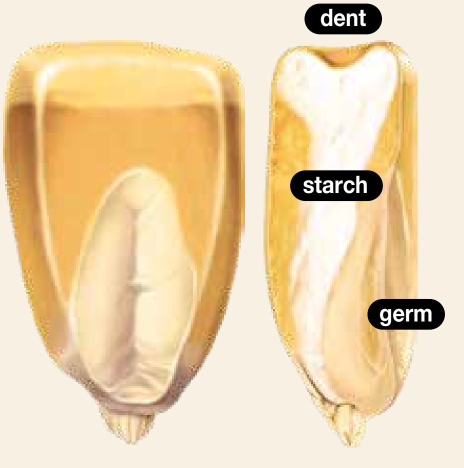
PROGRESSION OF MILK LINE DURING R5 (DENT) STAGE

			AVERAGE PER SUBSTAGE	
R STAGE	% KERNEL MOISTURE	KERNEL DRY MATTER ACCUMULATION (% OF TOTAL DRY WEIGHT)	GDU	DAYS
5.0	60%	45%	75	3
5.25 (1/4 milk line)	52%	65%	120	6
5.5 (1/2 milk line)	40%	90%	175	10
5.75 (3/4 milk line)	37%	97%	205	14
6.0 (Physiological Maturity)	35%	100%	360	360
TOTAL (AVERAGE)			**575**	**33**

HOW TO DETERMINE MILK LINE



1. Break several representative ears in half.
2. Visually look at milk line of the kernel in your hand holding the ear tip.
3. Sometimes visually determination can be misleading so a more reliable method is to “bite” an individual kernel from the tip of the kernel until you reach the hard starch area. This will give a very accurate determination of how far down the milk line has reached.



It is common for the corn plant to dry down in the fall about 0.5-1.0 points of moisture per day, depending on drying conditions. It is also common for corn silage to deposit 0.5-1.0 points of starch per day until the kernel reaches physiological maturity at black layer. Starch deposition is what is significantly contributing to reducing the moisture in the whole-plant and the also increasing the tonnage and energy density of the silage.

The continued health of the overall plant allows for continuation of photosynthesis and the deposition of sugar through the vascular system of the plant. In essence it is the "laying down of starch" in healthy plant that reduces the water content of the kernel. Thus, healthy plants are quicker at lowering their kernel moisture than those that are impaired (drought, disease, etc.). The transformation of sugar to starch is dependent on the pathway remaining not only open but steadily fed, in effect, a two way valve, at the kernel attachment to the cob. It is clear what can happen when the inputs lag (aborted kernels near the tip) or where supply (and extremity, farthest away from the source), slow the process (which can even induce premature black layer).

Most people assume the kernel "air" dries from the pericarp, but prior to black layer the general consensus is that there is very little moisture movement across the pericarp. After black layer (the two-way valve now closed), kernel drydown is through the pericarp and dependent upon environmental weather and genetics. Within hybrids there appears to be varying genetic difference in levels of porosity affecting their ability to dry down quicker than comparable maturity hybrids.

During corn maturation, the dry matter of the entire plant, being composed of stover and grain, increases for two reasons:

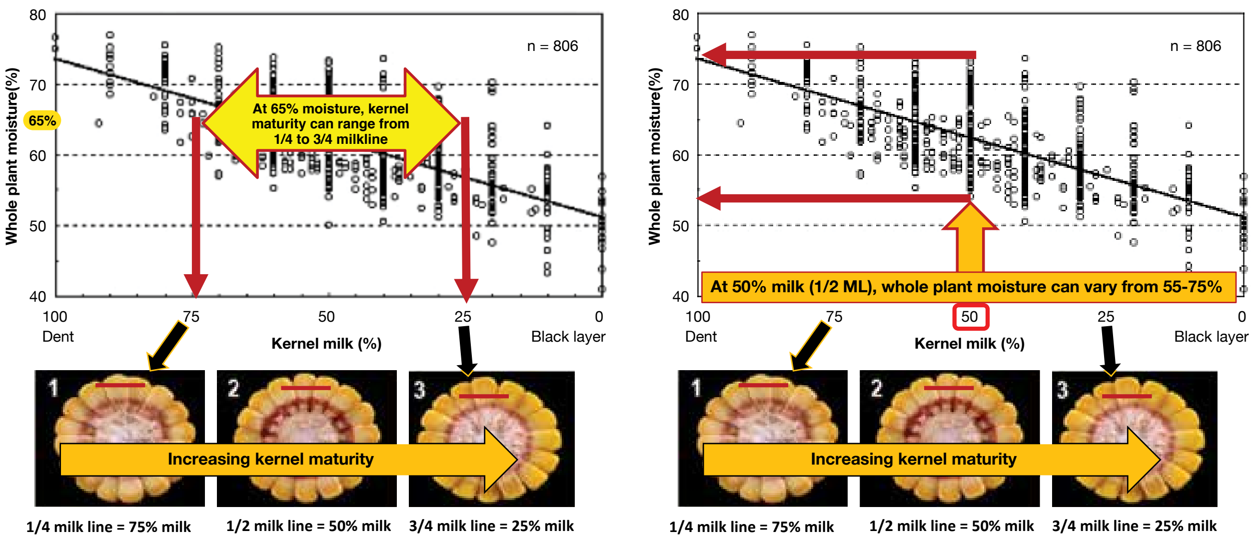
- First, the stover is drying as leaves dry and stalks brown. Given that NDF digestibility decreases as plant

