# SILAGE ZONE® MANUAL

**FIFTH EDITION**

PIONEER®

The Silage Zone®
Plant
Grow
Harvest
Store
Feed

# CONTENTS











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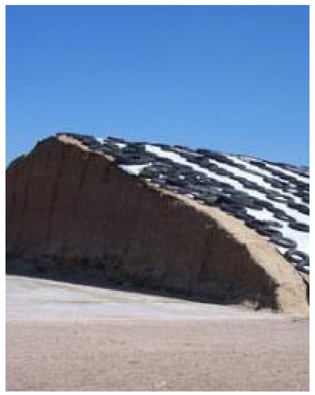
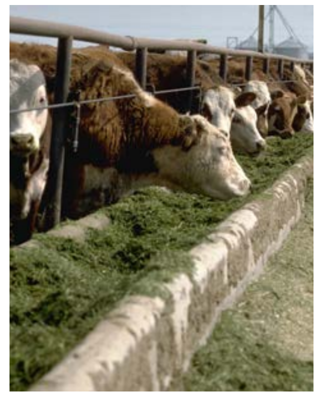
# INTRODUCTION

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 purchased concentrates and supplements. For dairy and beef producers, whole-plant corn, high-moisture corn, alfalfa, cereals, and a variety of grass species are the silages of most economic significance. This manual will focus primarily on corn silage, high-moisture corn (earlage, snaplage), alfalfa silages and a short section on managing and feeding Plenish® high oleic soybeans.

This 5th edition of the Pioneer 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 yield of a high energy (starch) crop, consistent fiber digestibility, 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 nutritional needs 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 protection),
3) agronomic stability (e.g. stress emergence, drought tolerance) and late-season plant health,
4) 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 tar spot) and ear rots (e.g. fusarium, gibberella, diplodia),
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 earlage/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 (blacklayer or when 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 (50°F) and maximum (86°F) 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 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 and late-season plant health (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

### 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*

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. The only germplasm with significantly higher NDFD is Brown MidRib (BMR) but reduced yields and lack of drought tolerance has limited their commercial adoption. 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 somewhat 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 ; especially when traits like NDFD are controlled primarily by growing environment and not hybrid genetics.. 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; especially when traits like NDFD are controlled primarily by growing environment and not hybrid genetics. 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.

Just like fiber digestibility, nutritional traits like crude protein and oil content are important to nutritionists balancing rations but are far less important hybrid selection parameters 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 harvest 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 to nutritionists balancing rations. However, their importance in selecting 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 dent 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 ruminal 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, nor does it account for intestinal starch digestion (total tract starch digestibility).

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 receiving the same growing environment) 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.

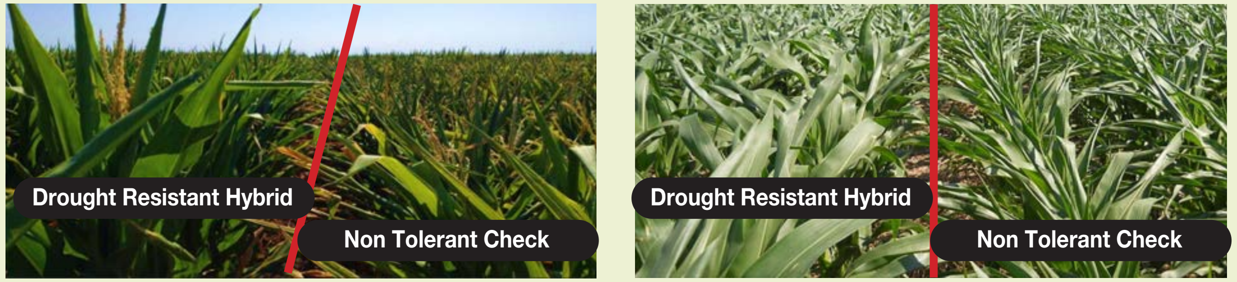
It is best to secure as much information as possible on the performance of a silage hybrid. Do not be satisfied with catalog scores (e.g. 1-9). Seed companies serious about silage will be able to provide absolute values for important silage traits compared against their own hybrids as well as competitors. 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.

## 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.*

## EAR FLEX HYBRIDS

Seed companies rate hybrids with ear flex scores. These scores reflect the ability of a hybrid to flex ear size as plant density is reduced or as growing conditions improve. The more a hybrid increases its relative yield at low population, the higher its ear flex score.

Fixed hybrids tend to produce similar ears at higher populations (34,000 – 36,000) that maximize yield potential and return on seed investment in productive, high management fields. Flex hybrids tend to be the opposite. These hybrids have the potential to flex ear size at lower populations (30,000 – 32,000) and add extra rows and cob length when experiencing good growing conditions in less productive soils.

## BROWN MIDRIB CORN HYBRIDS

Brown MidRib (BMR) corn silage hybrids have been on the market for over 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 reduces drought tolerance and 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 significantly reduced silage yield compared to non-BMR silage hybrids. Newer BMR hybrids have improved agronomics and disease resistance but 10-20% lower yields compared to non-BMR hybrids and the slow pace at which new technologies are available in BMR hybrids has limited their commercial viability especially among large dairies where strong agronomics and silage tonnage is of paramount importance.

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. Several university trials including a 2015 trial conducted by Miner Institute, showed 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 4-6 point higher NDFD-30 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 disappearance 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 negative side of BMR is that feeding it to dairy cows that are past their milk production milk will reduce feed efficiency. This is because post-peak cows will consume more of a TMR containing the fragile-fiber BMR but will not produce any more milk than being fed a higher yielding, agronomically superior non-BMR silage hybrid. It should be noted that even if laboratory NDFD data shows a similar level in fiber digestibility between BMR and high-chopped corn silage, or reduced stature corn (with extremely large diameter stalks), these will not result in the same increases in total ration intakes exhibited by BMR hybrids which have more fragile fiber due to lower lignin content.

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.

## LEAFY HYBRIDS

Depending upon maturity, normal corn plants will have from 11 (short-season hybrids) to 30 (tropical hybrids) leaves at harvest. Some germplasms have the potential to set an extra 3-4 leaves above the ear resulting in appealing silage "appearance" while growing in the field.

The true test of hybrid performance must extend beyond field appearance to actual harvest data and nutritional analysis. Leafy genetics have consistently shown no improvements in fiber digestibility and a significant reduction in grain yield; presumably due to the extra leaves above the ear shading the ear leaf which produces 70% of the plants photosynthate. This also relates to issues with lower dry matter yields given that leaves do not contribute much to yield compared to grain which accounts for about 50% of silage dry matter yield.

Finally, several dairy studies published by the University of Minnesota and the University of Wisconsin have shown no improvement in lactation performance compared to normal silage hybrids.

## REDUCED-STATURE CORN

The potential for developing reduced-stature corn has been explored by the seed industry for decades. Reducing plant height in corn makes the plants better able to resist lodging in high wind events and increases accessibility for in-season applications without the need for high-clearance or aerial equipment.

Normal corn grown in the Midwest can reach mature heights of upwards of 8 feet. Reduced-stature corn currently being evaluated by researchers at Corteva Agriscience is typically 5-6 feet tall with an ear height consistently above the 24-inch combine header threshold to facilitate grain harvest.

Reduction in plant stature by Corteva Agriscience corn breeders is achieved by uniformly reducing the length of internode distances between leaves over the entire height of the plant. Reduced-stature plants have the same number of leaves as standard-stature corn with similar relative maturity; however, the leaves are typically shorter in length and wider.

**Reduced-stature corn next to a current commercial hybrid in the Corteva Agriscience field demonstration plots at Johnston, IA, July 2023.**

Reduced-stature corn is less likely to be lodged, or blown over, during high wind events, due to its shorter profile and thicker stalks. Stalks are generally 10-25% larger in diameter in reduced-stature corn compared to standard-stature. Several research studies have shown that the differences in stalk diameter by planning normal hybrids from 20-40,000 plant per acre has no significant impact on fiber digestibility. More data is needed but there may be an improvement in fiber digestibility in reduced-stature corn given the reduced ratio of rind : pith in reduced-stature corn.

Early research suggests that reduced-stature corn may also produce acceptable biomass yields for silage production given the increased stalk diameter and leaf size.

# FLOURY VERSUS FLINTY (VITREOUS) ENDOSPERM HYBRIDS

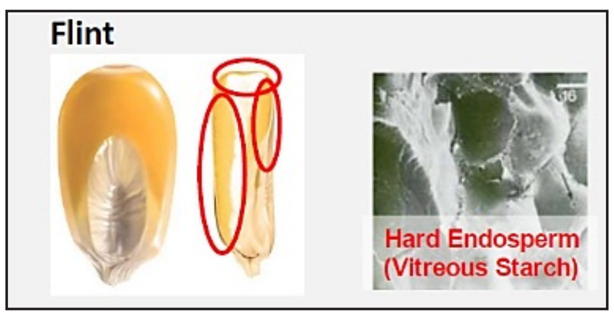
There has been an explosion of interest among silage growers about the differences in the type of kernel starch found in hybrids due to some seed companies suggesting higher starch digestion This is referencing the amount of floury (also called soft or dent) endosperm versus vitreous (also called glassy, hard or flinty) endosperm found in the kernel. 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 is the white-colored starch granules found in the center of dent 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 dent 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 at grain harvest 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 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).

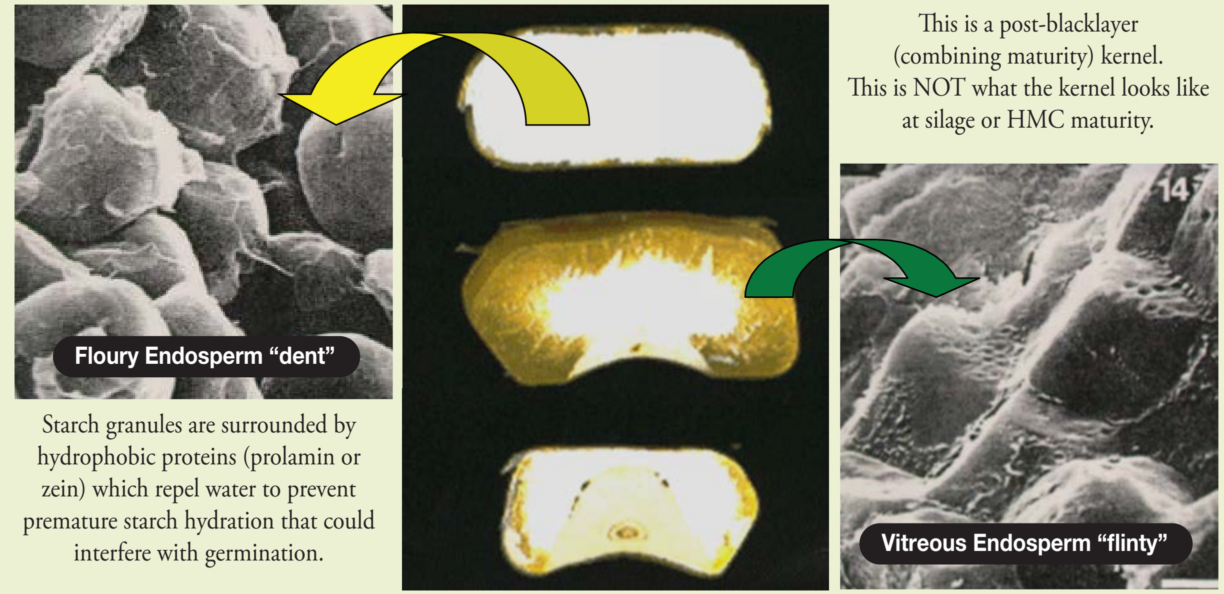
Research comparing the starch digestibility of floury genetics versus flinty hybrids has certainly furthered the understanding of the mechanisms of starch digestion. However, caution is needed when extrapolating these "bookend" comparisons to what producers will observe from high-yielding, commercially-available 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 97-99 percent for adequately processed and fermented corn silage or high-moisture corn.

It is well proven that while significant 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 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 4-6 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 fecal samples from 10-12 cows and submitting to a lab for fecal starch analysis. The current goal is to have less than 1-2% starch in feces and most herds are below this level despite growing hybrids that are not advertised as floury.


## CORN KERNEL PHYSIOLOGY



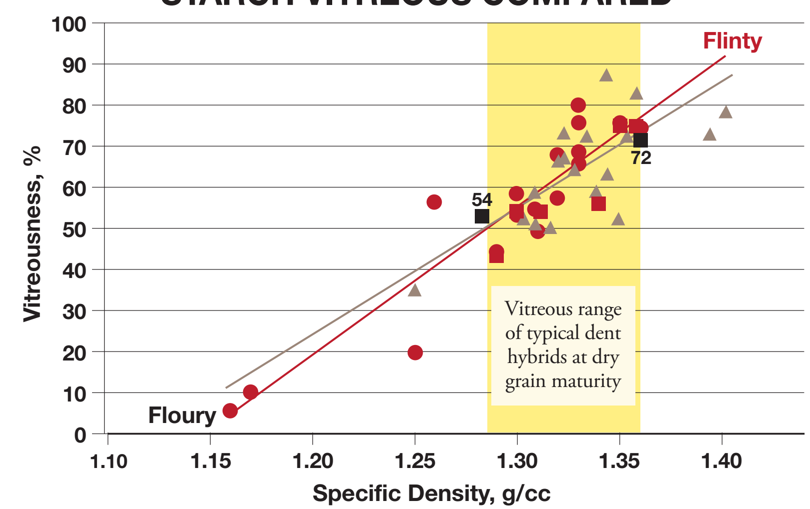

This is a post-blacklayer (combining maturity) kernel. This is NOT what the kernel looks like at silage or HMC maturity.

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

**More mature kernels tend to have more prolamin (zein)**

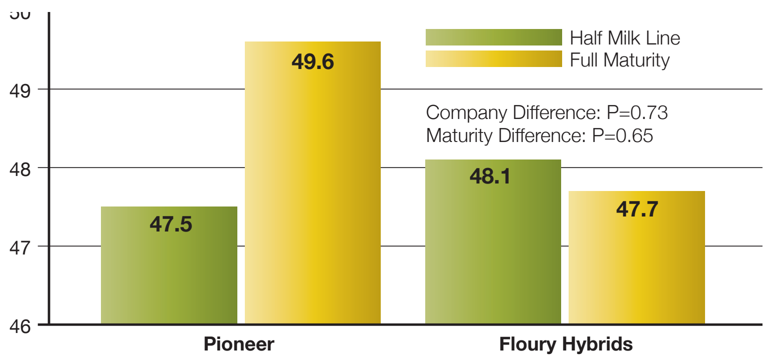
**Higher test weight kernels at combining maturity have more prolamin**

## CORN DENSITY AND STARCH VITREOUS COMPARED




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

## *IN VITRO* RUMEN STARCH DIGESTIBILITY AT 7 HOURS




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 dent corn fed as fermented corn silage or high-moisture corn, more vitreous hybrids with large kernels (reduced pericarp: endosperm ratio) are 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. Recently, Enogen® feed corn hybrids entered the market as transgenic corn with alpha-amylase enzyme contained in the endosperm of the kernel which breaks down corn starch into sugar. This technology was originally designed for the ethanol industry to replace liquid fermentation enzymes used in ethanol production.

As of 2024, there are five peer-reviewed university trials in which Enogen corn was fed either as silage, earlage or dry ground corn to dairy cows. All trials used the corresponding isogenic counterpart (background hybrid minus the alpha-amylase transgene) as the control.

None of these trials showed an advantage in ruminal starch digestion from the kernel-imbedded enzyme. Researchers at the University of Wisconsin attributed lack of effects of Enogen in their study to either differences in maturity at harvest or silage temperature and pH impacting amylase activity causing *in situ* starch disappearance to actually be lower for the Enogen hybrids compared with an isogenic control.

It appears counterproductive to recommend any hybrid selection pressure for floury endosperm or improved ruminal starch digestion given these facts:

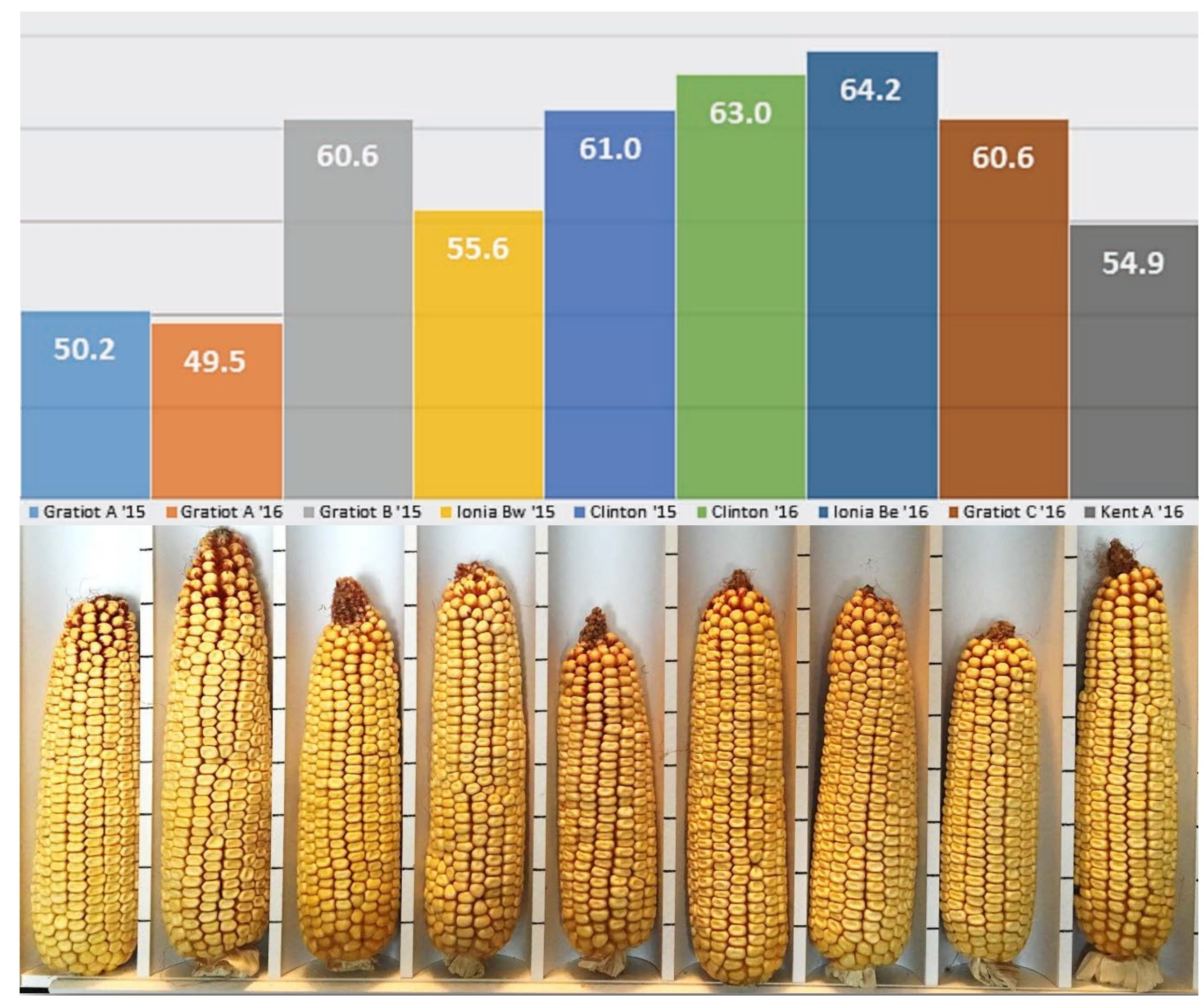
1) low rumen pH is a major contributor to ruminal acidosis and milk fat depression so it makes little sense to further decrease pH in high corn silage diets already containing high levels of rumen fermentable starch. This is why many nutritionists prefer to supplement high corn silage diets with dry corn which has not been fermented and is less prone to reducing ruminal pH.
2) 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,
3) vitreousness of grain harvested at silage maturity is considerably lower than for dry grain,
4) adverse effects of vitreousness in dry, unfermented corn can be largely alleviated by fine-grinding,
5) fermentation significantly reduces the impact of vitreousness,
6) 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.



## THE IMPACT OF GROWING ENVIRONMENT ON 7-HOUR *IN SITU* RUMINAL STARCH DIGESTIBILITY

for the Same Hybrid Grown in Michigan in Multiple Fields in 2015 and 2016




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

# 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. Intakes among close-up, fresh and high-production cows will 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.

A common misconception is that taller plants are better for silage than shorter plants. There are many factors that can influence plant height, including planting date, row spacings, plant population, hybrid genetics and relative maturity.

Corn plants adapted to the central corn belt produce more leaves resulting in taller plants than shorter season hybrids suitable to more northern environments. Factors that lead to greater interplant competition within a field, such as late planting, narrower row spacing, and high plant population, also result in taller plants.

Planting corn late results in taller plants and lower grain yield. Young corn plants grow and develop more rapidly in response to warmer temperatures and greater sunlight availability under late planting. Therefore, interplant competition in the canopy occurs sooner than it does with earlier plantings. This causes the plants to grow taller with greater internode length on the stalk between each leaf node. It also reduces stalk diameter. While vegetative biomass can be similar between early and late plantings, the reduction in grain yield with later planting will reduce overall silage yield.

The bottom line is that early planting should be the goal when planting corn for grain or silage. Grain yield is the ultimate target for both the combine and the chopper given grain constitutes half of silage dry matter yield and provides about 65% of the energy in silage. Even with early planting, growing conditions such as water availability, GDU accumulation and nitrogen fertility will influence yield and nutritional value far more than planting date. Early plantings have a better chance of success if planted 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.

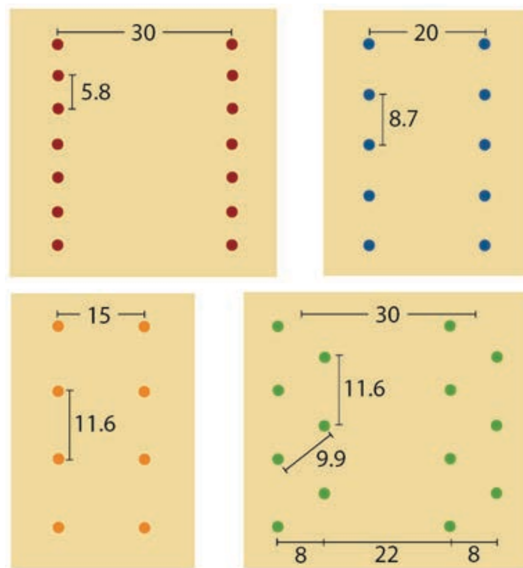
The yield of a particular corn hybrid is greatly influenced by stand density and uniformity. Planter maintenance and effectiveness are certainly important (particularly proper depth and trench closure) but so are seedbed conditions (e.g. minimal compaction which inhibits root growth) and the genetic 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 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). 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.

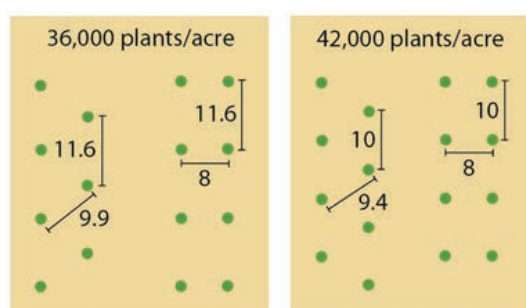
## ROW SPACING

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 where shorter-season hybrids are planted into typically cooler soils. These hybrids are shorter in in stature and have fewer leaves so narrow rows results in greater sunlight interception. Plant population and row spacings should ideally result in 95% light interception (only 5% hitting the ground) during the corn reproductive stage.

**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.

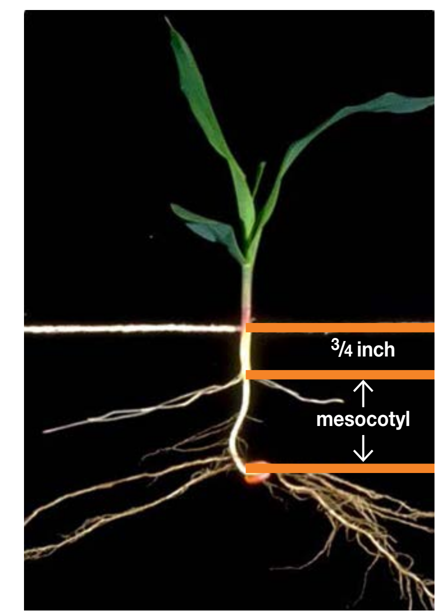
## PLANTING DEPTH AND SPACINGS

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.

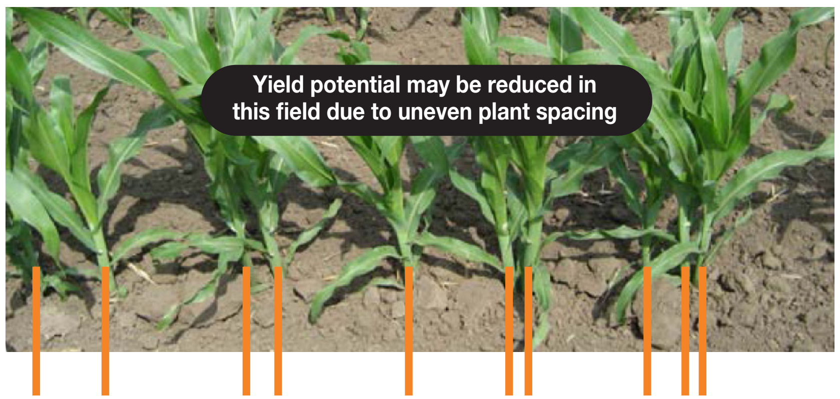
Rootless Corn Syndrome

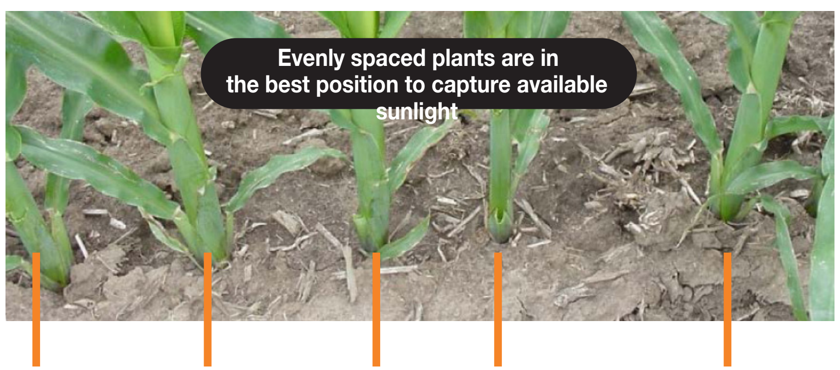
Corn planted too shallow is unable to uptake water and nutrients through the roots. They also can develop a condition called "rootless or floppy corn syndrome" where the root tip desiccates prior to reaching soil moisture. The above ground appearance of the corn plant may appear fairly normal until a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

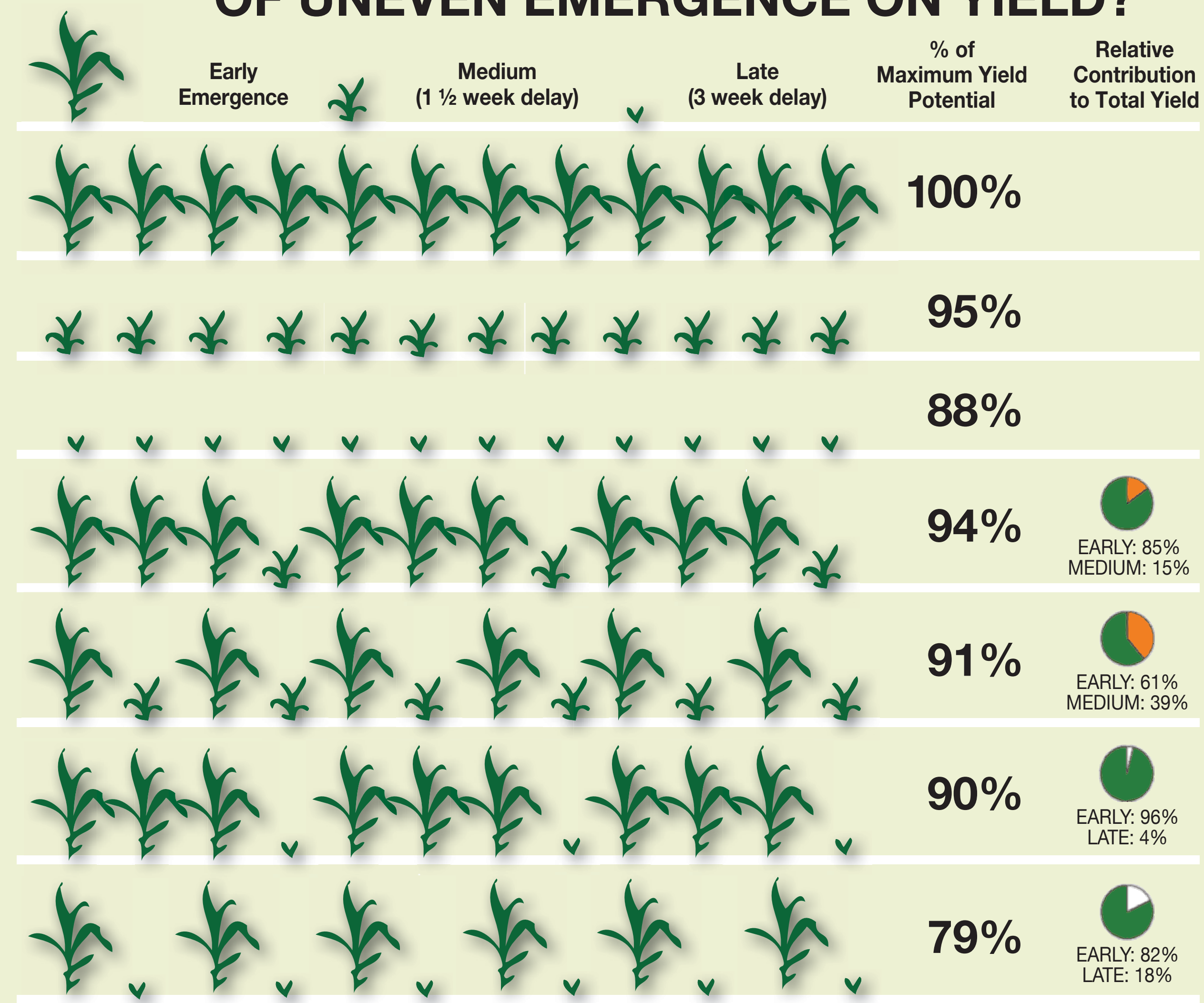
Corn is a warm season crop. Optimal temperature for emergence is 85°-90°F, so it is almost always under some degree of cold stress. Corn will germinate at 46°F but the common thumb-rule is to delay planting until soil temperatures reach 50°F because prolonged exposure to soil temperatures below this 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 50°F. Below 50°F., 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 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

## 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*

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 1.5-2.0 bushels/year grain yield increase over the past 90 years. This is primarily 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. 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. 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 38-40,000 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. Some studies have shown a small but biologically insignificant reduction in NDFD with increasing plant population. A summary of Pioneer silage hybrid studies from 2004-2007 show that 24-hour NDFD was reduced by 1-percentage point in hybrids planted from 18,000 to 42,000 PPA. This small decrease would have no impact on cow performance, even if corn silage was the primary forage in the diet. 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. A 2017 study at Virginia Polytechnical Institute examined two different hybrids planted in seven different fields at 23,000, 29,000, 35,400, 41,600 PPA. This study demonstrated that planting density significantly increased yield and while reducing stalk diameter it did not significantly reduce 30-hour ruminal *in vitro* NDFD of the resulting silage.

Corn breeders are actively developing reduced stature hybrids to counter the issue of lodging. These hybrids have a significantly larger diameter stalk and early research indicates they exhibit a significant increase in fiber digestibility due to the lower rind:pith ratio. This unique germplasm is a complete step change in stalk diameter, much more so than the stalk diameter differences in normal hybrids planted from 20-40,000 PPA. 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 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.

**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 |

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 stands 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.

# ALFALFA

## VARIETY SELECTION

The following factors should be considered when selecting an alfalfa variety: yield and quality expectations, winter survival, soil types and drainage, disease control (e.g. anthracnose, bacterial, verticillium and fusarium wilts, root rots such as phytophthora and aphanomyces race 1 and race 2), pest pressure (e.g. leafhoppers, aphids, nematodes), rotation and stand life expectations, and ease of harvest (lodging susceptibility).

It is important to understand that alfalfa is genetically different from other crops. Most crops have two copies of each chromosome, but alfalfa is an autotetraploid, meaning it has four copies of each chromosome. Unlike corn hybrids where each plant of the same hybrid is genetically the same, individual alfalfa plants within a variety are not genetically identical. Alfalfa plants within a variety are like siblings in a family; they are similar but not identical.

Alfalfa cannot be truly hybridized. Due to the tetraploid nature of the alfalfa plant genome, it is not possible to breed homozygous inbreds, like in corn. Without true inbreds to cross, there can be no true hybrid alfalfa. Breeders who claim to have developed inbred alfalfa are essentially crossing two alfalfa varieties, to produce seed from the cross. However, the resultant seed from this male sterile approach is simply a mix of the two parent varieties and the cross, rather than a true hybrid. This can be observed by the variability among plants in a commercial hybrid alfalfa field which would not be expressed if alfalfa were a true hybrid like corn. Much of the increased yield in hybrid alfalfa varieties entered into University plots is due to the fact that "synthetic 1" seed was submitted which will express 7-10% higher yield. However, this yield advantage disappears due to general self-incapability in alfalfa when actual parent seed for commercial varieties is produced.



## REDUCED-LIGNIN ALFALFA

High quality varieties marketed as having higher NDF digestibility (NDFD) have been available via conventional alfalfa breeding techniques for several years. These varieties were selected for 5-10% lowered lignin content resulting in higher NDFD. Reducing lignin became the breeding focus because cell wall content (measured as NDF) increases and cell wall digestibility (measured as NDFD) decreases with increasing maturity (and yield) from vegetative through bloom stages. The decreasing level of digestibility is due primarily to the production of lignin which the plant lays down to provide structural support as plants grow taller. Lignin is a complex organic compound which is indigestible by ruminants. As it forms cross-linkages with cellulose it causes a decrease in the digestibility of alfalfa cell walls.

The development of genetically-modified, reduced-lignin alfalfa took more than 10 years to achieve approval and commercialization. Scientists at the Noble Foundation identified and suppressed several lignin genes. After a testing and selection process by a team of alfalfa breeders, commercially viable products were developed and introduced to the market in 2016. Commercial products, known as HarvXtra® alfalfa, combine the reduced-lignin gene and Roundup Ready® technology. In research conducted by Pioneer and Forage Genetics International, alfalfa varieties containing the HarvXtra® trait reduced-lignin 10-15% resulting in 10-15% increases in NDFD and RFQ.

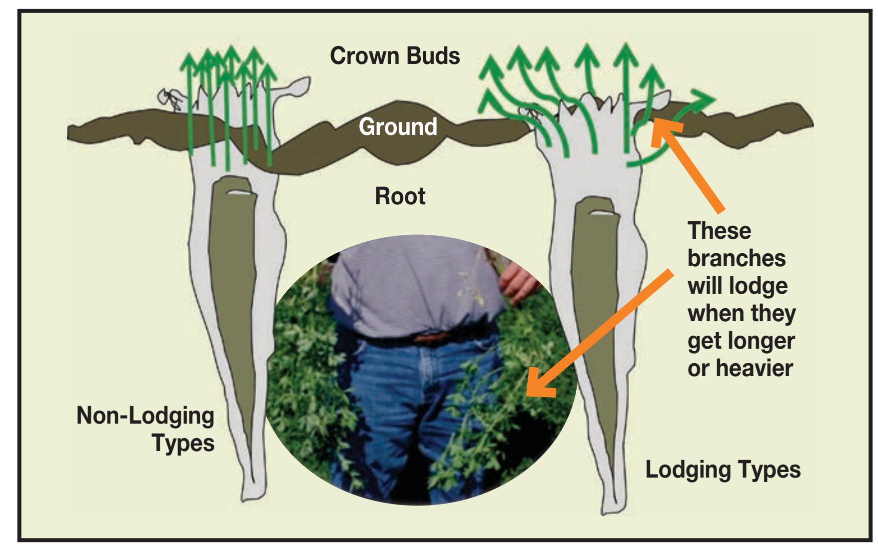
Studies showed a slower change in quality with advancing maturity when compared with conventional alfalfa varieties allowing for extending harvest intervals to capture more yield while still maintaining acceptable levels of fiber digestibility. Also, lodging susceptibility was no different than with conventional varieties. Technology fees for this technology must be weighed against:

1) the improved harvest flexibility and reduced risk of delayed harvest due to weather and
2) the value of harvesting a higher digestible crop (maintaining aggressive cutting schedules) or the savings from eliminating one cutting during the season.

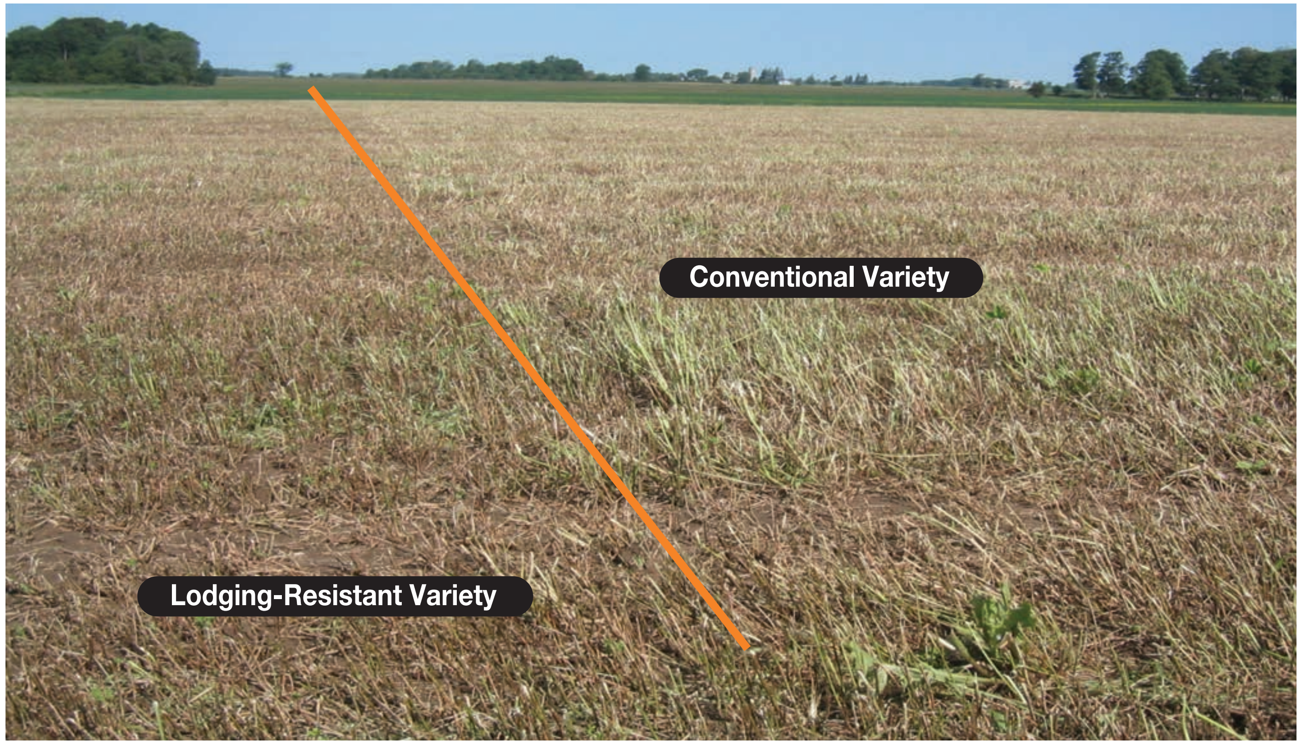
Estimates are that harvesting alfalfa can cost upwards of $50/acre. If a 50-lb bag of reduced lignin alfalfa will seed approximately 3.3 acres, eliminating one cutting per year would result in a $165 savings every year of the stand life.

## LODGING-RESISTANT VARIETIES

One of the more recent innovations in alfalfa genetics is the commercialization of lodging-resistant varieties. They have much improved standability when exposed to wind and rain events due to a more upright stem and crown architecture. Lodged alfalfa is more difficult to harvest. Every inch of uncut stem equates to 0.13-0.15 tons per acre of lost hay yield. Uncut stems left in the field can turn 'woody' and lower the forage quality of subsequent cuttings. Research also shows that more vertical plant architecture which reduces lodging has no effect on lowering fiber digestibility.



## LODGING-RESISTANT VARIETIES ALLOW FOR MORE HARVESTABLE YIELD AND REDUCE LOWER QUALITY RESIDUE IN SUBSEQUENT CUTTINGS




# ALFALFA BLENDS

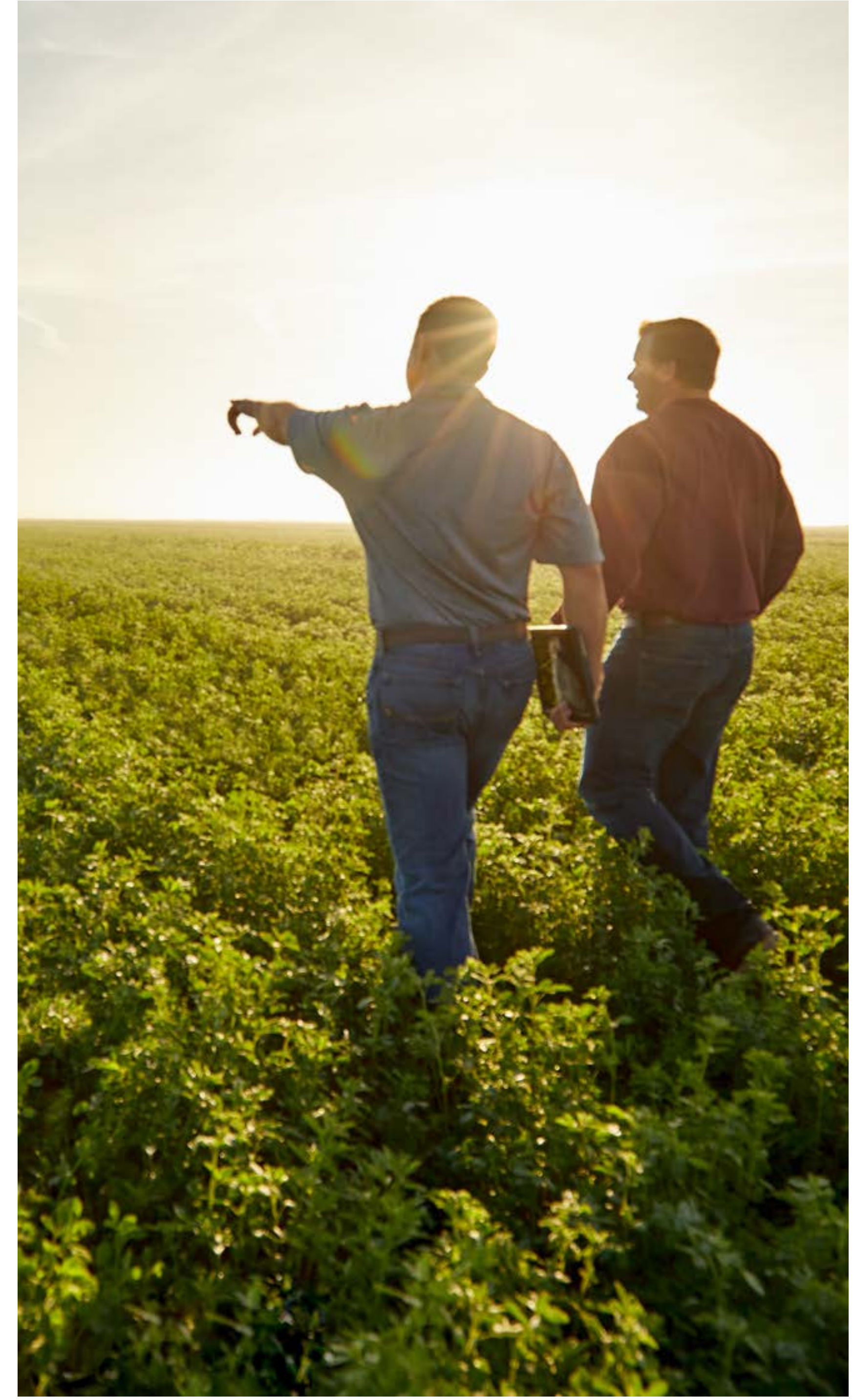
When considering the value proposition of an alfalfa blend, most growers understand the need to critically compare price against seed purity and quality. Alfalfa blends from most reputable seed suppliers contain relatively high quality seed, however, depending upon the supplier; blends are certainly more variable and can range from high germination and high purity, to products with lower germination (often older seed) and low purity. Blends may have suitable performance for short rotations, or field situations where specific pest resistance traits or performance of a pure variety are neither needed nor valued. Carefully consider the economic impact of increased variability and reduced performance of blends in fields seeded down only every 3-5 years.