MONITOR BOTH KERNEL MILKLINE AND WHOLE PLANT MOISTURE

Targeting 65% whole plant moisture can equate to kernels anywhere from ¼ to ¾ milkline which is NOT optimizing the value of starch deposition in healthy plants

At 50% milk (1/2 milkline), plant moisture can vary from 55-75% which is not ideal for reducing silage porosity or silage runoff

Relationship between whole plant moisture and kernel milk. Each data point is one hybrid in an environment.



Note: University researchers use milk % which is the inverse of milk line, used by most producers and crop consultants.

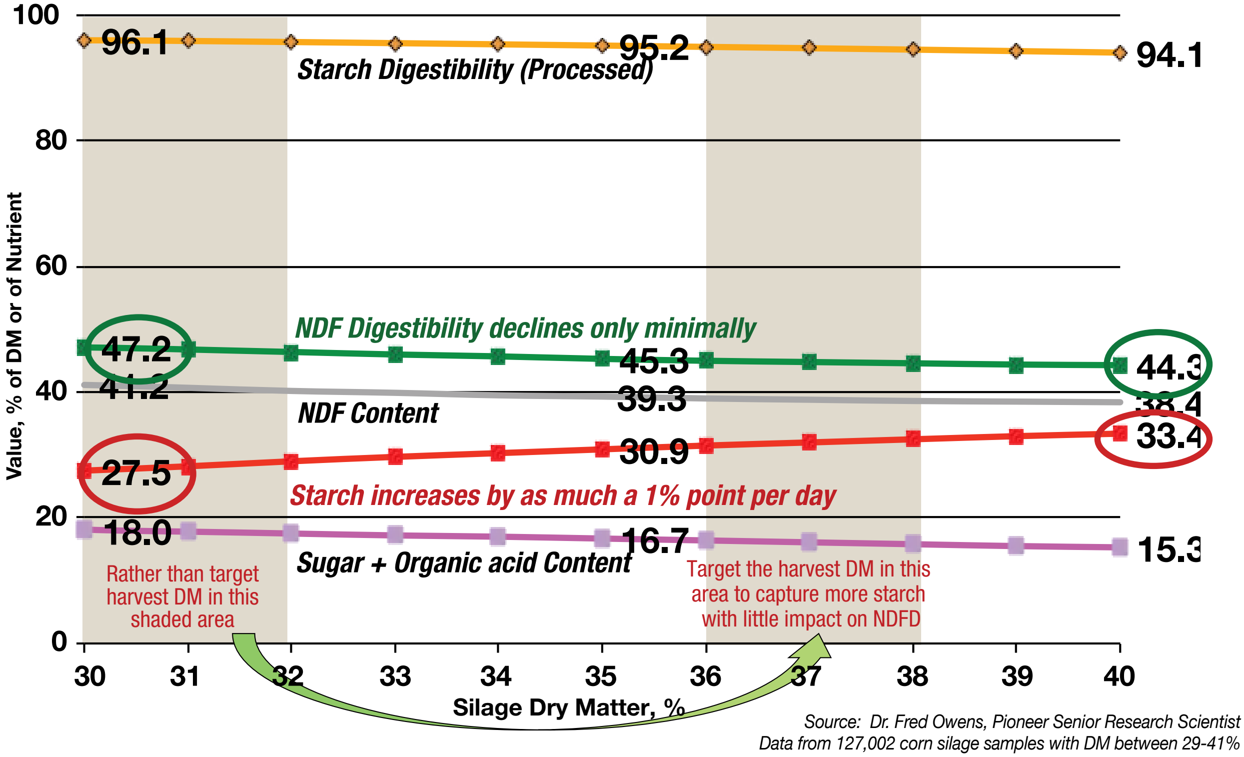
Data Source: Joe Lauer. April 1999. Kernel Milkline: How Should We Use It for Harvesting Silage? Field Crops 28.4723. http://corn.agronomy.wisc.edu/AA/A023.aspx tissue dies, NDFD also should be dependent primarily on dry matter (DM) content of the stover, not on DM content of the full plant (including the ear) because it should vary primarily due to health of the stover portion of the plant.