There are two main sources for blended alfalfa seed in the marketplace. One is "common seed" sold as variety not stated (VNS) products produced by individual farmers who allow a field to go to seed. This is not legal if it involves patented varieties or varieties containing proprietary transgenic traits. This "farmer source" seed generally finds its way into the market through seed brokers. Rather than the traditional VNS, these products often get sold as micro-brands marketed through retailers and companies possessing no seed production, conditioning or bagging capability.

There are a few major seed brands that also offer blends, typically from their own genetics and produced through their normal production channels. These blends are sold without stating the variety to allow seed companies the option of selling end-of-lifecycle products or excess inventory due to over-production. Blends can also include excess parent seed, experimental varieties that do not advance to commercial status or inventory that may not meet purity specifications for outcrosses or self-fertilized plants due to failed isolation standards. For all these reasons, blends can vary considerably from lot-to-lot, and almost certainly from year-to-year.

Some seed companies have built name recognition around premium blend products. These higher-priced blends may vary in variety but have a consistent branded name with a guaranteed specification for some trait such as a minimum DRI (Disease Resistance Index), or having a stated level of a known variety. Premium blends reduce the company's options for inventory management, but offer growers more information about expected performance. Be cautious when a premium blend approaches the price of a pure variety. Unless you know all the varietal components of a blend, and have a specific reason for their inclusion levels, you will likely be better off purchasing a pure variety that fits your specific needs.

Growers should rely on the bag tag to evaluate any seed purchase. The tag will indicate the crop species, germination level, crop purity and weed seed content. Discerning growers should look at the seed tag for germination levels, and adjust seeding rates accordingly. Some blends are sold with descriptive information that narrows the range of variation, such as stating if the product is a "fall dormant" or "non-dormant" alfalfa blend. More reputable seed suppliers take extra measures to insure that blends meet minimum disease resistance criteria for the specific region the blend will be sold. Beware of blends with a tag showing lesser crop purity. If the tag says there is 3% "other crop," don't be surprised if your new alfalfa seeding looks like a mixed stand.



# FALL DORMANCY

Alfalfa varieties have a range of dormancy from very dormant to non-dormant. Dormancy allows alfalfa plants to "shut down" in late fall for the purpose of winter survival by storing carbohydrates in the roots and crown. Dormancy is measured by comparing the amount of vegetative growth produced during a specific period in the fall and then given a numerical rating as shown in the table. A rating of one on the scale indicates the greatest fall dormancy with the least fall plant height while a rating of eleven indicates the least fall plant dormancy with the greatest plant height.

In general, less-dormant alfalfa varieties initiate regrowth more quickly than more-dormant varieties, leading to higher yield potential. Non-dormant varieties have shallow crown depth and often suffer winter damage and reduced winter survival. In modern varieties, fall dormancy does not equate to winterhardiness.

## FALL DORMANCY DESCRIPTIONS FOR ALFALFA

| FD RATING | DESCRIPTION |
|---|---|
| 1-2 | Very Dormant |
| 3-4 | Dormant |
| 5 | Moderately Dormant |
| 6-7 | Semi-Dormant |
| 8-9 | Non-Dormant |
| 10-11 | Very Non-Dormant |

## WINTER SURVIVAL RATINGS FOR ALFALFA

| WS RATING | DESCRIPTION |
|---|---|
| 1 | Extremely Winterhardy |
| 2 | Very Winterhardy |
| 3 | Winterhardy |
| 4 | Moderately Winterhardy |
| 5 | Slightly Winterhardy |
| 6 | Non- Winterhardy |

*Source: National Alfalfa & Forage Alliance (NAFA)*



# WINTERHARDINESS, SURVIVAL AND STAND PERSISTANCE

Winterhardiness is a general term referring to the ability of plants to survive all the factors influencing winter survival including temperature, moisture, disease, insects, and previous crop management. Alfalfa varieties are classified using a standard test.

Alfalfa plants accumulate carbohydrate reserves in the root and crown tissue during fall regrowth. These feed the plant over winter, and help initiate regrowth in the spring. Fall regrowth facilitates additional nutrient reserves in the roots. Younger, healthy plants have a greater capacity to store food reserves. These plants will be more tolerant of cold temperature stress and have a greater capacity to initiate regrowth in the spring. Alfalfa can usually survive temperatures of 15°F at the crown. It likely will take multiple weeks of exposure to these low temperatures to actually kill crown buds. Four inches of snow cover provides enough protective insulation to allow a 20°F difference between air and crown temperature.

Winterhardiness was historically associated with fall dormancy, where varieties that are more dormant had lower winterhardiness scores. However, alfalfa breeders have "broken" the genetic link between fall dormancy and winterhardiness. Modern fall dormancy 4 to 6 varieties have very good winterhardiness scores when evaluated by stand persistence. With modern alfalfa varieties, fall dormancy does not equate to winterhardiness.

Stand persistence is a measure of the productive life of an alfalfa stand and impacts total cost of production. Stand persistence ratings are taken at the end of stand life and are based on plant appearance, vigor, and stand integrity after at least 3 harvest years. Persistence in northern geographies depends primarily on winterhardiness whereas persistence in the south is influenced more by disease resistance.

# DISEASE CONSIDERATIONS

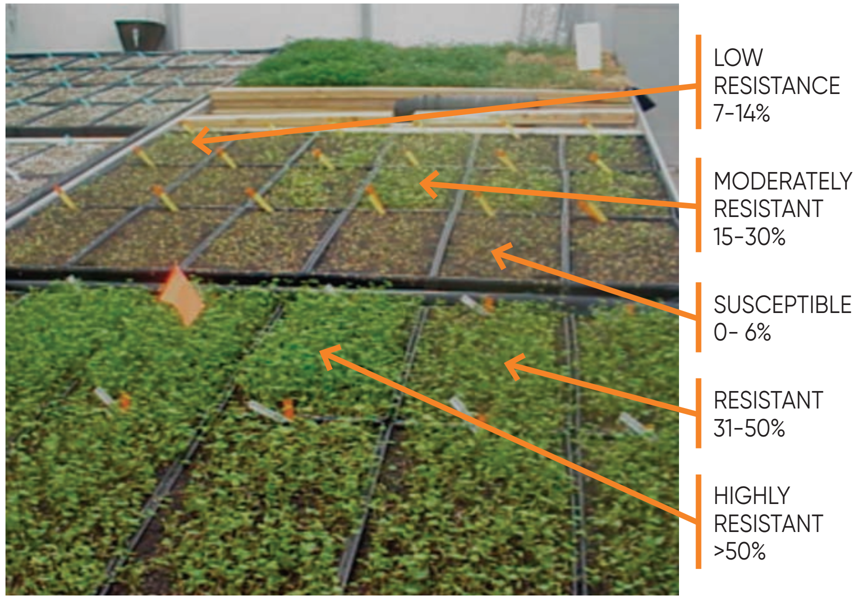
The major alfalfa diseases include:

1) stem and crown disease (anthracnose),
2) bacterial, Fusarium and Verticillium wilts and
3) Root rots such as Phytophthora and Aphanomyces (race 1 and race 2).

Root rots are especially problematic in susceptible varieties when planted in poorly drained soils with free water in excess of field capacity. Alfalfa is not a good crop choice for poorly drained soils.

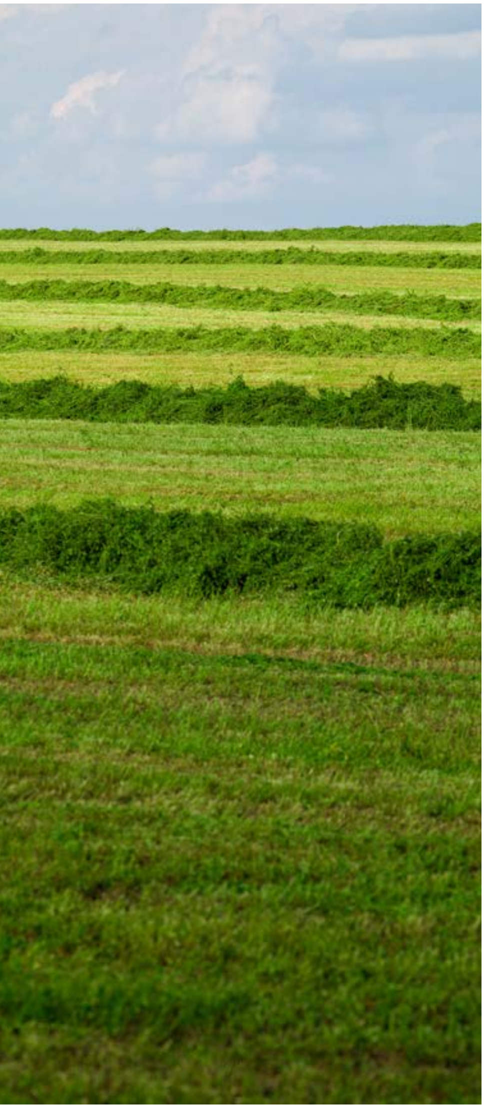
The fact that alfalfa plants within a variety are not identical, not all the plants within a variety will carry the same genes for insect and disease resistance. Therefore, alfalfa breeders measure gene frequencies within a variety to determine the level of pest resistance. The gene frequency percentages determine the resistance level for a given pest trait, and the variety is then classified in a resistance class for each pest trait. This rating scale is standardized throughout the alfalfa seed industry.

## ALFALFA RESISTANCE RATINGS



For example, if a variety has 88% of plants expressing anthracnose resistance, it meets the threshold of >50% resistant plants, and merits a rating of "High Resistance" to anthracnose.

The alfalfa Disease Resistance Index (DRI) was developed by the University of Wisconsin. It represents a tally of points determined by how a variety rates for the six main alfalfa diseases in North America. Each variety is assigned points, between 1 and 5, based on its resistance class. With six major diseases and the highest individual score being 5, varieties can score up to 30 points on the original DRI index. Over the years, some companies have added a seventh disease, Aphanomyces Race 2, for a possible total of 35 points. The closer the DRI score is to 35, the more general disease resistance the variety will exhibit. There is no industry standard for DRI. Pioneer uses the 35 point, modified DRI scoring system but some seed companies still use the 30 point DRI scale.



## ALFALFA DISEASE RESISTANCE RATINGS

| % RESISTANT PLANTS | RESISTANCE CLASS | CLASS ABBREVIATIONS |
|---|---|---|
| <6 | Susceptible | S |
| 7-14 | Low Resistance | LR |
| 15-30 | Moderately Resistant | MR |
| 31-50 | Resistant | R |
| >50 | Highly Resistant | HR |

## EXAMPLE OF HOW AN ALFALFA VARIETY IS ASSIGNED A DISEASE RESISTANCE INDEX SCORE

| DISEASE | RESISTANCE CLASS | POINTS |
|---|---|---|
| Bacterial Wilt | HR | 5 |
| Verticillium Wilt | R | 4 |
| Fusarium Wilt | HR | 5 |
| Anthracnose | HR | 5 |
| Phytophthora Root Rot | HR | 5 |
| Aphanomyces Race 1 | HR | 5 |
| Aphanomyces Race 2 | R | 4 |
| **DRI Score** | | **33** |



# INSECT CONSIDERATIONS

Alfalfa pests of concern vary depending on growing region and whether the crop is grown commercially or for seed. Varieties are typically rated for resistance to spotted aphid, pea aphid, blue aphid, northern and southern nematode and stem nematode. However, the potato leafhopper is the most impactful insect pest of alfalfa in the eastern half of North America. Leafhopper-resistant varieties have been available for more than a decade.

If a grower is successfully scouting (sweep netting weekly) and spraying for control of leafhoppers, a leafhopper-resistant variety may not be required. However, for growers who are not scouting, or who notice leafhopper damage in their alfalfa despite spraying, then a leafhopper-resistant variety might be a better option. Varietal resistance comes from small hairs on the stems which repel the leafhopper. These varieties are especially recommended where intense PLH pressure spans multiple cuts during most growing seasons. As with disease resistance, not all plants will exhibit the same level of resistance in a leafhopper-resistant variety.

# SEED COATINGS

Many seed companies sell coated alfalfa seed. A common heavy-coating contains 34% limestone. Heavy-coated or limestone-coated seed has no consistent advantage in cloddy or dry soil conditions. In fact, a heavy coating can slow water uptake under moderate to dry soil moisture conditions. Some companies offer a light 9% polymer seed coating. The different seed coatings needs to be account for in determining appropriate seeding rates.

# PURE LIVE SEED COUNTS

Pure live seed (PLS) can be calculated from information found on an alfalfa variety seed tag. It is the percent pure seed multiplied by the percent total germination, divided by 100. Pure live seed is the seed you can expect to germinate and contribute to stand establishment. If the tags states 91% pure seed (excluding coatings, inert matter, weed and other crop seed) and 90% total germination, multiply 90% pure seed, times 90% germination, to equal 82% pure live seed. By contrast, varieties with 34% heavy coating and 90% germination start with just 59% PLS.

Hard seed is viable seed that does not germinate within the seven day germination test period. There is sometimes confusion about whether to count hard seed when calculating pure live seed. State seed certifying agencies do include hard seed as viable seed. Practically, the hard seed ends up being out competed by seeds which germinated earlier. Given that hard seed is included in the total germination on the seed tag, it needs to be included in the PLS calculation. Some companies scarify seed lots in order to keep hard seed at 8-10% or less of finished seed. High percent hard seed from some suppliers tends to indicate a lack of scarification, and may lead to lower than expected stand counts.

The accompanying chart shows the seeding rate in pounds per acre (lbs/A), and the seed coating impact on the number of seeds per square foot. To obtain 70-75 seeds per square foot, growers would have to seed 24 lbs/A of heavy-coated alfalfa seed, but only 18 lbs/A of light-coated seed. When a grower plants a heavy-coated seed but does not increase the seeding rate, there is a higher risk of thin/weedy stands, stand establishment failure and reduced yield over the total life of the stand. The level of coating can dramatically impact the cost of alfalfa seed.

## IMPACT OF SEED COATING AND SEEDING RATES ON ALFALFA SEEDS PLANTED PER SQUARE FOOT

| SEEDING RATE (LBS/A) | ACRES SEEDED PER 50 LB UNIT | 9% LIGHT-COAT | 34% HEAVY-COAT |
|---|---|---|---|
| | | PLS PLANTED PER SQUARE FOOT | |
| 26 | 1.9 | 110 | 80 |
| 24 | 2.1 | 101 | 74* |
| 22 | 2.3 | 93 | 67 |
| 20 | 2.5 | 85 | 61 |
| 18 | 2.8 | 76* | 55 |
| 16 | 3.1 | 68 | 49 |
| 14 | 3.6 | 59 | 43 |
| 12 | 4.2 | 51 | 37 |

*Recommended final pure live seed (PLS) count at planting is 70-75 alfalfa seeds per square foot*

# FIELD PREPARATION

Soil tests are needed to determine fertility needs before ground preparation begins. Phosphorus is critical for healthy alfalfa root development and potassium is needed for high yields. Soil pH levels of 6.2 to 7.0 provide the best environment for nodule bacteria to fix nitrogen. A firm seedbed is critical for successful alfalfa establishment. It improves seed-to-soil contact and prevents the seed from being planted too deep. Soil clods can cause uneven seeding depth, impede emerging seedlings and cause soil surface to dry rapidly.

No-till seeding can also be a viable option because the seedbed is already firm and top soil moisture is generally good. Take special care to adjust seed depth gauge wheels for field conditions, and adjust press wheels for optimum seed-to-soil contact during planting. With attention to these details, no-till stand establishment can be very successful.

# PLANTING DEPTH

Depth of planting is critical for alfalfa given the extremely small seed size. It is recommended to seed ¼-½ inches deep on clay or loam soils and ½-¾ inches deep on sandy soils. Topsoil moisture may be inadequate to sustain young seedlings with shallow planting, and seedlings may not be able to push to the surface with deep planting.

# PLANTING DATES

Alfalfa requires 37ºF soil temperatures to germinate compared to 46ºF for corn and 55-60ºF for soybeans. The fact that alfalfa germinates at much lower soil temperatures is why we are able to plant alfalfa earlier in the spring than many other crops.

In dormant alfalfa growing regions, spring seeding typically takes place between April 1 and May 15 when there is less chance of frost, along with reduced potential for moisture stress and crusting problems. Clear seeding (no nurse crop) in the spring will usually allow for at least two cuttings during the seeding year. Clear seeding is best on level fields where soil erosion is minimal.

The critical period for stand survival is the two week period after emergence. Premature seeding can increase the risk of poor germination from seed rotting in cold, damp soils. Young alfalfa seedlings can tolerate temperatures as low as 20ºF (for a few hours) but extremely early seeding can be risky if temperatures turn cold leaving the stand susceptible to seedling diseases. The growing point of alfalfa (like soybeans) is above the soil for up to several weeks after germination. This risk of stand injury from low temperatures exists until contractile growth is completed (about when the second trifoliolate leaf has emerged) and the growing point (crown buds) is protected below the soil surface. Freezing danger is actually greater after alfalfa plants lose cold tolerance when they are about 4 inches tall (3rd or 4th trifoliate leaf stage).

August 1 to August 15 are typical dates for late summer seeding with reduced weed competition and less concern about diseases (Pythium, Phytophthora and Aphanomyces) on heavy, poorly drained soils. Alfalfa seedlings need at least six weeks of growth prior to killing frost (~23ºF) to grow large enough and lay down adequate root reserves to survive the winter and thrive in the spring. It is possible to also seed alfalfa after a small grain or vegetable crop, if harvest occurs by early August, field conditions are suitable and previously used herbicide will not harm new seedlings.

# SEEDING RATE

Seeding rates in alfalfa traditionally focused on how many pounds per acre to plant. A more precise method is to set a target seeding rate in terms of seeds per square foot. Most university researchers recommend planting between 60-70 seeds/ft$^2$. High seeding rates (70-80 seeds/ft$^2$) allow alfalfa seedlings to better compete with weeds and help compensate for cloddy soil conditions in non-optimal seedbeds. Seeding at lower rates (50-60 seed/ft$^2$) may be adequate in optimal soil conditions or sandy soils, however low rates increase risk of non-uniform or spotty stands which can hurt production over the entire life of the stand.

Research suggests that only about 50% of planted seeds will emerge as seedlings in three to four weeks, with another 50% lost by the next spring. So at a seeding rate of 70 seeds/square foot, we would typically have 15-20 alfalfa plants by the beginning of the second year (1st year after seeding). This is within guidelines of 15-25 plants per square foot as a goal for the first production year.

Planter adjustments are required to compensate for seed coatings, inert materials, and germination (found on seed tag). Use the accompanying table to help determine how many pounds per acre ("out-of-the-bag") are needed to hit the target seeding rate (assumes 220,000 seeds per lb and 90% germination).

While seed cost, spread over the typical life of a stand (4-6 years), equates to a small percentage of the total alfalfa planting and harvesting investment, proper seedbed preparation and seeder calibration makes sense to help reduce seed and technology costs as much as possible, especially as technology fees increase for important alfalfa transgenic traits.

## ALFALFA SEEDING RATES

What is your target seeding rate at planting?[1]

| | 80 | 70 | 60 | 50 |
|---|---|---|---|---|
| What should your planter's seeding rate be set at to achieve you target?[2] (lbs/ac) | | | | |
| 9% Coating[3] | 19 | 17 | 15 | 12 |
| 34% Coating[3] | 27 | 23 | 20 | 17 |
| How many acres will your bag of seed plant? (acres/bag) | | | | |
| 9% Coating | 2.6 | 2.9 | 3.3 | 4.2 |
| 34% Coating | 1.9 | 2.2 | 2.5 | 2.9 |

*Notes: 1) Universities recommend 60-70 viable seeds per sq. ft.*
*2) Assumes alfalfa has 220,000 seeds per pound, germination is 90%, and a unit or bag of alfalfa contains 50 lbs.*
*3) Seed coating includes fungicide, inoculant, and other inert materials*

# MANURE

Applying manure before seeding alfalfa can provide phosphorus, potassium, sulfur, boron and soil attributes beneficial to alfalfa growth, despite the lack of need for the nitrogen in manure. University of Nebraska recommends applying as much as 12,000 gallons of cow manure (50-tons dry manure) per acre can boost alfalfa yield in both high and low fertility soils. The exact amount of manure to apply should be determined by soil tests and manure analysis. It is not recommended to apply manure if planting a companion crop (e.g. oats, barley) due to potential for lodging and smothering the alfalfa. For best results, alfalfa seed should not be in direct contact with fresh manure (injected or well incorporated), the seedbed should be firm and the weed program well thought out as manure can be a significant source of weed seeds.

The primary concern with manure applications to established stands is damage from equipment and from the manure, not due to excess nitrogen. High yielding alfalfa has the capacity to buffer high amounts of nitrogen in manure. University of Missouri extension suggests each ton of harvested alfalfa can contain 50 pounds of nitrogen and in low nitrogen soils most of the alfalfa nitrogen will be derived from plant nodules fixing nitrogen. However, there is an energy benefit to the alfalfa plant to use nitrogen from the soil in preference to fixing nitrogen from the atmosphere. Alfalfa plants that have access to manure nitrogen will reduce fixation and preferentially use the alternative nitrogen supply.

Alfalfa plants can be damaged by high salt or ammonia concentration in the manure, by physical damage to the crowns by application equipment or by water deficits induced by high salt concentrations in the manure. The greatest danger is from slurry or solid manure that is applied with large equipment. Lagoon water from unagitated lagoons typically possess less risk because nutrient and salt concentrations are lower. It is recommended to apply manure immediately after cutting alfalfa and before budding on the alfalfa crowns. The alfalfa plant is less vulnerable to salt damage which no green leaves are showing. This is particularly important for surface applications of slurry.

# HARD SEED

Alfalfa produces a percentage of seed with an impermeable seed coat, referred to as hard seed. Hard seed fails to absorb water and does not immediately germinate when planted in a field, but rather is delayed by anywhere from one week to two months or more. Since hard seed does not improve stand establishment or yield, seed companies minimize the amount of hard seed in a bag of seed through scarification (mechanical abrasion) of the seed coat. Once scarified the hard seed germinates like normal seed, although even after scarifying, some hard seed remains. Seed quality is determined after the final batch is blended and the seed tag will then reflect the new germination percent. Alfalfa seed tags will show hard seed percentage in addition to total germination. Ideally, hard seed should be less than 10-15% of total germination.



# USING A NURSE CROP

Seeding alfalfa with oats, barley or Italian ryegrass as a nurse-crop is a common practice in geographies seeking erosion control during early stand establishment or when additional early-season forage is needed. To avoid excessive competition with alfalfa seedlings, growers using a nurse crop should seed it at less than optimum seeding rates, and harvest it in the boot stage of growth. The primary disadvantage of a nurse crop is increased competition for moisture and nutrients, and therefore not recommended for late summer alfalfa seeding.

With the use of glyphosate resistant alfalfa, nurse crops can be eliminated early with a timely application of glyphosate herbicide. This practice provides early season erosion control benefits, along with improved weed control and more rapid alfalfa growth for higher alfalfa yields and quality in the seeding year.

## ALFALFA SEEDING OPTIONS

| DIRECT SEEDING | COMPANION SEEDING WITH NURSE CROP |
|---|---|
| • Recommended for high quality forage<br>• Balances seeding year tonnage, forage quality, and alfalfa establishment success<br>• Select fields with low erosion<br>• Weed control options include traditional herbicides or glyphosate-based system | • Suitable for land prone to wind or water erosion<br>• Select suitable early-maturity, short-stature companion crops like oats, spring barley, or spring triticale<br>• Seed at 1bu/A (sandy soil) - 1.5 bu/A (heavy soils) at a planting depth of 1-2 inches deeper than alfalfa<br>• Limit nitrogen applications. Not >30lb/acre to prevent increased lodging in cereals and N for weeds<br>• Harvest early (boot stage) - recommended<br>• Harvesting for grain/straw - not recommended |

# WEED CONTROL AT STAND ESTABLISHMENT

One of the most important limiting factors of alfalfa production is weed control. When growers eliminate weeds from an alfalfa stand, both alfalfa yields and forage quality are frequently improved. Weed-free stands can also result in longer stand life. Growers have several options in the seeding year to control weeds and to promote vigorous, healthy establishment of alfalfa.

For spring seedings, growers frequently use conventional tillage field preparation which provides a clean initial seedbed. However, without herbicidal control, weeds can emerge and outgrow seedling alfalfa to dominate the stand in just a few weeks. One option in this situation is to take an early first clipping which may contain more weeds than alfalfa. As long as weeds do not smother the young alfalfa plants, it will tend to outgrow most weeds. An alternative option some growers choose is to plant up to 10 more lbs/A than recommended seeding rates to crowd out weeds. Today the seed cost versus the cost of herbicidal weed control, means it is less expensive and more efficacious to use a well-chosen herbicide.

No-till seeding or late-summer seedings may offer less weed competition during stand establishment, especially if the prior crop was not weedy. No-till avoids bringing soil-borne weed seeds to the surface where germination will occur. Clear seeding of alfalfa in a no-till environment works best in conjunction with a burndown herbicide to eliminate weeds in the field. Growers can then assess the need for a post-emergence herbicide as the alfalfa grows to manage weed pressure.

Non-glyphosate alfalfa herbicide options frequently provide adequate weed control including both pre-emergence and post-emergence products. However, traditional alfalfa herbicide products often have limitations on the spectrum of weeds controlled or may have a small reduction of alfalfa yield in the seeding year.

The introduction of alfalfa varieties with resistance to glyphosate herbicide provides yet another weed control option. Weed control needs are different depending on the growing environment. In drier growing regions like the Western US, alfalfa is not very competitive against weeds. Similarly, the southern US has grass weed species like fescue which are hard to control with other herbicides. The use of glyphosate resistant alfalfa technology provides an excellent tool to control these weeds without plant injury or stunting. When planting alfalfa with glyphosate resistance it is important to spray these fields with glyphosate during the early seedling establishment phase (3rd to 4th trifoliate stage of growth). This eliminates the 3-7% of alfalfa plants without resistance to glyphosate. Also, alfalfa growers may need to make additional glyphosate applications as new weeds emerge during the life of the stand because it does not have residual activity.

## MIXED STANDS

If soil conditions are suitable for growing alfalfa, it is difficult to beat pure alfalfa stands for yield or forage quality. However, when growing conditions are more challenging (e.g. fields with variable drainage), mixed alfalfa-grass stands may have merit being somewhat less susceptible to diseases associated with wetter soils, winter-heaving, winterkill and pests such as potato leafhopper. Timothy, orchardgrass, perennial ryegrass, and endophyte-free tall fescue are the most common grasses seeded with alfalfa. In general, mixed stands will be seeded with 10-40% grass seed. Seeding rates will vary due to differences in seed size given that orchardgrass has 400,000 seeds per pound while timothy has over 1,100,000 seeds per pound.

A key in choosing the proper forage grass for seeding with alfalfa is the heading date of the grass. Many forage grasses head out before the alfalfa is at the ideal (late bud) stage for harvest. Some forage grass species have a wide range in heading date among the varieties. There can be a two week range in heading date between the earliest and latest timothy varieties, and a similar range with orchardgrass. The challenge for mixed stands in the future may be identifying a forage grass with the maturity to match the modified harvest schedule of reduced-lignin alfalfa.

Orchardgrass needs well-drained soils and has poor tolerance of ice sheets. Timothy has a wider range of soil adaption but doesn't yield well once the soil warms up in the summer and in a mixed stand often doesn't persist longer than about two years. Tall fescue has become popular due to tolerance of moderate drainage and low pH, and it produces well from spring into fall with a relatively narrow range in heading dates. Perennial ryegrass is better suited to Southern climates as they don't survive winter as well as other grasses. Smooth bromegrass does not mix well with alfalfa because it cannot handle the intense cutting schedule of alfalfa and typically requires a 6-week cutting schedule to persist.

It is not recommended to seed alfalfa-grass in fields where soil test potassium levels are medium to low. While the initial stand may perform well, once the grass becomes established their root system will take up potassium to the detriment of the alfalfa. Start with adequate soil test potassium levels and maintain potassium fertility throughout the life of the stand.

Meadow fescue is a new companion grass gaining attention. Genetically similar to ryegrass but dries faster and more winter hardy, meadow fescue may not yield quite as high as tall fescue, but is higher in fiber digestibility than other cool-season grasses at all stages of maturity. Miner Institute suggests that meadow fescue be the recommended grass for most growers seeding alfalfa-grass and recommend 12-14 lbs of alfalfa with 3-4 lbs of meadow fescue.

### RECOMMENDED RATES FOR GRASSES SEEDED WITH ALFALFA*

| SPECIES | RATE (LBS/ACRE) |
|---|---|
| Reed Canarygrass | 5-7 |
| Smooth Bromegrass | 6-10 |
| Timothy | 2-5 |
| Orchardgrass | 2-5 |
| Tall Fescue | 4-8 |
| Festulolium | 4-8 |
| Perennial Ryegrass | 4-8 |

*Alfalfa seeding rate, 7-10 lbs/acre pure live seed*
*Source: University of Minnesota*

## OVER-SEEDING THIN STANDS

Growers are sometimes tempted to over-seed additional alfalfa into a thin stand. The problem with over-seeding alfalfa into alfalfa stands that are over one year old is autotoxicity (discussed in the GROW section). Over-seeding with cereals, Italian ryegrass, sorghum-sudangrass, orchardgrass or clover into alfalfa can extend the stand life one or more growing seasons when economics or conservation planning require maintenance of the current thin alfalfa stand.

University of Wisconsin extension has summarized the research around over-seeding and suggests it is not beneficial unless the alfalfa stand has less 40 stems/$ft^2$. Older alfalfa stands that carry a heavy weed load should likely be rotated rather than over-seeded. Over-seeding with legumes such as red clover can yield forage suitable for lactating dairy cattle when harvested at typical late-bud maturity. Grasses over-seeded into alfalfa stands generally produce higher yields of forage than when over-seeded legumes. Adding a perennial like orchardgrass is useful if extending the stand life beyond the current growing season is desired. Annual grasses and cereal grains provide tonnage early in the growing season but decline by mid-summer so are best suited to a stand that will be harvested with only one or two more cuttings. Early harvest of cereals and annual grasses (prior to boot stage) will maximize quality and likely yield a second cutting. Perennial grasses are usually harvested slightly later as they will need a longer initial establishment period. Legumes added to a thin alfalfa stand should be inoculated prior to seeding to ensure adequate nodulation and nitrogen fixation. Cereals and grasses may need additional nitrogen (depending upon previous manure applications) to support yield and forage quality.

## FROST SEEDING

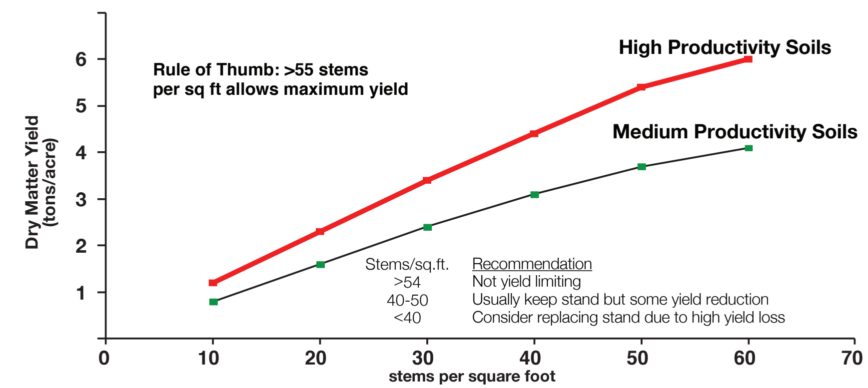
Frost seeding is an inexpensive method of distributing seed by broadcast seeders early in the spring after snow melt, but while ground is still frozen. Repeated freezing and thawing allows seed to penetrate the soil. This method, typically only 60-70% effective, is acceptable for pasture improvement but not for establishing pastures or hay fields. According to University of Wisconsin researchers, frost seeding works best for legumes (red clover, white clover, birdsfoot trefoil) and grasses (orchardgrass, Italian ryegrass, timothy) that germinate rapidly and at low temperatures. Frost seeding alfalfa is not recommended as it does not germinate at low temperatures as well as other legumes.

## STAND EVALUATION

It is best to check the viability of alfalfa fields after they have started to green up in the early spring. Check for bud and new shoot vigor. Healthy crowns are large, symmetrical and have many shoots. Watch for delayed green-up, lopsided crowns, and uneven growth of shoots. If any of these characteristics exist, investigate further by digging a few plants 4-6 inches deep and look at the taproot for any signs of browning or dehydration indicating root damage.

If heaving is evident, also dig some plants to determine if the taproot is broken. Plants with broken tap-roots may green-up, but perform poorly and eventually die. Slightly heaved plants can survive, but their longevity and productivity will be reduced. Crowns that are heaved one inch or less are not as likely to have a broken taproot. With time these plants can reseat themselves. Raised crowns are susceptible to weather and mechanical damage. Raise cutter bars to avoid damaging exposed crowns. Using a cultipacker or roller to push the crowns back in the ground can do more harm than good by damaging crowns and breaking taproots.

### ALFALFA STEM COUNT AND YIELD POTENTIAL



When alfalfa growth is 4-6 inches in height, use stem counts (stems per square foot) as the preferred density measure to evaluate if thin stands need rotating. Count only the stems expected to be tall enough to mow. A stem density of 55 per square foot has good yield potential. Expect some yield loss with stem counts between 40 and 50. Consider replacing the stand if there are less than 40 stems per square foot; and the crown and root health is poor. Stem counts are an effective evaluation tool for stands of all ages. Older stands have fewer plants per square foot, but older plants produce more stems than younger plants.




# 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, 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.

## 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.
- Corn plants adapted to the central corn belt typically have 20 leaves.
- Corn plants typically have one less leaf for each 4-days earlier maturity
- Plant height is maximized at the VT stage

## 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

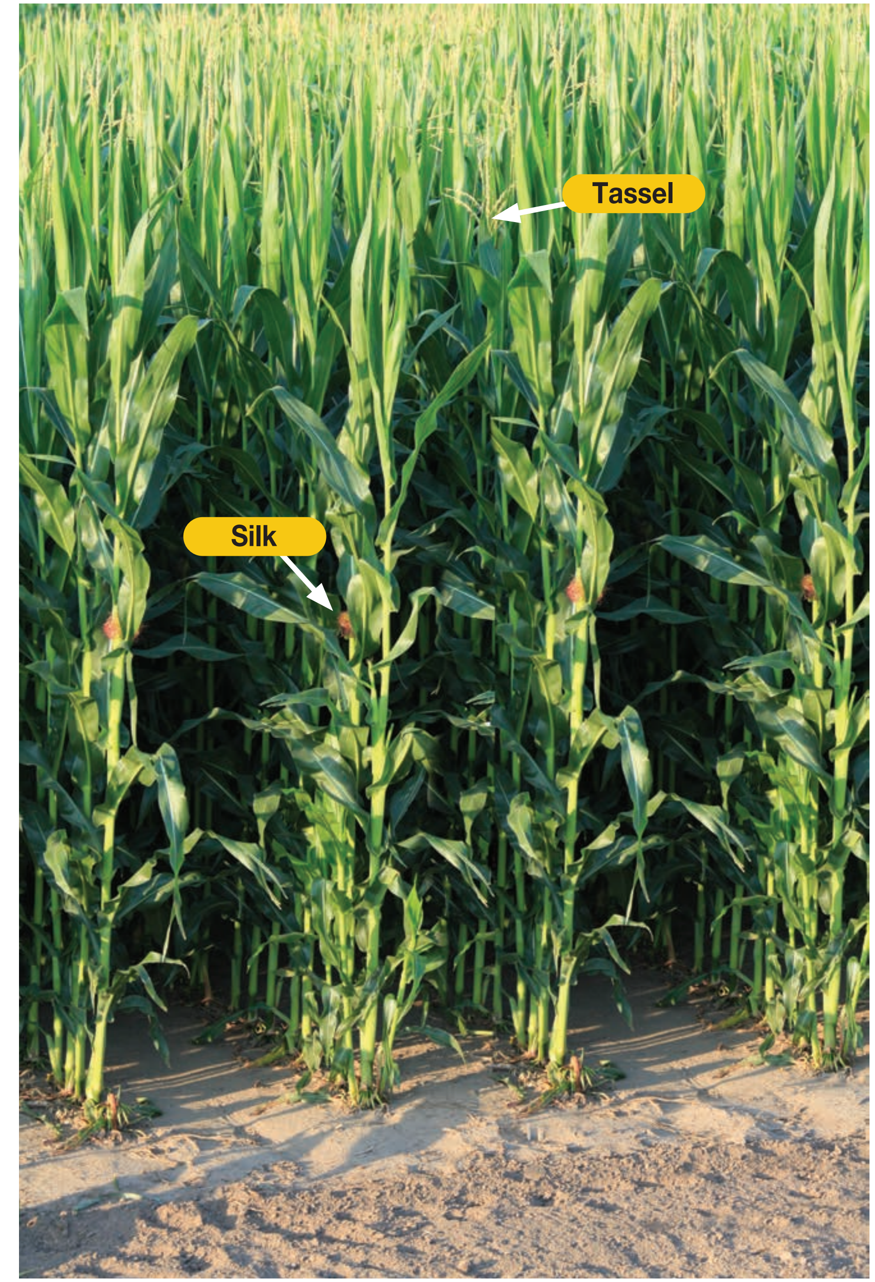
Fiber influences energy density dry matter intake and rumen health (mat development and stimulation of cud-chewing to buffer the rumen)

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.

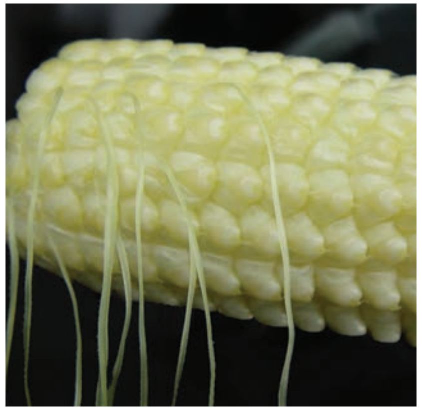
Silks emerge from the husk over a period of three to five days, starting with those silks attached at the lower middle portion of the ear and progressing toward the ear tip. Depending on the environment, an individual silk continues to grow for about seven days or until the silk intercepts pollen grains. 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.

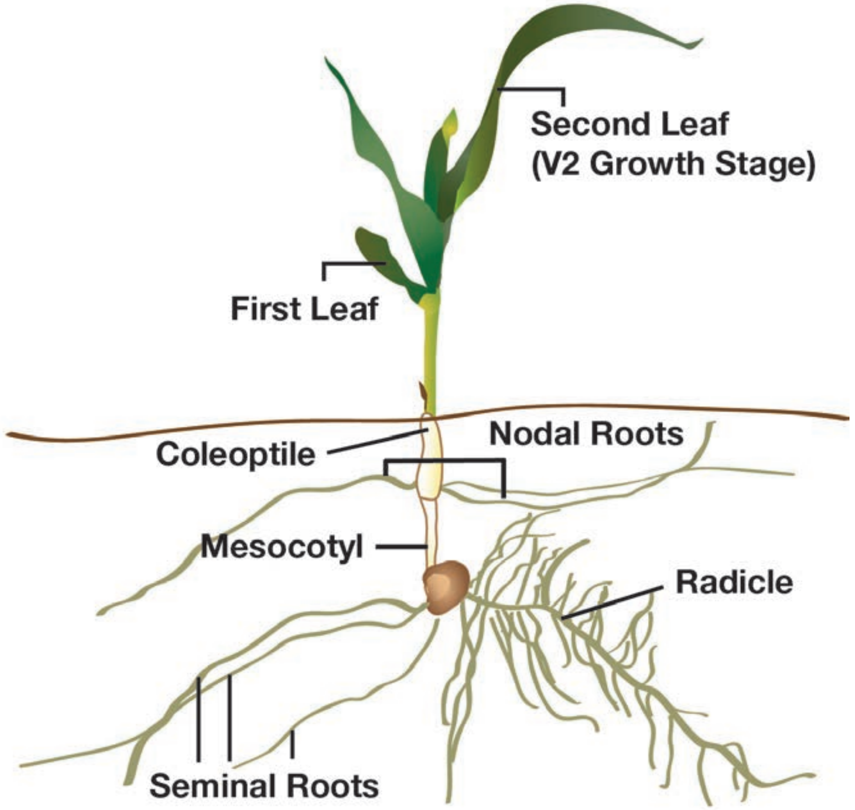



Kernel set (actively growing kernels after pollination) can be checked two or three days after pollen shed stops by carefully removing the husks from an ear and then gently shaking the ear to see if the silks are detached. Silks drop off ovules that have been successfully fertilized (kernels), but any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

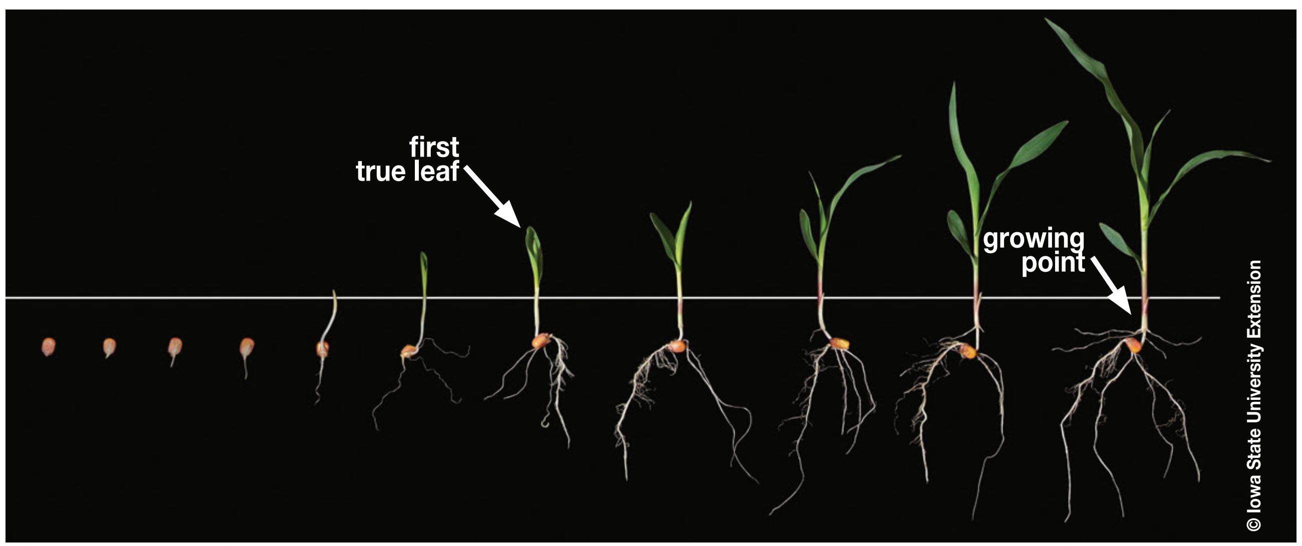
It is important that pollen shed and silk emergence happen concurrently to ensure successful pollination, which is called "nick." However, with today's modern hybrids, it is not unusual to see silks emerging from the husks one or two days before full tassel emergence occurs. This is a large change from 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, and remains below ground until V5 maturity. 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.