- Secondly, grain, being the driest portion of the plant, is still being deposited when plants are healthy. The ear is always drier than the stover, so an increase in the ear to stover ratio increases not only the total plant dry weight but also the percentage of DM in the total plant. This could indicate that waiting until the plant is over 30% DM might not prevent seepage if the plant is still fully green and growing but the kernel has reached the black layer stage as sometimes happens in geographies producing very tall, healthy plants.

Overall, this supports the idea that both kernel milk line and whole plant DM should drive the time to start harvesting silage. And secondly, high chop decisions to potentially improve NDFD should be based on stover DM and the amount of dead tissue (perhaps of the lowest foot of the plant in particular) and not on DM content of the entire plant.

Research studies clearly show that fiber digestibility declines only minimally in healthy corn plants as they dry down from 30% dry matter to 38% dry matter (70% to 62% moisture). The combination of healthier plants in the fall, the need for starch to increase yield and digestibility and the ability to achieve higher compaction densities in bunkers/piles has allowed growers to harvest corn silage at ¾ milk line rather than 1/3 to 1/2 milk line which was common in the past. Producers who lack the ability to process (roll) kernels on the chopper may have to harvest at earlier kernel maturities and/or shorten the chop length to ensure adequate kernel processing at the cutter head.

HIGHER HARVEST DRY MATTER INCREASES STARCH CONTENT WITH MINIMAL EFFECT ON REDUCING FIBER DIGESTIBILITY IN HYBRIDS WITH EXCELLENT LATE-SEASON PLANT HEALTH



Source: Dr. Fred Owens, Pioneer Senior Research Scientist
Data from 127,002 corn silage samples with DM between 29-41%

ESTIMATING CORN GRAIN YIELDS

This procedure is based on information used in developing the “Corn Yield Calculator” slide rule published by the University of Illinois:

1. Count number of ears in 1/1000 acre.

ROW WIDTH (inches)	LENGTH EQUAL TO 1/1000 A
15″	34′ 10″
20″	26′ 1″
28″	18′ 8″
30″	17′ 5″
36″	14′ 6″
40″	13′ 1″

2. Select 3 representative ears and count the number of rows of kernels and the number of kernels per row for each. Do not count tip kernels that are less than half size.

3. Estimate the yield for EACH of the 3 ears as follows: (Number of ears in 1/1,000 A) x (number of kernel rows) x (number of kernels per row) x 0.01116 = bushels per acre at 15.5% moisture

4. Average the yield estimates from the 3 ears. Repeat steps 1-4 at several sites and average the results to estimate grain yield for the entire field.

HIGH CHOPPING

Harvesting corn silage at higher chop heights is used by some producers to increase starch content and improve neutral detergent fiber digestibility (NDFD). Research shows that increasing chop height by about 12 inches can increase starch content by 2-3% units and increase NDFD by 2-4% units, depending on the specific hybrid and growing season. The impact on yield depends to some extent on the yield potential of the hybrid, but in general, expect yield (35% DM basis) of the stover to drop by about 300 pounds per acre for every inch of higher chop height.

In some areas, such as California, it is a common practice to chop as low as 2-3 inches; whereas in other regions like the Northeast, chopper operators harvest higher so as not to risk damaging equipment by hitting stones. There is less potential gain in quality by raising chop height if normal chop height is already high (greater than 8-10 inches).

It typically does not make economic sense to reduce silage yields by high chopping Brown MidRib (BMR) hybrids because BMR stalks are already very high in fiber digestibility. However, given that growing environment during the vegetative growth stage also has an impact on the NDFD of BMR genetics, there could be instances where wet growing conditions could justify high chopping BMR, especially for very high production herds.

Not all hybrids will behave the same when high-chopped as there appears to be a significant hybrid-by-environment interaction. This implies that hybrids will

respond differently to high chopping depending upon growing conditions. One approach to determining the potential impact is to hand-harvest 5-10 representative plants at normal chop height and at high chop height at about one to two weeks prior to harvest. The samples can then be sent to a laboratory and analyzed for NDF digestibility to see if high chopping was worth the yield loss.