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 60°F followed by nighttime air temperature below 50°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.

**Purple corn**

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.

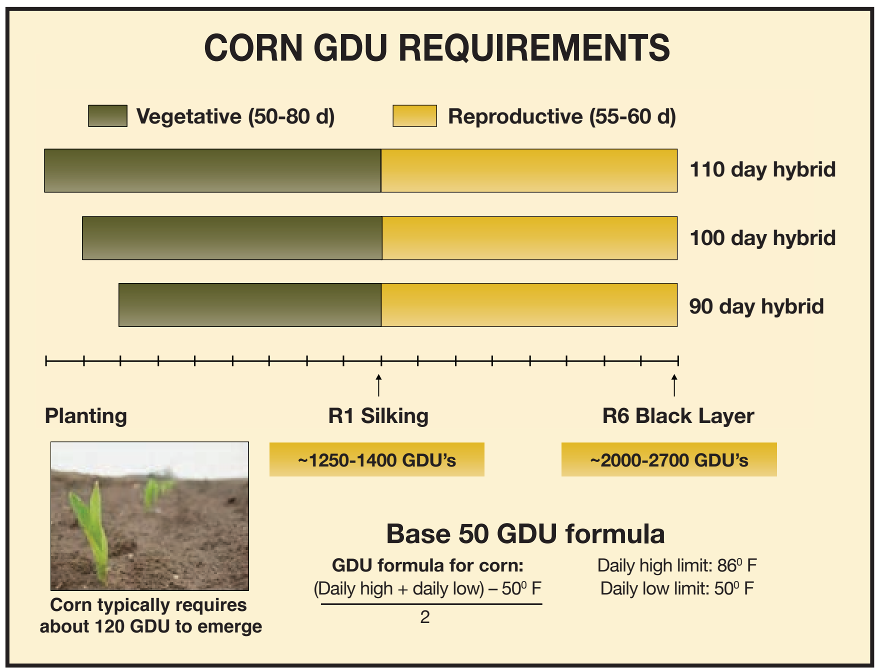
Starting at about the V5-V6 stage of growth, a corn plant will begin to determine yield potential. It is during this period when the number of kernels around the ear, or ear girth, is determined. For this reason, minimal stress at this time is essential for plants to maximize ear girth potential.

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.

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.

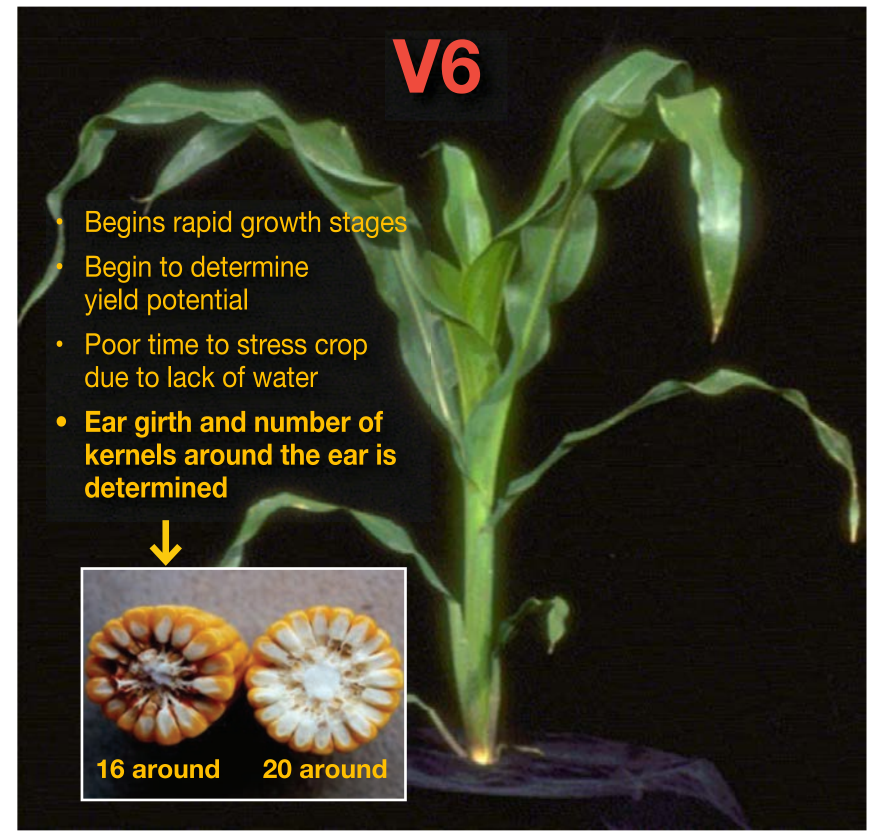



Corn tillers are lateral branches that form at lower, below-ground nodes. The number of tillers that develop depends on the plant population and spacing, soil fertility, early season growing conditions and hybrid genetics. Tillering is more common in stands with low populations or within-row gaps due to planting error. Extensive tillering can also occur if the primary growing point is damaged by hail, frost, herbicides or other injury. In most normal planting situations tillers will typically be shaded by leaves on the main plant and shrivel and die. Extensive research indicates that tillers do not drain the main plant and have no appreciable influence on grain yield.

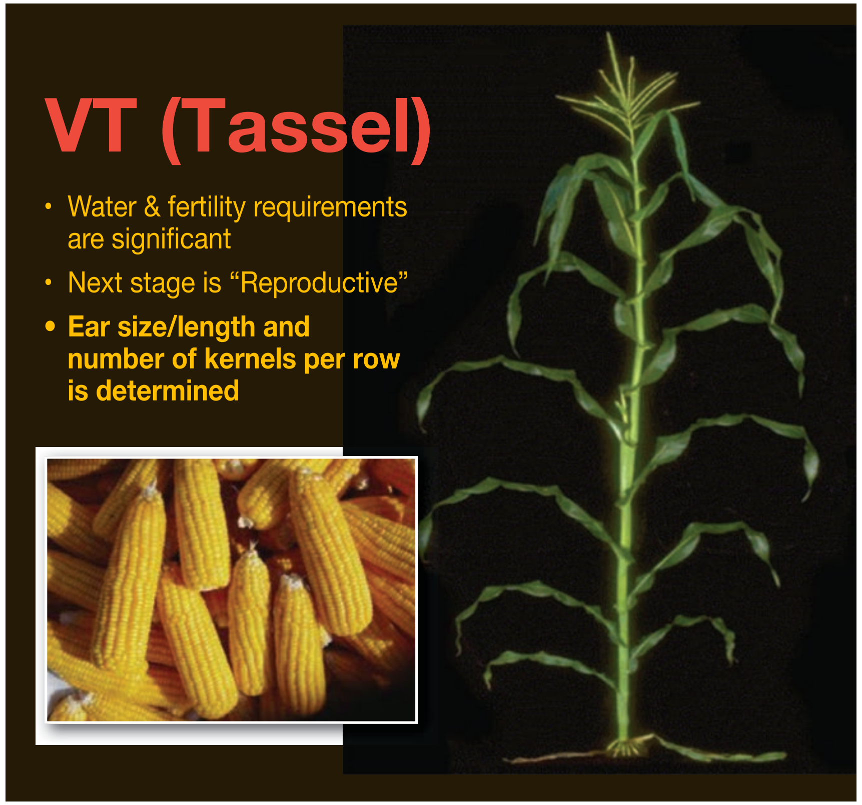
Soon after tasseling (VT), the plant begins the "reproductive" stages of growth. The transition from vegetative development to reproductive development (VT to R1) is a crucial period for grain yield determination. At this point, the upper ear shoot becomes dominant. VT occurs when the last tassel branch 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 achieved. Stalk cells will continue to lignify to improve stalk strength as the plant transitions to reproductive development (R1).

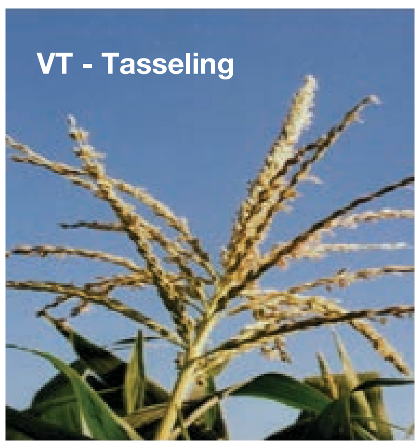
R1 officially starts when silks are visible outside the husks and typically occurs a couple of days after tasseling. Once a pollen grain lands on a silk (pollination), a pollen tube forms and takes about 24 hours to go down the silk to the ovule. Silage growers should note the date when corn plants silk (R1) and count ahead

**Corn plants in rapid growth phase showing wrapping of leaves**



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"), high temperatures, 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. It also can significantly reduce fiber digestibility. 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 appear white on the outside but the endosperm and the inner fluid are clear liquid. 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. The kernels are yellow outside while the 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.

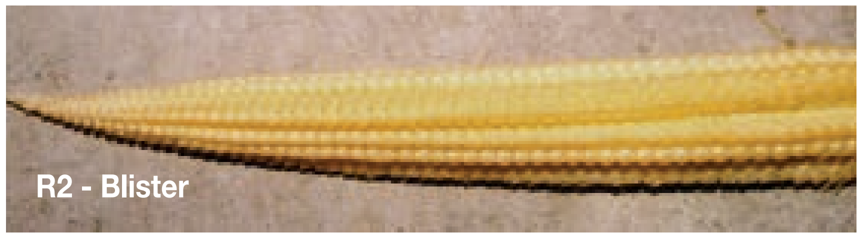
Dent stage (R5) occurs 35 to 42 days after silking and accounts for nearly one half of the reproductive development time. Kernels are comprised of a hard starch outer layer surrounding a soft starch core. Kernels dry down from the top, toward the cob, where a hard layer of starch is forming. An indentation (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).

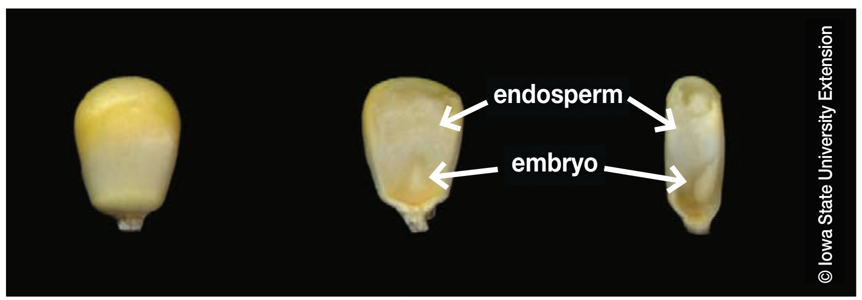
Monitoring kernel "milk" line is a practical approach to field evaluations for timing of silage harvest. The milk line forms as a visible separation between hard starch and soft starch. It forms at the crown of the kernel and progresses toward the base, or kernel tip. Milk line stages are generally referred 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

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


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



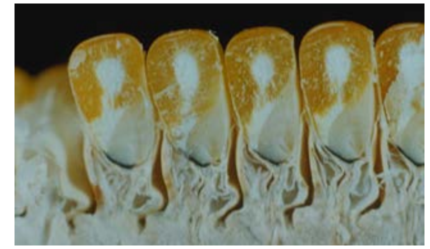

Kernels from a R3 plant.

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 earlage/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



R6 - Kernel abscission (black Layer)

loss through evaporation. Drying rates are normally 0.4-0.8% moisture per day. Ideal combining harvest moisture for corn is 15-20%, 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.


Progression of black abscission layer formation

## 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).

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

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.

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.

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.

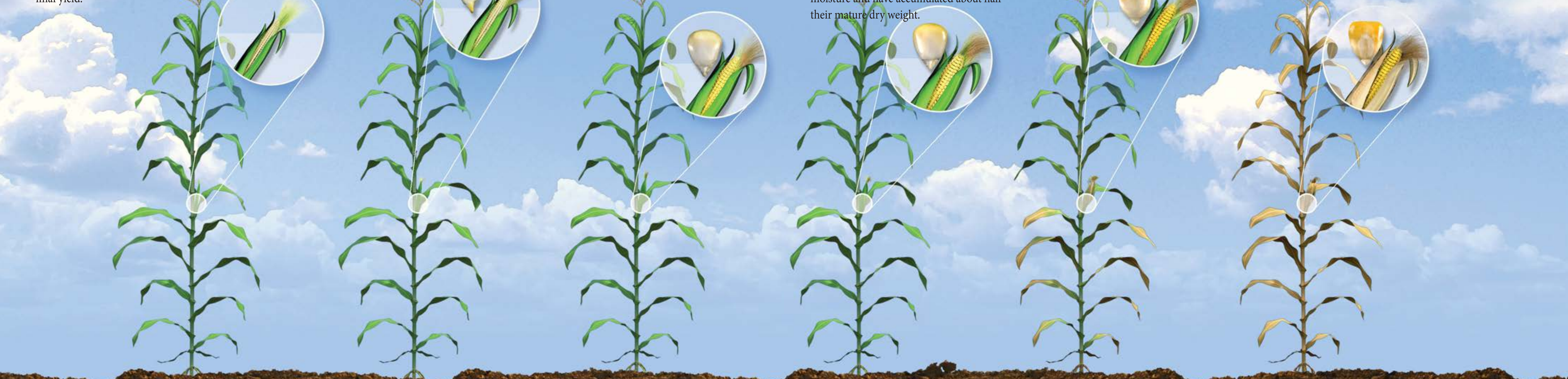
TIPS: Stress at this stage will reduce yields by reducing kernel weight. At the beginning of R5, kernels have about 55 percent moisture content.

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.



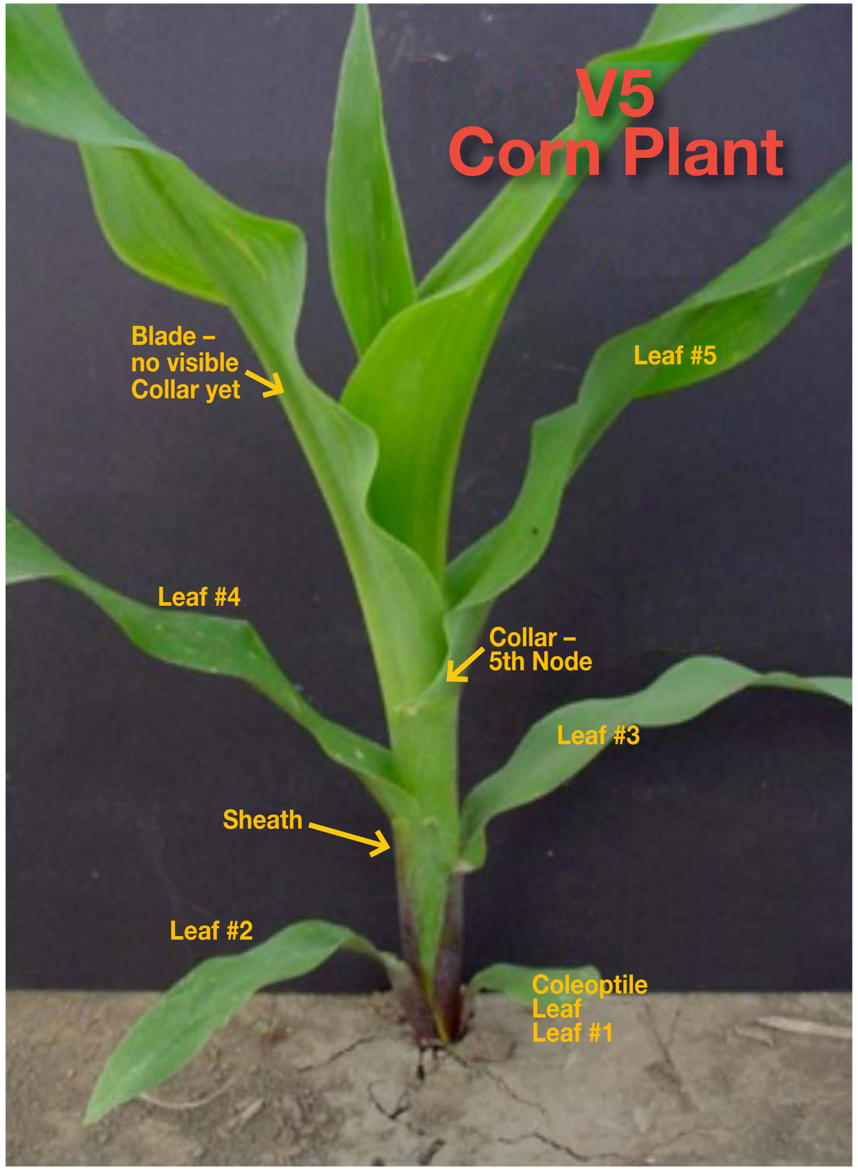
# DETERMINING CORN LEAF STAGES

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. Foliar diseases are important to monitor and reduce with fungicide applications given that a healthy ear leaf produces 70% of the photosynthate needed for ear development.

# 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


Southern Rust


Northern Leaf Blight


Southern Leaf Blight


Northern Leaf Spot


Goss's Wilt


Common Rust


Gray Leaf Spot


Tar Spot

# HAIL/WIND 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. Some plants that are severely damaged by hail may have difficulty regrowing.

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.

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 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. It is important to note that 70% of the plants photosynthetic production occurs in the ear leaf. Only leaf tissue completely removed, or brown in color, should be considered when determining the percentage of leaf area destroyed or removed.

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

## 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*

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.

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, Tar 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, lodging, and lowered fiber digestibility.

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 a three growing season 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 and be controlled 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, deliver healthier plants with higher grain (starch) content, in addition to maintaining fiber digestibility and widening/extending the harvest window. 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 right 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. Phosphorus, zinc and potassium (in dry, heavy soils) are relatively immobile in the soil and need to be available at the root level compared to more leachable nutrients such as nitrate (NO3, not ammonium-N, NH4), sulfate, boron and chloride.

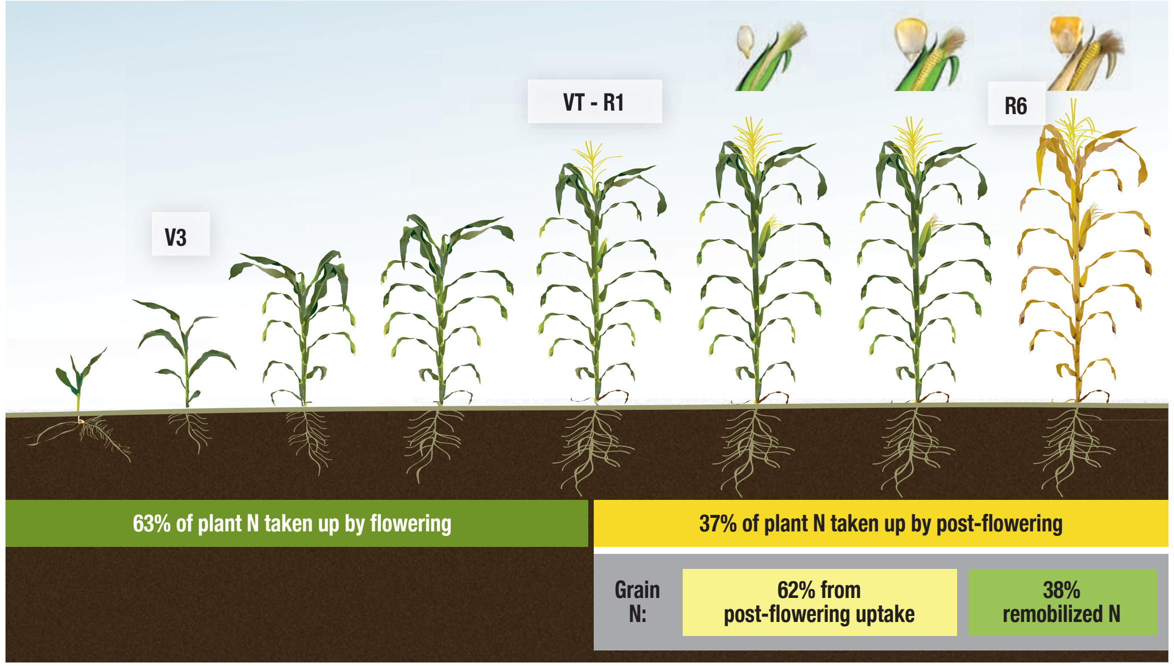
A pH between 6 and 7 along with soil moisture in the top 2-6 inches of the soil profile is needed for optimum plant nutrient availability.

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

## 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 |




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. Nitrogen stabilizers can help maintain ammonium-N (NH4) levels which is preferred by corn compared to the nitrate form which is more prone to denitrification and/or leaching. 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.

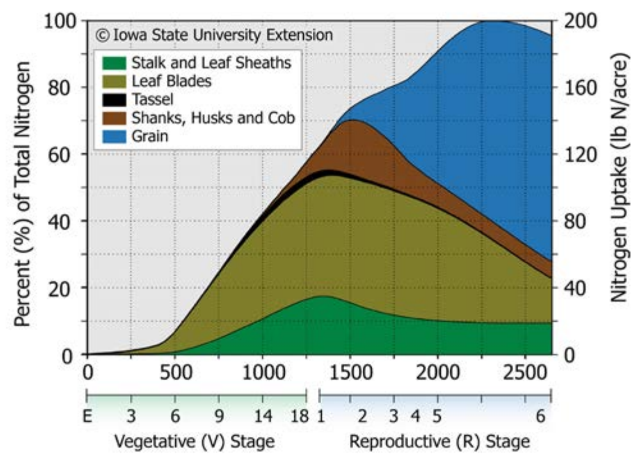
Plants are colonized by a wide diversity of microorganisms that live both on and inside plant tissue; a community of organisms referred to as the microbiome. Recent advances in high-throughput genome sequencing and several other technologies have greatly expanded the ability to study complex microbiomes.

This growing body of research on plant-microbe interactions has led to a rapid proliferation of microbial products in the crop input marketplace, all seeking to improve crop health and productivity by altering some aspect of the microbiome.

Bacterial and fungal symbionts are the most well-known and studied, but the plant microbiome can also include archaea, protists, oomycetes, and viruses.

Research thus far has demonstrated several beneficial effects that microbial symbionts can provide in crop plants, including nitrogen fixation, enhanced stress tolerance, and disease suppression.

The need for sustainable solutions for existing issues in agricultural production and to drive gains in crop yield and resilience in the coming years will continue to fuel growth in microbiome research and microbial products.






## IN-SEASON NITROGEN FERTILITY

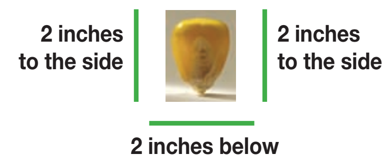
- One of the most important nutrients.
- Most prone to loss by leaching from:
  - High rainfall
  - Excessive irrigation
  - De-nitrification into the atmosphere

## 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




- 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).

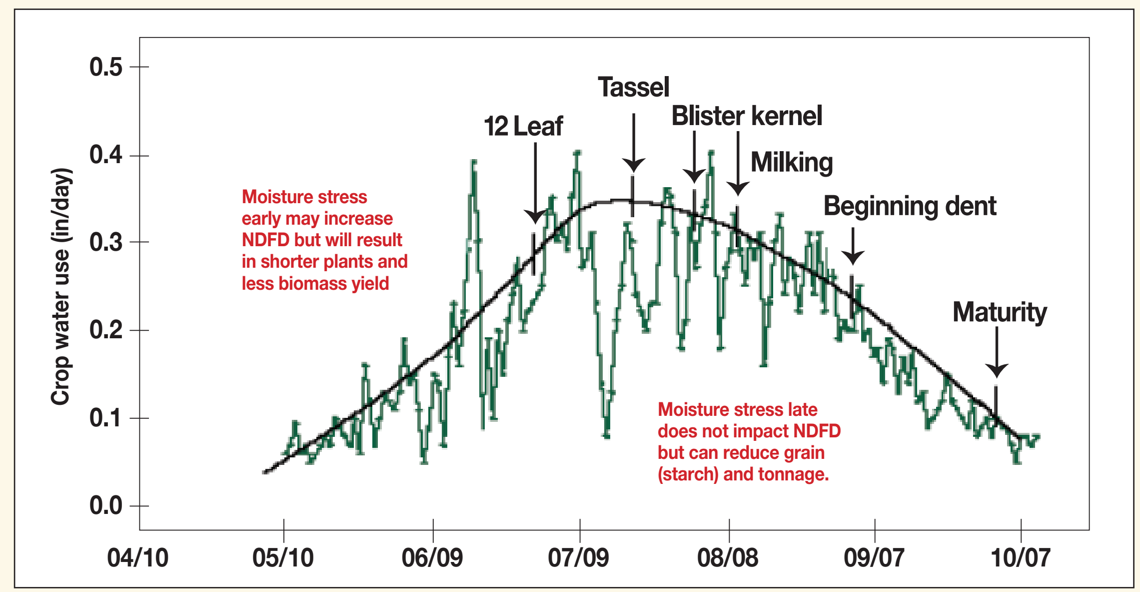
Drought can result in plants ranging from barren plants with no ears or starch content to varying levels of starch (grain) depending upon stress at pollination and subsequent kernel abortion. Energy will be partitioned more into sugar and fiber in the stalk and leaves rather than to grain. Studies conducted 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,

## CORN WATER USE

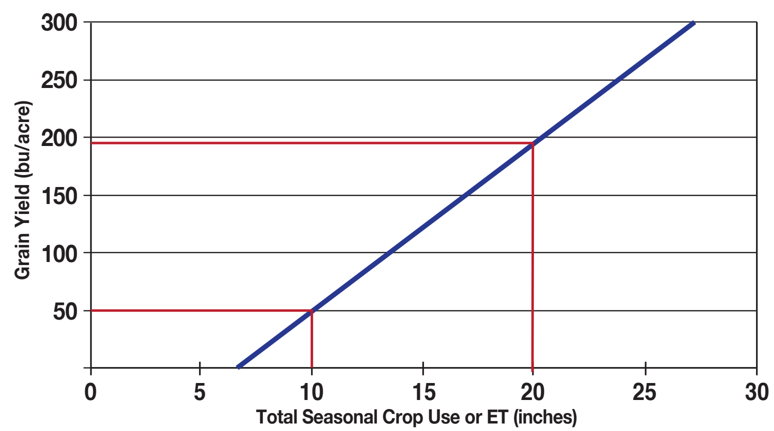
- Crop evapotranspiration (ET) is driven by the drying that the atmosphere exerts on soil/plant surfaces. For corn plants range is 0.1 to 0.4 inches/day.
    - ET is increased by high solar radiation and air temperatures, low humidity, clear skies and high wind.
    - ET is decreased by cloudy, cool 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)*

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.

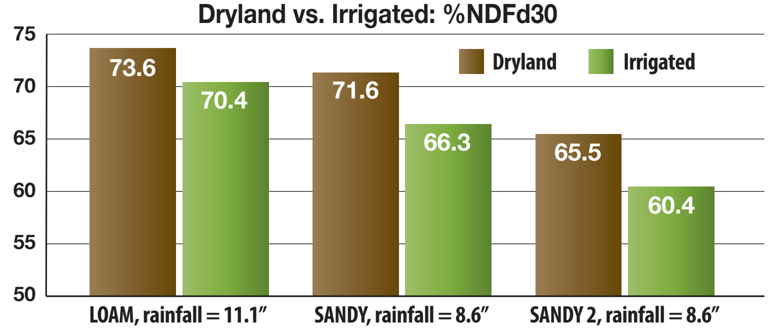
The growing conditions before and after silking (R1) affects corn silage nutritive values in different ways. In general, dry (or limited irrigation) conditions during the vegetative stages of plant growth shortens plant stature, but enhances fiber digestibility (Neutral Detergent Fiber Digestibility, 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 fiber digestibility. Fiber digestibility and plant height are fully determined by the VT stage of maturity. However, late-season disease, early frost or plant nitrogen deficiency can all result in lower fiber digestibility.

Don't be fooled into thinking that tall plants are the ones producing the most silage dry matter yields. Earlier planted corn is shorter than late planted corn but one has to consider that the grain contributes about 45-50% of silage dry matter yield and grain yield declines about 1% per day past the optimum planting window. Further, early reports are that reduced stature corn harvested as silage yields very close to the normal isogenic control due to larger leaves, greater diameter stalk and high grain yield.

## IRRIGATED CORN TENDS TO BE LOWER IN NDFD

**(high-chopping to increase NDFD may have more merit in irrigated fields)**

**Dryland vs. Irrigated: %NDFd30**

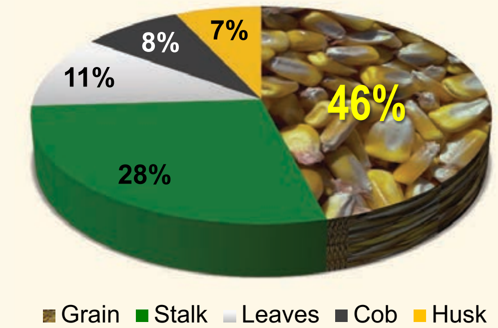



*Same hybrids sampled at VT to R1 under irrigation (irrigated) or at the pivot corners (dryland).*
*Source: Dann Bolinger, Pioneer Dairy Specialist.*

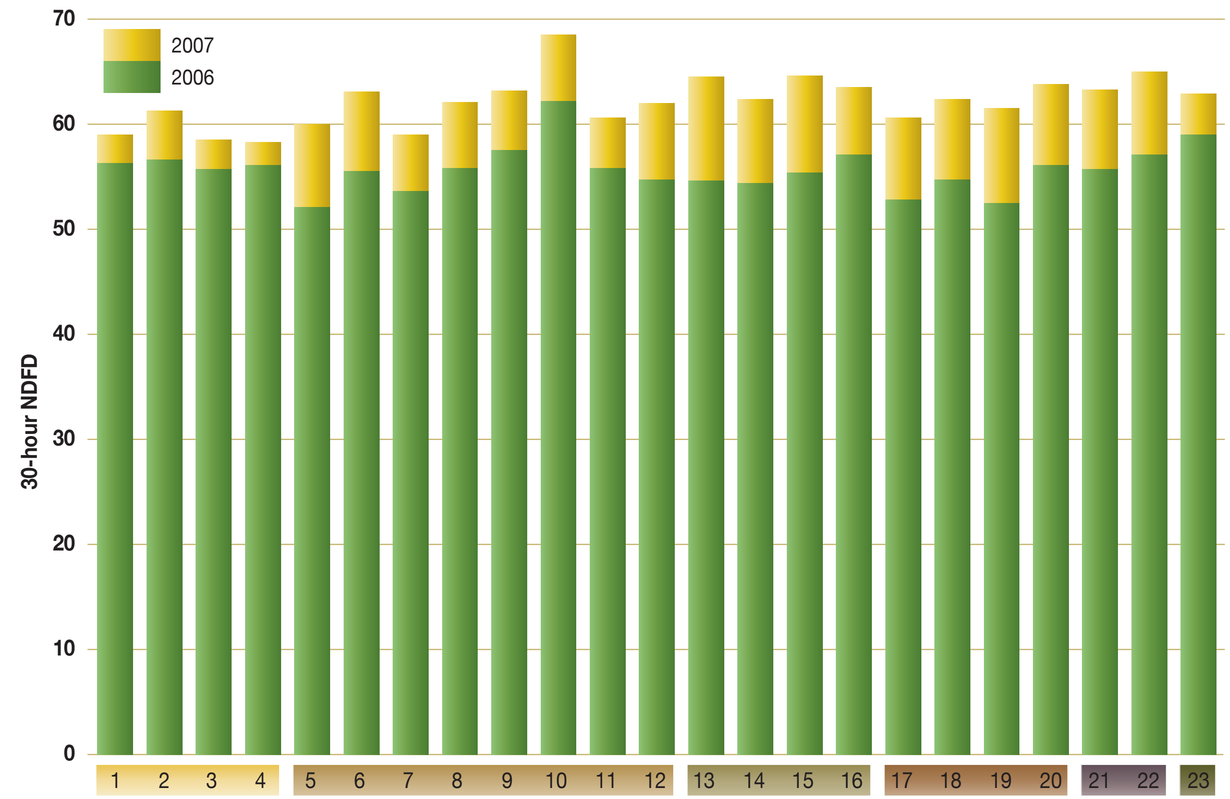
## INFLUENCE OF MOISTURE STRESS AT VARIOUS GROWTH STAGES ON CORN GRAIN YIELD

| 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% |

## GRAIN CONSTITUTES 45-50% OF CORN SILAGE DM YIELD AND 65% OF THE ENERGY IN CORN SILAGE




## 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

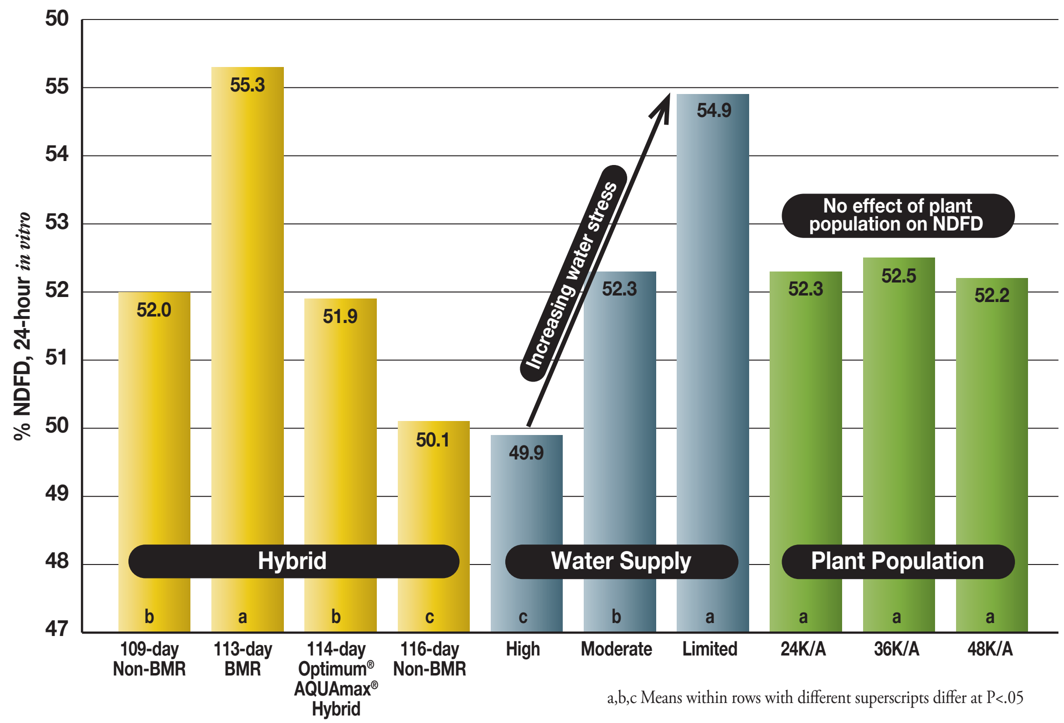
Data from Michigan State University silage plots harvested in a relatively wet growing season (2006) compared to the same hybrids harvested from the same plot in a relatively dry growing season (2007) appears in the chart on the opposing page. Hybrids averaged 6.5 points higher in 30-hour NDFD in the 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 given that starch accounts for 65% of the energy in corn silage. University and seed company research shows minimal genetic differences (3-4 percentage units) between non-BMR hybrids for 30-hour 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 (precipitation, water-holding capacity of the soil, nitrogen status) and harvest timing (1/3rd, 1/2, or 3/4 kernel milkline). 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 fiber 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.

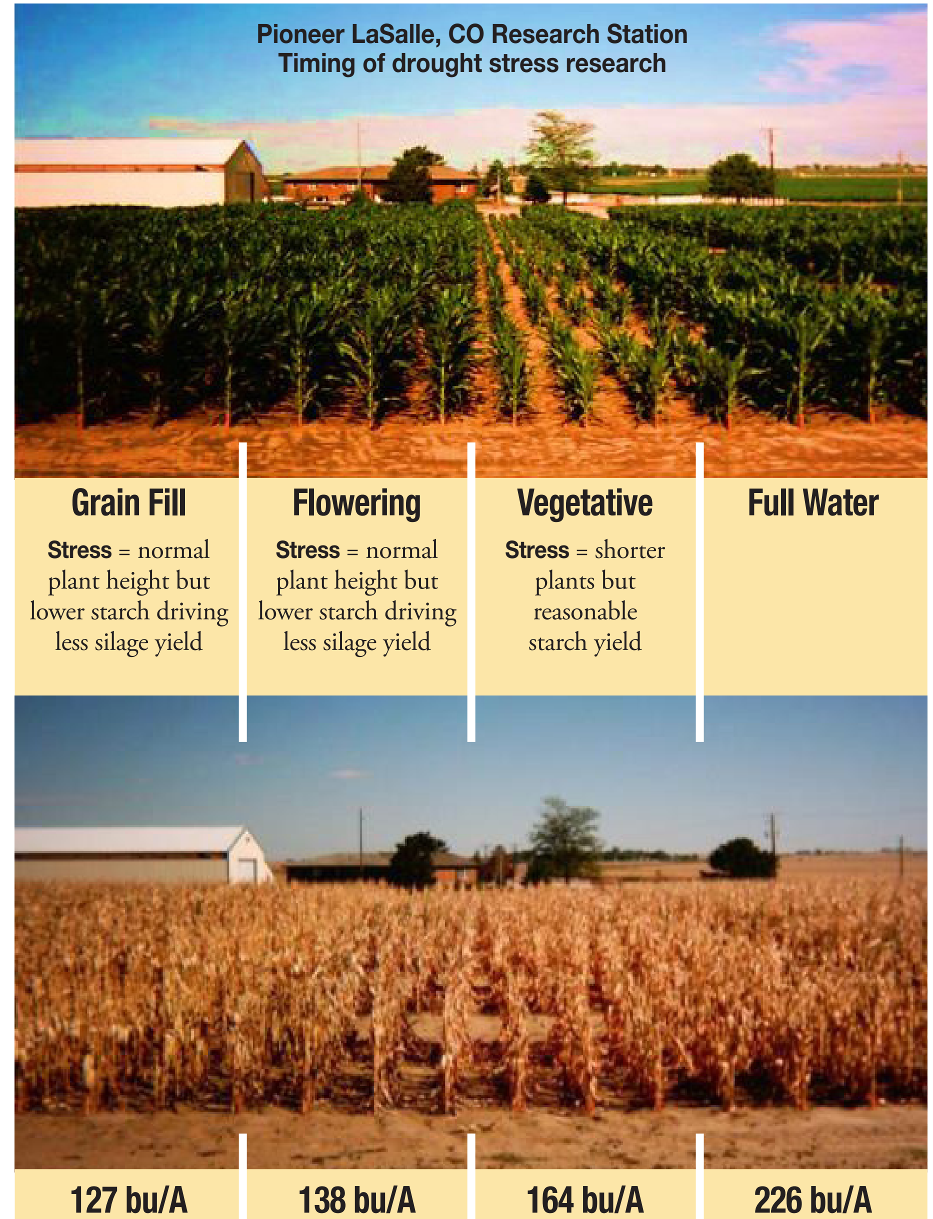
Corn breeders are very interested in the interaction between genetics and environment (GxE). If GxE (in a statistical sense) is significant, it means hybrids grown in different environments could rank differently for any particular trait. Compare this to

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

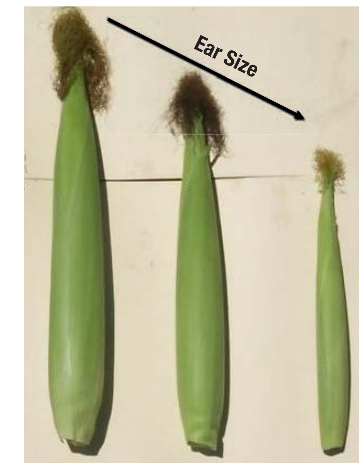


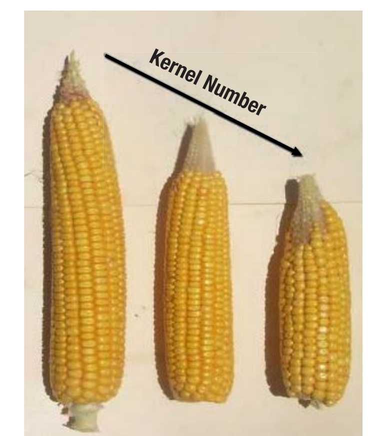

a,b,c Means within rows with different superscripts differ at P<.05

## EFFECTS OF MOISTURE STRESS








*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.*

# 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 and 65% of the energy in corn silage.
- 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.
- Minimal 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 ruminal starch digestibility.
- Very little difference in ruminal or total-tract 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 agronomics to ensure late-season plant health, disease/trait package and yield stability for your growing environment. Choose genetics that deliver high biomass yield and high starch content. 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 healthy late-season plants allowing for harvesting at 3/4 milkline without compromising NDFD), chop height and degree of kernel processing (biggest influence on starch digestibility) are the primary influencers.

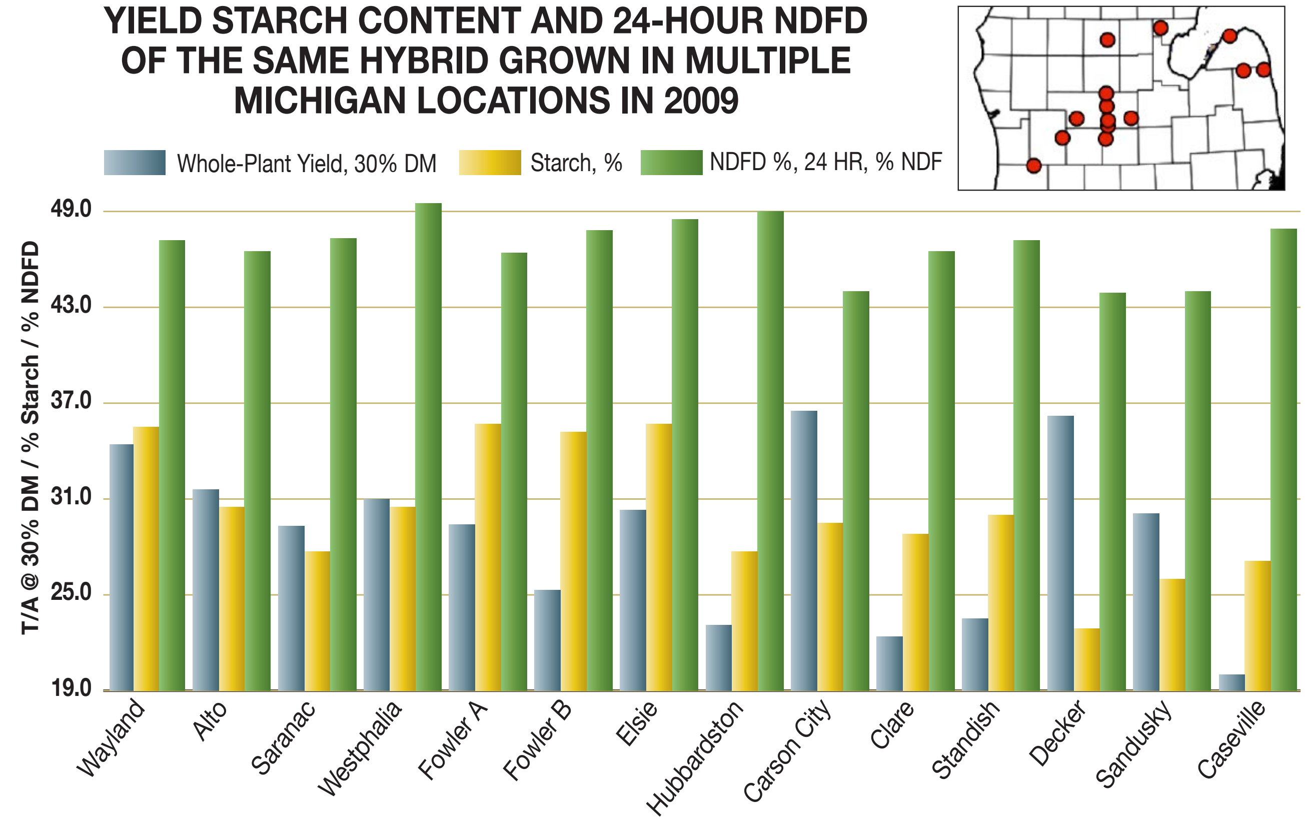


environmental influence on genetics, meaning they will rank similar across environments, but the relative magnitude of difference will depend on the particular environment. It could also indicate the absolute values will change with no change in the relative hybrid differences between environments. The 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.