High-chop corn can be a practical management tool to boost corn silage NDFD, especially when hay or haylage already in storage is low in fiber digestibility. It can also be used by growers with more corn than needed for silage (at normal chop heights) but no economical way to harvest the crop for grain. Raising chop height will also allow the crop to fit into limited storage space and provide the nutritionist with higher quality corn silage.

KERNEL PROCESSING

Kernel processing of corn silage has long been popular in Europe and started to gain acceptance in North America in the late-90’s with the introduction of choppers that came from the factory with the kernel processor (on-board roller mill) as standard equipment. The combination of higher dietary corn silage inclusion rates coupled with higher dry matter silages to capture more starch has focused the need to assure aggressive kernel damage.

There has been much debate about what level of kernel processing is acceptable. This was complicated by the lack of a lab method to quantify the extent of kernel damage and lack of accepted processing standards. This changed with the commercialization of a standard laboratory assay (Ro-Tap Kernel Processing Score) developed by Pioneer in conjunction with the U.S. Dairy Forage Research Center and Dairyland Laboratories (Arcadia, Wisconsin). Pioneer openly shared the kernel processing protocol with commercial laboratories around the world and is now offered by many as a routine analysis.

While it is helpful to have a post-harvest, standardized laboratory measurement of kernel damage, it is equally important to have an easily-implemented field method to make processing adjustments as the crop is being harvested. Pioneer has developed a simple field test using a 32-ounce cup. Producers are encouraged to sample several loads each hour by filling the cup level with silage; spreading the sample out and quickly picking out every whole and half kernel. If that number exceeds 2-3 kernels, it is important to discuss with the chopper operator how to improve kernel processing. If left unattended, the result will be a loss in energy as unprocessed kernels escape ruminal and intestinal digestion. Validation of degree of kernel damage can be further accomplished by collecting fecal samples from 10-12 cows and submitting to a lab for fecal starch analysis. The goal is to have less than 3-5% starch in feces. Levels higher than that could indicate poor processing of corn silage (or other starch sources) resulting in inefficient use of dietary starch in addition to possibly predisposing cows to maladies such as hemorrhagic jejunum (or bowel) syndrome (HJS or HBS).

Pioneer Corn Silage Processing Monitoring Cup

There are several factors that chopper operators can check to improve processing: length of chop (longer typically more difficult to damage kernels), roller mill wear (life of 400-1000 hours depending upon mill), roller mill gap (1-3mm depending upon chop length and kernel maturity), aggressiveness of the rolls, and perhaps the most important, roller mill differential (typically 20-40%). There have also been recent innovations in roller mill design and differential speed including Shredlage® (Claas) and KernelStar Technology (John Deere).

DROUGHT-STRESSED CORN

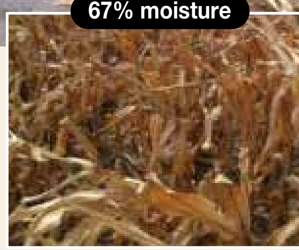
On average, corn utilizes 24-27 inches of water per acre during the growing season. Timing and duration of drought stress will determine yield loss. Silk emergence is the most critical time to avoid drought stress with early vegetative growth being the least critical period for drought stress. Repeated moisture stress during the silk to tassel stage can result in grain yield losses as high as 50 percent. Corn silage yields may be 50 to 90% of normal due both to shorter plant height and loss of kernel development. If little or no grain is present, a general rule is there will be one ton of 70% moisture yield per foot of plant height.

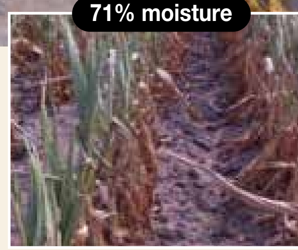
An advantage of growing corn for silage is less water is required to raise silage than to grow a grain crop. Corn silage is harvested before black layer or physiological maturity is reached, thereby reducing the amount of water needed to fully mature the crop. Depending on soil type and available water, harvesting irrigated corn for silage can reduce the number of irrigations needed by one to two compared to corn harvested for grain.