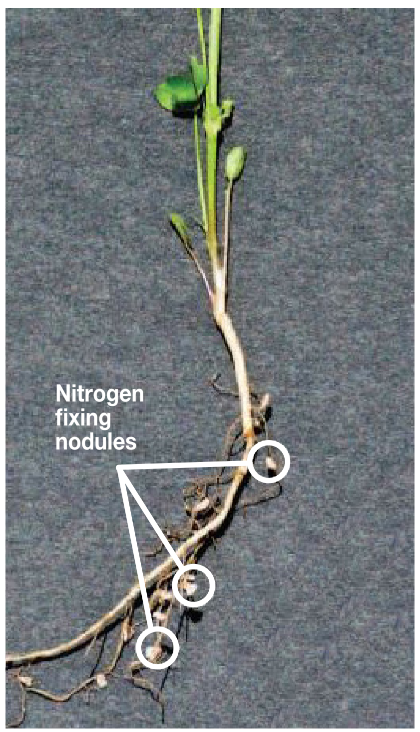
### YIELD STARCH CONTENT AND 24-HOUR NDFD OF THE SAME HYBRID GROWN IN MULTIPLE MICHIGAN LOCATIONS IN 2009




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

# ALFALFA

Alfalfa is very small with about 220,000 seeds per pound. This makes proper planting and seed placement critical to the success of a stand. Alfalfa germination and seedling emergence occur in 3-7 days depending upon soil moisture and temperature conditions. Alfalfa seed can germinate at temperatures above 37°F but optimum soil temperature is between 65-77°F. Higher soil temperatures facilitate increased metabolic activity and water movement into the seed. Under good growing conditions, the seedling is fully developed by 10 to 15 days after planting.




## ALFALFA GERMINATION AND EMERGENCE

- Begins after seeds absorb approximately 125% of their weight in water and swell, breaking the seed coat
- Ideal temperature is 65-77° F (18-25°C)

- The radicle emerges through the seed coat
- Radicle anchors itself in the soil as an unbranched taproot

- As the radicle grows, portion nearest the seed forms a hook
- Seedling emerges through the soil's surface
  - Drags cotyledons and seed coat with it
- Small root hairs develop on the lower radicle
  - Absorb water and nutrients from the soil

*Photos courtesy of University of Madison-Wisconsin*

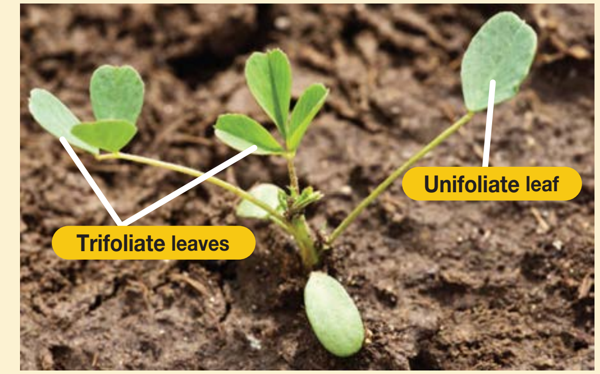
Within four weeks of germination, root hairs on the radicle become infected with a nitrogen fixing bacteria and begin to form nodules. Atmospheric nitrogen fixation occurs within these nodules, which results in the availability of nitrogenous compounds for their host plants. Only Rhizobium meliloti will infect alfalfa root hairs as other strains of the bacteria cannot infect alfalfa. Approximately 5% of alfalfa root hairs become infected with the bacteria, but only about 30% of these infections result in nodule formation. The alfalfa plant can utilize soil nitrogen should nodulation not occur as in the case of low soil pH or heavy nitrogen (manure) application during seeding year.

Within about four months, the lower-most buds have been completely pulled into the ground forming the crown. Winterhardy varieties have several nodes pulled below the soil surface in the seeding year. This is termed contractile growth and involves a shortening and widening of the cells in the upper portion of the primary root as a result of carbohydrate storage. This pulls the lower stem nodes 1-3 inches beneath the soil surface and improves winter survival of the crowns.



## ALFALFA SEEDLING GROWTH AND ESTABLISHMENT





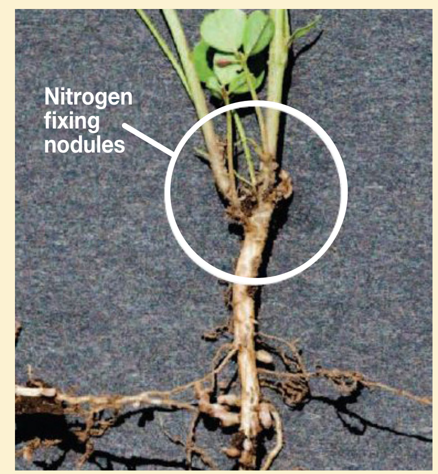

- Cotyledons are the first visible portion of an alfalfa seedling as it emerges
- The first true leaf to develop is a unifoliate leaf (one leaflet)

*Photos courtesy of University of Madison-Wisconsin*

- The second leaf to appear is a trifoliate leaf (three leaflets)
  - Some varieties produce multi-foliate leaves (four or more leaflets per leaf)
  - Leaf stages are counted by the number of fully expanded trifoliate leaves

- As leaves develop, cotyledons fall off
  - Alfalfa plant adds new shoots in their place
- At the two-leaf stage, the seedling can manufacture all of its energy through photosynthesis

## ALFALFA CROWN FORMATION AND DEVELOPMENT

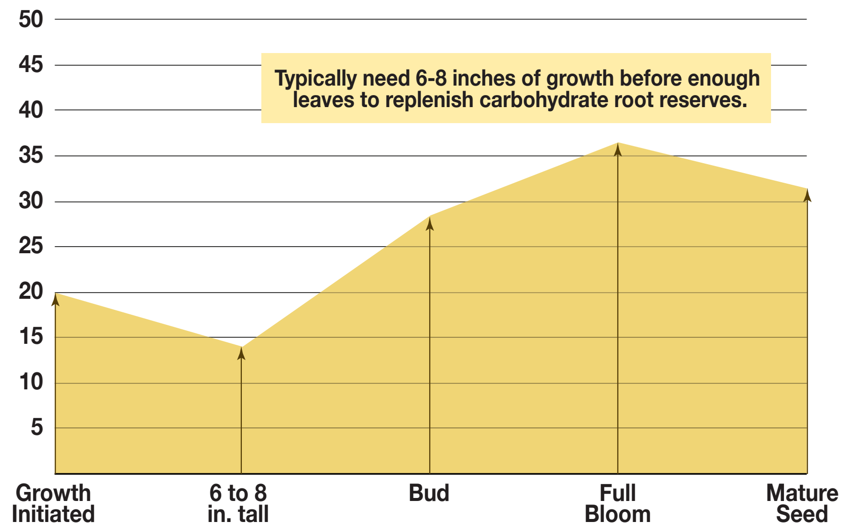



- The crown is the area between the soil surface and the cotyledonary nodes
  - Growth points
- Contractile growth pulls the lowermost axillary buds below ground to form crown buds
  - Begins as early as one week after emergence
  - Usually complete within 16 weeks
- Crown buds are formed during the fall
  - Source of growth the following spring
- Plants with deep crowns are more persistent
  - Increased soil protection from cold temperatures

**Lowermost buds have been pulled below ground to form the crown.**

Spring growth occurs from the crown buds relying on carbohydrate reserves contained in the root and crown. Following harvest, subsequent plant growth is primarily from the crown buds, but can also be from the auxiliary buds (where the leaf attaches to the stem) if cutting is high enough. Vegetative growth of alfalfa is comprised of three stages: early vegetative, mid vegetative, and late vegetative. During early vegetative growth alfalfa has insufficient leaf area to produce enough energy from photosynthesis to support growth. The carbohydrates and nutrients stored in the root and crown supply the energy needed for regrowth. When the alfalfa plant has reached approximately eight inches tall, leaf area and photosynthesis have increased. This will supply adequate energy for continued growth and replenishment of root and crown carbohydrate reserves. The maximum number of stems per plant and weight of each stem are determined during vegetative development. Important factors that impact plant growth during this stage include soil pH, fertility, moisture, and pest pressure.

## CARBOHYDRATE RESERVES IN ALFALFA ROOTS




The growing conditions during the first two weeks following harvest are critical to determining the number of stems on each plant. A high leaf-to-stem ratio results in higher nutritional value (more protein from leaves and less fiber from the stem). Leaf-to-stem ratio is lower for spring compared to summer regrowth and also declines as the plant increases in maturity from vegetative to full flower. Total alfalfa yield is a cumulative

## ALFALFA GROWTH STAGES

| MATURITY INDEX | STATE OF MATURITY |
|---|---|
| 0 | Stem length less than 6 inches |
| 1 | Stem length 6 to 12 inches |
| 2 | Stem length greater than 12 inches |
| 3 | Early bud, 1-2 nodes with visible buds, no flowers or seed pods |
| 4 | Late bud, more than 2 nodes with visible buds, no visible flowers/pods |
| 5 | Early flower, 1 node with at least 1 open flower |
| 6 | 2 or more nodes with an open flower |

*Source: Cornell University.*


Alfalfa stems representing maturity index 0-6



## ALFALFA VEGETATIVE GROWTH

### SPRING GREEN-UP

- Growth comes from crown buds formed the previous year during late summer and fall
- Occurs when the buds located in the crown begin to grow in response to warm spring temperatures
- Timing of spring green-up depends on:
  - Plant health
  - Genetic fall dormancy of the variety
  - Amount of dormancy developed in plants during fall


*Photo courtesy of University of Madison-Wisconsin*

### REGROWTH AFTER CUTTING

- Regrowth is primarily from crown buds
  - May also come from axillary buds if cutting is high
- Number of stems that develop from axillary or crown buds depends on:
  - Variety
  - Developmental stage at time of cutting
  - Health of crown
  - Cutting height
- Maximum number of stems on a plant is determined within 14 days after cutting
  - Declines as plant matures
- Stress can reduce number of stems produced during regrowth

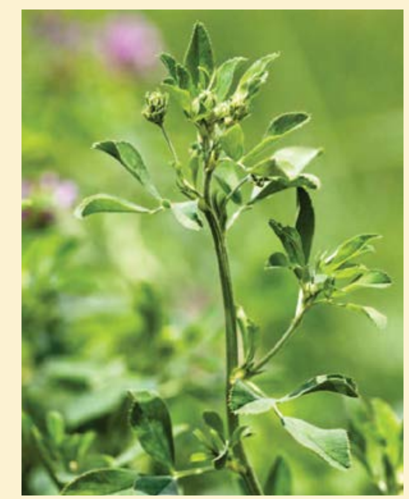
## ALFALFA BUD DEVELOPMENT

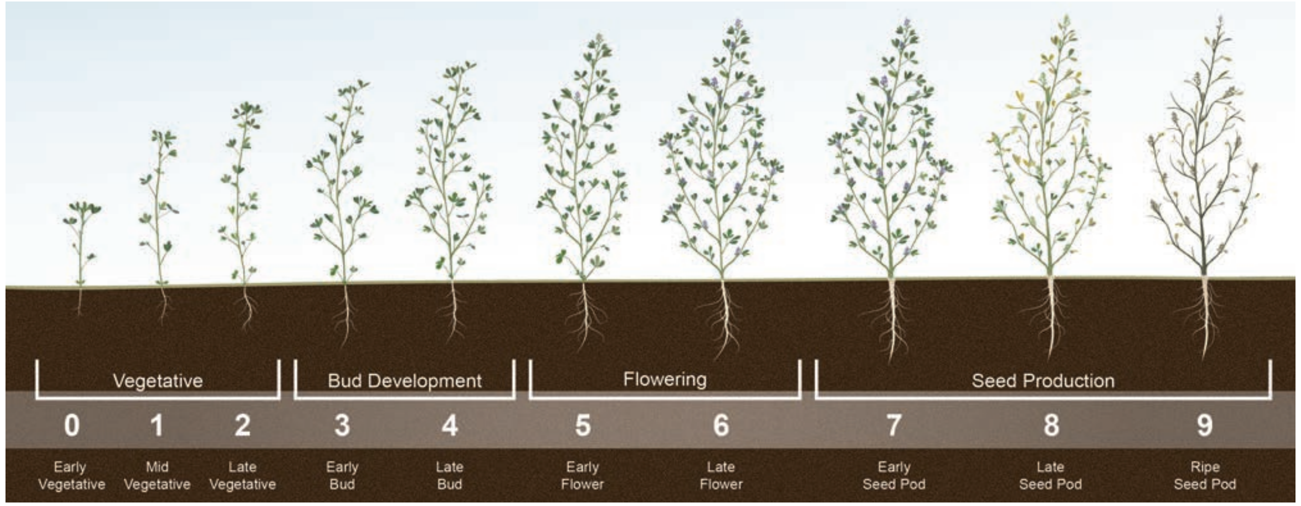
### EARLY BUD

- Buds form in the top 1 or 2 leaf axils
- Appear as small swellings in leaf axils
- Forage cut at this stage will be very high quality

### LATE BUD

- Buds begin developing on three or more leaf axils lower on the stem
- Flower buds are large and lengthen rapidly


*Photos courtesy of University of Madison-Wisconsin*

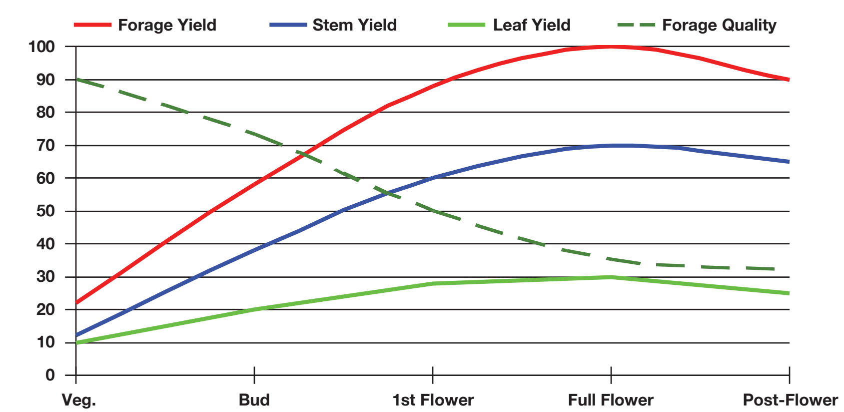



function of number and weight of each individual stem.

Shortening days and declining temperatures in the fall cause varieties to change vegetative growth patterns. This typically results in winter hardening when dormant alfalfa varieties alter their metabolism in preparation for winter by using sugar as an anti-freeze to protect the crown, crown buds and roots in soil temperatures as low as 17°F. During the winter, plant tissue below the soil surface is insulated from cold air temperatures by soil and layers of snow. Without snow cover, extreme cold may cause the soil temperature to drop below 17°F, which can kill or injure plants. Injured plants become less vigorous and are slow to recover in the spring.

The Cornell University plant growth staging scheme used in assessing stand development is shown in the accompanying charts.

## YIELD VS QUALITY AT DIFFERENT GROWTH STAGES



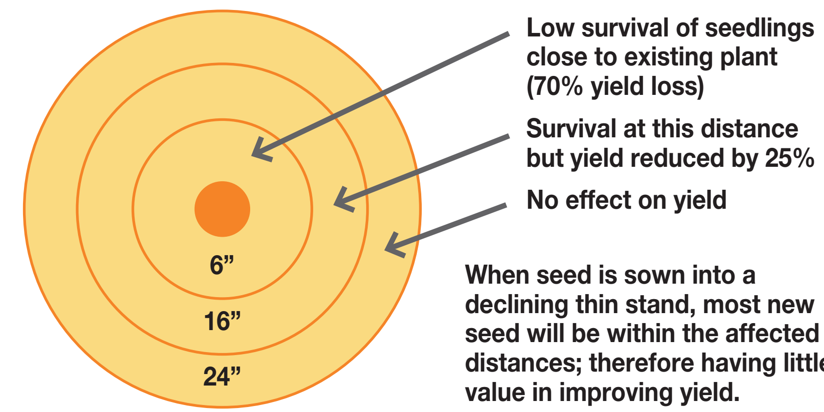

# AUTOTOXICITY

Growers are sometimes tempted to over-seed additional alfalfa into a thin stand. The problem with over-seeding alfalfa stands over one year old with additional alfalfa seed is autotoxicity. Alfalfa plants exhibit autotoxicity designed to reduce competition by the production of chemical compounds which are toxic to other alfalfa plants. When an alfalfa stand is killed by winterkill, spraying or plowing, these compounds are released into the soil. The result is arrested root development in new alfalfa seeds planted into the same field. The length of time these alfalfa-toxic compounds are active is influenced by soil type (more tightly bound in heavy soils), temperature (warmer soils speed microbial degradation), rainfall (more rain facilitates leaching) and tillage practices (plowing helps dilute and reduce levels). Research conducted at the University of Missouri showed significant yield loss when new seedlings were planted within the 8-16 inches of an existing plant.

The degree of autotoxicity is directly related to the amount of time between killing the old stand and establishing the new stand. The University of Wisconsin suggests the best way to avoid autotoxicity is to rotate to some other crop for at least a year before seeding the same field back to alfalfa. All other options can lead to potential yield losses in the newly established stand. If alfalfa directly follows alfalfa, it is advised, at a minimum, to kill the established stand in the year (fall) prior to (spring) seeding. If alfalfa is planted in the same year in which the established stand was killed, a late-summer seeding is the best option. Planting alfalfa into an established, but poor stand in an effort to enhance yield potential is not recommended.

However, for failed spring seedings, growers can re-seed to alfalfa immediately.

## AUTOTOXICITY IN ALFALFA ZONE OF INFLUENCE




# FERTILITY

A soil test should be used to determine fertility needs before ground preparation. Phosphorus (P) is critical for healthy root development and potassium (K) is needed for high yields. If needed, broadcast and incorporate lime, P and K for new seedings.

Alfalfa has a high requirement for nitrogen because it is high protein forage. There is no need to apply nitrogen fertilizer because rhizobium bacteria fix nitrogen from the air in root nodules. Soil pH levels above 6.5 provide the best environment for nodule bacteria to fix nitrogen. Alfalfa has a high requirement for potash ($K_2O$), and high yields require maintenance applications in most soils. Try not to exceed 200 lbs $K_2O$ per application to avoid luxury consumption. It is not recommended to seed alfalfa-grass in fields where soil test potassium levels are medium to low. While the initial stand may perform well, once the grass becomes established their root system will take up potassium to the detriment of the alfalfa.

Response to potassium is unlikely when soil test for $K_2O$ exceeds 150 ppm. Response to phosphorus is unlikely when soil test for P exceeds 15 ppm. Sulfur deficiency is becoming more common with reduced environmental sulfur emissions. Sulfur levels should be closely monitored in high yield situations, particularly in low organic matter soils. Alfalfa may also respond to annual applications of boron, especially in lighter-textured soils. Soil fertility research has shown a tremendous effect on alfalfa yield and persistence, however, there does not appear to be much of an effect of fertility on alfalfa nutritional quality.

## ALFALFA NUTRIENT REMOVAL RATES

| NUTRIENT | POUNDS PER TON OF ALFALFA DRY MATTER | YEARLY REMOVAL 4 TON DM YIELD | YEARLY REMOVAL 6 TON DM YIELD |
|---|---|---|---|
| Nitrogen | 60 | 240 | 360 |
| $P_20_5$ | 12 | 48 | 72 |
| $K_20$ | 60 | 240 | 360 |
| Sulfur | 5 | 20 | 30 |

# MANURE

The primary concern with manure applications to established stands is damage from equipment and from the manure, not due to excess nitrogen. High yielding alfalfa has the capacity to buffer high amounts of nitrogen in manure. University of Missouri extension suggests each ton of harvested alfalfa can contain 50 pounds of nitrogen and in low nitrogen soils most of the alfalfa nitrogen will be derived from plant nodules fixing nitrogen. However, there is an energy benefit to the alfalfa plant to use nitrogen from the soil in preference to fixing nitrogen from the atmosphere. Alfalfa plants that have access to manure nitrogen will reduce fixation and preferentially use the alternative nitrogen supply. Be cognizant of over application of phosphate ($P_2O_5$) and potential for weed seed when manure is a high proportion of the fertility program.

Alfalfa plants can be damaged by high salt or ammonia concentration in the manure, by physical damage to the crowns by application equipment or by water deficits induced by high salt concentrations in the manure. The greatest danger is from slurry or solid manure that is applied with large equipment. Lagoon water from unagitated lagoons typically possess less risk because nutrient and salt concentrations are lower. It is recommended to apply manure immediately after cutting alfalfa and before budding on the alfalfa crowns. The alfalfa plant is less vulnerable to salt damage when no green leaves are showing. This is particularly important for surface applications of slurry.