Green, barren stalks will typically be much wetter than they appear in the field containing upwards of 75 to 90% moisture because there is no grain to dry down the moisture contained in the stalks. It is recommended to sample plants and conduct dry matter tests at a laboratory, with a microwave or Koster® Moisture Tester. The tendency is to harvest drought-stressed corn too early and too wet causing excess effluent (run-off) and the loss of nutritious sugars. Hybrid maturity, drought tolerance, and late-season plant health may influence harvest timing significantly. If conditions remain hot and dry, silage harvest may occur earlier than normal. Harvest assessment will be required on a field-by-field basis. For example, spider mite infestation, whose activity is greater under hot and dry conditions, may warrant earlier harvest. If the corn has any grain, the kernel milkline can be a general indicator to determine the proper time to chop, but given the variability in droughty corn, whole-plant sampling is still the best approach.

Drought can result in the crop ranging from barren plants with no ears or starch to varying levels of starch (grain)

EXAMPLE OF HOW LACK OF EAR DEVELOPMENT AFFECTS WHOLE PLANT MOISTURE CONTENT





Whole plant samples from Colorado on 8/14/12 demonstrating high moisture content even in severely drought-stressed plants due to lack of ear (starch) development

depending upon stress at pollination and subsequent kernel abortion. It is important to realize that starch deposition is the primary driver of lowering the moisture in the chopped plant. The stover is often much wetter than expected in droughted corn because ear development is lacking. North Dakota State University researchers tested standing corn, including the cob, for moisture content on August 15, 2018 and found:

- Corn with the entire plant still green, tasseled and having two cobs in the R2 kernel stage (early kernel, no denting and no milk) was at 77.4 percent moisture.
- Drought-stressed corn with the bottom three to four leaves that were brown tested at 76.5 percent moisture. The plants had one cob in the R2 kernel stage.
- Drought-stressed corn with the bottom four to seven leaves that had turned brown and no cobs had a moisture content of 67.9.

In these situations, energy will be partitioned more into sugar and fiber in the stalk and leaves rather than to grain. Studies conducted by Michigan State University indicate that severely stressed corn (short plants with essentially no ears) still had a feeding value of approximately 70% of normal corn silage due to the highly digestible fiber and sugar content. Due to the potential variability, it is important to analyze droughty corn silage for dry matter, NDF (neutral detergent fiber), NDF digestibility, sugar, starch and nitrates (see FEED section). Consider segregating storage based on fields that may have relatively higher feed value.

FROSTED CORN

Corn plants that have been frosted prior to harvest can experience premature leaf or whole-plant death. The plant may remobilize stored carbohydrates from the leaves or stalk tissue (leading to standability issues) to the developing ears, but yield and nutritional potential will still be lost mostly from the cessation of starch deposition. Approximate yield losses due to premature death of leaves (but not stalks) range from 36, 31, and 7% when the leaf death occurs at R4 (dough), R5 (early dent), and half-milkline (R5.5) stages of kernel development.

Loss of nutrient value from leaf loss or undesirable microbial/fungal growth can be minimized if the crop is harvested as soon as possible after the frost. Post-frosted corn is predisposed to spoilage organisms with the onset of warm days and cool nights, coupled with high humidity from rainy/drizzly conditions. Fortunately, husks tend to open up and dry down rapidly following a frost which mitigates the ear condensation although stalks will retain considerable moisture. Fungi growth often attributed to conditions set up by a frost, were many times already active in the field prior to the frost event.

Corn that has experienced a killing frost at ⅓ to ½ milk line maturity will typically be below 72% moisture and can be harvested soon after the event. Corn that is pre-dough stage will be too wet (>75% moisture) to harvest and may require several days in the field to dry to acceptable harvest moistures (to prevent excess effluent). If the frost event did not freeze kernels and only damaged the top of the plant leaving leaves around the ear still healthy, the plant will continue to mature and lay down starch in the kernel.

Leaves of immature frosted plants make the crop appear very dry but most of the moisture is in the stalk further compounded by lack of starch which also serves to dry down the plant. If harvest must proceed, it is possible (but inconvenient) to add dry materials (e.g. dry corn, beet pulp etc.) to the silage to increase the dry matter. For example, one bushel of dry corn per ton of immature silage will increase the silage dry matter by 1.5% units.

Immature corn that has experienced a killing frost will have high sugar content in the stalk from sugars that will not be translocated to the kernel. This helps to improve the crops nutritive value to offset reduced starch levels. However, these excess sugars will also provide nutrients for spoilage organisms to grow during feedout. These high sugar corn plants will also have a natural population of fermenting bacteria (epiphytes) that will be greatly reduced by the frost event. For these reasons, a combination *L. buchneri* inoculant is highly recommended. A “combination” product means that the inoculant contains both homofermentative strains to quickly reduce pH along with a *L. buchneri* strain to inhibit yeast growth at feedout.