# WEED CONTROL IN ESTABLISHED STANDS

A dense canopy of alfalfa and a frequent cutting schedule will tend to keep most weeds in check. However, some weeds begin growth when alfalfa is dormant, including winter annual broadleaves like chickweed, henbit, mustard species, and cheatgrass in the plains and western states. There are several options for controlling weeds in established stands, including herbicides which can be applied in-season or during the dormant period. Some herbicide options have long residuals. Carefully consider weed species and rotational restrictions when making a herbicide selection for an older stand. Using a glyphosate resistant alfalfa variety along with glyphosate herbicide often provides the most flexibility for timing of applications and is frequently the most economical system for maximizing yield, quality, and stand life. To maximize the benefits of glyphosate resistant alfalfa, glyphosate should be applied to seedling alfalfa at the 3 to 5 trifoliate stage when weeds are less than 4 inches tall. If weed problems persist, an additional application of glyphosate can be made up to 5 days prior to harvest. Even if there are no weeds, a glyphosate application is necessary at the 3 to 5 trifoliate stage to remove the small (~5%) percentage of glyphosate susceptible alfalfa plants that are present in the new seeding.

# DISEASE AND INSECT CONSIDERATIONS

Alfalfa growers should place considerable emphasis on selecting alfalfa varieties with disease resistance relative to where the crop will be grown. The major diseases for which seed companies provide resistance ratings include stem and crown diseases, anthracnose; wilting diseases, (bacterial wilt, Fusarium wilt and Verticillium wilt); and root rot diseases Phytophthora and Aphanomyces (Race 1 and Race 2). Root rot diseases can be important selection criteria in heavier soils; therefore it is important to understand the soil type and drainage in fields where alfalfa is planted.

Alfalfa weevil larvae, potato leafhopper, aphids and other pests can limit yield, quality and regrowth of alfalfa stands. The potato leafhopper (PLH) is the most impactful alfalfa insect pest in the eastern half of North America. There is no reliable method to forecast damage, so scouting fields and using a sweep net is the only effective method to monitor PLH activity. Once visible symptoms of hopperburn and plant stunting become evident, it is too late for corrective action. The greatest impact on the crop is yield reduction. Severe damage can reduce crude protein content, taproot carbohydrate reserves and plant regrowth. Harvesting can help reduce egg, nymph and adult populations, and harvesting severely damaged alfalfa stands may be the only method to initiate regrowth of stems.

If scouting and spraying is not controlling



leafhoppers, then planting a leafhopper-resistant variety is a logical choice. The threshold for spraying a leafhopper-resistant alfalfa variety is about three times that of non-leafhopper resistant alfalfa. New seeding of a leafhopper-resistant variety should be scouted and managed similar to a non-leafhopper-resistant variety. As a thumb rule, spraying is justified when leafhopper counts per ten sweeps of a sweep net exceeds the average plant height in inches. For example, if a field has eight inches of regrowth and ten representative sweeps yield 16 leafhoppers, spraying is justified since leafhopper count exceeded plant height in inches. If the field was planted to a leafhopper-resistant variety, a leafhopper count three times the plant height is the threshold to consider spraying; or in this example at least 24 leafhoppers per ten sweeps.

Completing the list of most important pest resistance ratings are aphid and nematode resistance. These are not considered major problems in the Midwest, or the Eastern U.S. and Canada, but are a more significant problem in Western alfalfa production regions.

# FUNGICIDES

The approval of several fungicides for use on alfalfa has spurred interest in this management tool to help reduce stem and leaf diseases, allowing for higher harvestable yields. The response to fungicides in university and industry trials has been very inconsistent across locations and cuttings. Despite the lack of consistent and statistically significant results from small-plot research, farmer testimonials seem to suggest many producers are observing a positive response to fungicide application. Even though grower ability to measure small differences in yield may be challenging, it appears that many growers are convinced of the economic advantage of fungicide treatment given it only requires about 0.1 to 0.2 tons per acre of added yield to justify the price of fungicide and application when the crop is selling for upwards of $200 to $250 per ton.

The required yield improvement necessary to justify fungicide use is also less if growers are adding it to tank mixes of insecticide that they are already applying to control leafhoppers. Positive grower observations may also be the result of greater variability in their production-sized fields compared to smaller, replicated research plot studies in terms of canopy humidity levels, fungal loads, trash content and less than optimum soil environments (low pH, low fertility, poorly drained soils) across larger acreages. Fungicides appear to offer most benefit in wet growing seasons and a heavy crop when it is common to see leaves at the bottom of the plant yellowing and falling off. Application in the fall may improve plant health to help stands weather the winter. Fungicides should also be more beneficial in stands which are harvested at later stages of maturity and thus more susceptible to greater leaf drop. Producer testimonials and company literature suggest early application to 6-8 inch tall alfalfa to prevent fungal growth rather than thinking later maturity applications will eliminate disease problems after they have become established.

# YIELD AND NUTRITIONAL IMPACT OF GROWING ENVIRONMENT

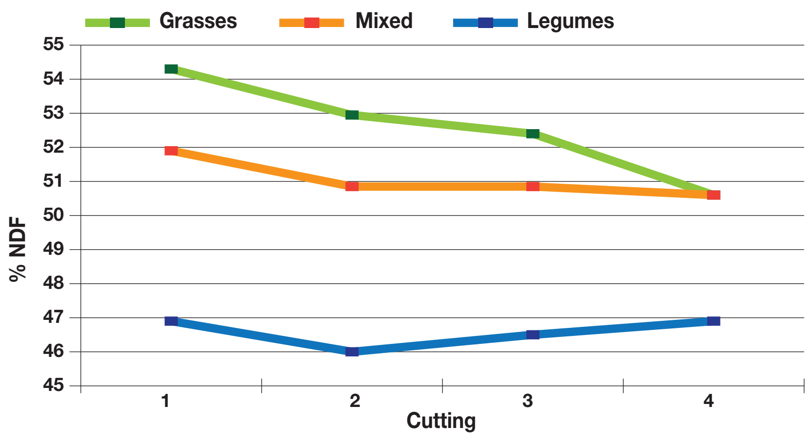
Alfalfa genetics play a relatively small role in nutritional quality differences. Rather, it is growing environment and harvest maturity that are the biggest drivers. It is well documented that environmental factors have a smaller effect on quality than on yield. Most factors that limit plant development (e.g. drought, cold weather) tend to reduce yields but promote higher quality through altering leaf : stem ratio. A higher leaf : stem ratio is nutritionally advantageous (if they are retained through harvest) because alfalfa leaves contribute over 90% of the plant protein as well as exhibit high NDFD compared to the stem.

Growing conditions which can negatively impact yield include low temperatures without snow cover, winter freezing and thawing, ice sheeting, low soil moisture levels, and spring desiccation of developing shoots and stems. The biggest environmental factors influencing alfalfa yields are temperature, water deficiency, solar radiation, and soil fertility a distant fourth. Growing conditions that promote the highest alfalfa quality are long day lengths, cool nights and moderately dry weather. Warm, wet weather tends to produce the poorest quality alfalfa. Cool, wet growing conditions produce high quality alfalfa due to low NDF and low lignification. However, getting the crop harvested in these conditions can be a challenge with harvest delays resulting in advancing plant maturity. Cool, wet conditions also increase the potential for higher respiration or leaching losses and fermentation/spoilage problems from increased exposure to soil-borne fungi and bacteria.

Solar radiation (light) is the only environmental factor promoting both yield and quality because light promotes carbohydrate production. Shortening photoperiod in the fall has a negative effect on digestibility but is somewhat offset by cooler temperatures. Cloudy weather reduces photosynthesis causing low sugar and mobilization of nutrients resulting in higher proteins; both of which limit pH decline if the crop is harvested as silage. There are also more 5-carbon pentose sugars in fall harvested alfalfa further contributing to the fermentation challenge of producing 3-carbon lactic acids. Drought conditions reduce yield, but the resulting stunted, yet leafy plants are generally higher in protein and digestibility due to the higher leaf : stem ratio. The digestibility advantages would be greater if not offset by increased lignification due to high temperatures that typically accompany drought conditions.

Temperature accelerates plant development. Warm weather accelerates NDF development and lignification (every 1°C increase in temperature will generally decrease digestibility of forages 0.3-0.7 percentage units). High heat units experienced by the crop following first cutting is why second cutting in North America tends to be lower in NDFD than first or subsequent cuttings. This is also the reason why forages produced in more northern latitudes or higher elevations (cooler nights) tend to be of higher quality. In the spring, light and temperature are positively correlated until June 21, after which light decreases and temperature increases, reducing alfalfa quality. Fall growing conditions are characterized by declining temperatures and decreasing day length and light which are favorable for producing higher quality alfalfa.

## NDF DIGESTIBILITY (30-HOUR) BY CUTTING




*Source: 30-hour NDFD data from legumes (13261 samples), mixed grass/legumes (10158 samples), and grasses (2407 samples) analyzed by NIR at Cumberland Valley Analytical Services*


# 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. Typical chop length for corn silage in North America is about 19mm. Recent research from the Miner Institute indicates that corn silage chop length over 22mm will prolong eating time without providing any significant improvement in buffering the rumen (rumination stimulation). 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.

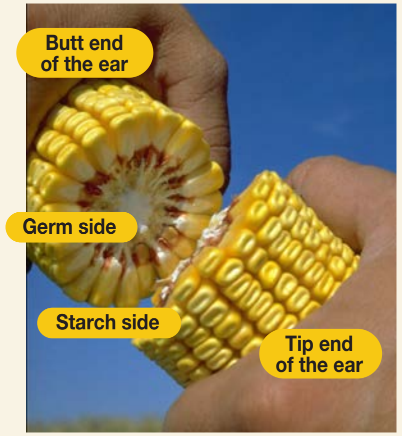
It is common for the corn plant to dry down in the fall about 0.5-1.0 points of moisture per day, depending on drying conditions. It is also common for corn silage to deposit 0.5-1.0 points of starch per day until the kernel reaches physiological maturity at black layer. Starch deposition is what is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

### PROGRESSION OF MILK LINE DURING R5 (DENT) STAGE

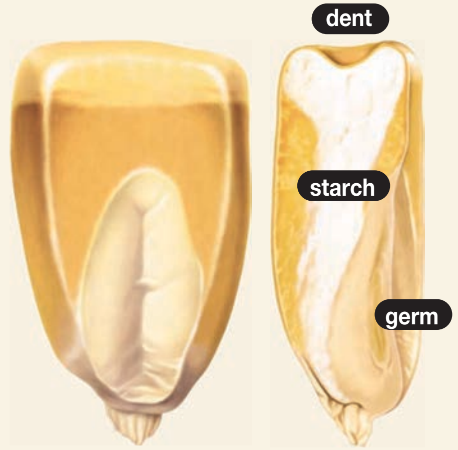
| R STAGE | % KERNEL MOISTURE | KERNEL DRY MATTER ACCUMULATION (% OF TOTAL DRY WEIGHT) | AVERAGE PER SUBSTAGE GDU | AVERAGE PER SUBSTAGE DAYS |
|---|---|---|---|---|
| 5.0 | 60% | 45% | 75 | 3 |
| 5.25 (1/4 milk line) | 52% | 65% | 120 | 6 |
| 5.5 (1/2 milk line) | 40% | 90% | 175 | 10 |
| 5.75 (3/4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

© Iowa State University Extension

### 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.



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 plants that dries down corn silage. The stalk retains considerable moisture even in droughted or hailed-on corn. Without starch deposition to dry down the biomass, whole-plant moistures are unexpectedly high in these growing conditions. 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 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.

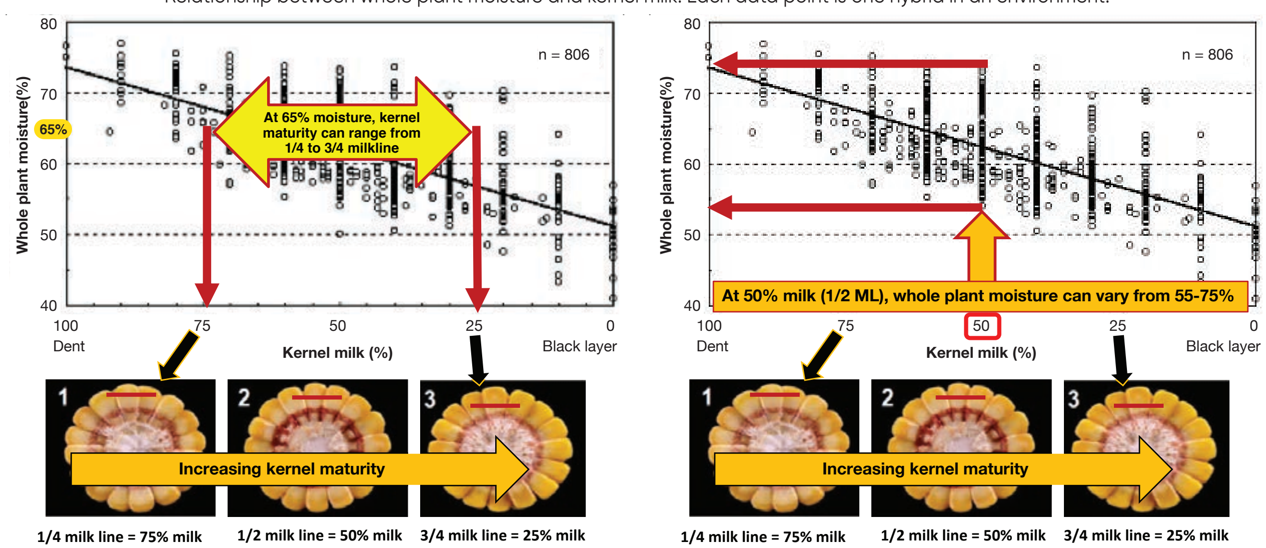
Overall, this supports the idea that both kernel milk line and whole plant DM should drive the time to start harvesting silage. And secondly, high chop decisions to potentially improve NDFD should be based on stover DM and the amount of dead tissue (perhaps of the lowest foot of the plant in particular)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

## 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*



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.

## AS A HEALTHY PLANT MATURES...

**(Based on Michigan data from silage hybrids yielding 23-30T/A at 35% DM)**

For every 1 percentage point increase in corn silage DM:

- 0.6% more starch in corn silage
  - translates to 5 bu/acre of dry grain equivalent
- 0.3 tons/acre at 35% DM
- 0.2% units lower NDFD30

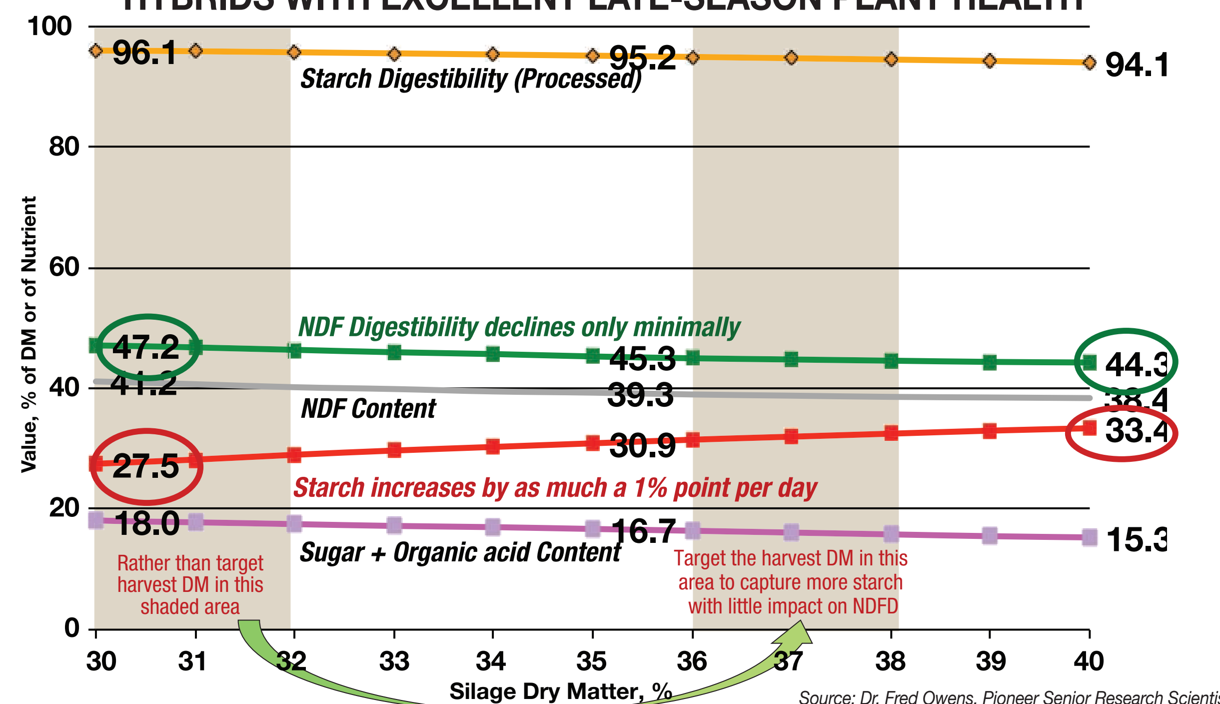
**Not biologically significant to the cow's entire diet**

Potential results, **with no additional input expenses**, of increasing harvest DM from 32% to 37% (5-7 days) because the plant was healthy:

- **3% points more starch**
  - translates to 25 bu/acre of dry grain equivalent
- 1.5 more tons/acre at 35% DM
- **1% point lower NDFD30**

*Source: Dann Bolinger, Pioneer Dairy Specialist*

## 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).

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.

Remember that fiber digestibility is basically determined by the growing environment the plant receives during the vegetative stage. Growers could conceivably predict NDFD at harvest by sampling plants and analyze for NDFD around VT or R1 stage of maturity. Doing this on a yearly basis can create a baseline to assess if the harvested crop will be below, above or average for fiber digestibility.




# 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%, but many dairies have fecal starch levels 1% or less. 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).

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 30-50%).


**Pioneer Corn Silage Processing Monitoring Cup**

# 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.

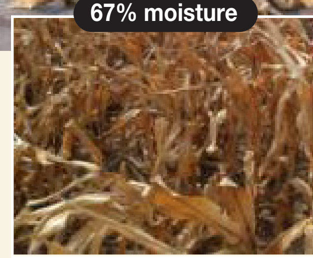
Green, barren stalks will typically be much wetter than they appear in the field containing upwards of 75 to 90% moisture because there is no grain to dry down the moisture contained in the stalks. It is recommended to sample plants and conduct dry matter tests at a laboratory, with a microwave or Koster® 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. During normal growing conditions with healthy plants, the kernel milkline is the best indicator to determine the proper time to chop, but given the variability in droughty corn, whole-plant sampling is still the best approach.

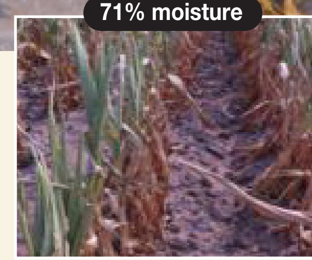
Drought can result in the crop ranging from barren plants with no ears or starch to varying levels of starch (grain) depending upon stress at pollination and subsequent kernel abortion. It is important to realize that starch deposition is the primary driver of lowering the moisture in the chopped plant. 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.

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


**Whole plant samples from Colorado harvested on 8/14/12 demonstrating high whole plant moistures in severely drought stressed and hailed-on plants due to a lack of ear development which normally serves to dry down moisture contained in the biomass (in this case, moisture in the stalks).**

# 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 grain 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 $^1/_3$ to ½ milk line maturity will typically be

**Frosted Corn**

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.

Research at the W.H. Miner Institute investigated the impact of frost and subsequent mold/fungal growth on NDF digestibility. They used corn that experienced a hard frost which killed much of the top third of the plant. The crop remained in the field for another week until it dried down enough to harvest and during that time, experienced significant mold/fungal growth on the damaged portion. Frost and resulting fungal deterioration of corn leaves resulted in a 6% unit drop in NDF digestibility (30-hour) and 5% unit increase in uNDFom30 compared to the lower, healthy green leaves. The frost and subsequent mold/fungal growth not only reduced the energetic value of the crop but also decreased intake potential by the increased uNDF. The researchers concluded that NDFD and uNDF is influenced by more than just hybrid selection or crop maturity at harvest, but also by any anti-nutritional factors such as of the quality of growing season, presence of weeds and pest or fungal damage.

# HIGH-MOISTURE CORN

The term "high-moisture corn" (HMC) can technically be applied to any corn harvested above traditional combining moistures and then allowed to ferment in the storage structure. It can range from as low as 22-24% kernel moisture recommended in sealed, upright storage structures to as high as 30-36% kernel moisture for bunker stored snaplage. High-moisture corn can be harvested with a combine (high-moisture shelled corn), with a corn picker or combine with some of the cob retained (high-moisture ear corn or earlage) or as snaplage (ear and husk harvested with a forage chopper retrofitted with a snapper corn head). There has been increased interest in snaplage due to the cost savings compared to harvesting with a combine and having to process kernels (e.g. tub-grind) at the storage structure.

To capture the most starch per acre, high-moisture corn harvest should not begin until the kernels have reached black layer and are physiologically mature. For most hybrids, kernels will be between 34-36% moisture at black layer. It is preferred to reference kernel moisture when making earlage (HMEC) or snaplage harvest recommendations because most growers own a kernel moisture tester and the final product may have varying amounts of cob or husks which impact moisture levels. The cob carries in more moisture than the kernel with the traditional thumb-rule that the final mix of earlage or snaplage will be about 3-4% units wetter than the kernel (based on ears in modern genetics being about 10-12% cob).

Targeting kernel moisture levels of 28% or greater generally results in a product that seems to work best in terms of both storage fermentation and ruminal starch digestibility. Nutritionists will need to be cognizant that ruminal starch digestibility in HMC (>28% kernel moisture) will increase over time in fermented storage due to solubilization of the zein proteins surrounding the kernel starch granules. This is especially important to consider if transitioning cows from drier HMC to a product with higher kernel moisture. This also occurs in corn silage but that plateaus after about 6 months because kernels in corn silage are less mature than kernels in HMC. Typically about 70% of the starch will be ruminally degraded in wetter HMC and this will increase by about 2% units per month, stabilizing after about 12 months of storage. HMC ensiled at <24% moisture will typically not increase in starch digestibility due to the ensiling process. There is limited research into ruminal starch digestibility in HMC that is stored as whole kernels in oxygen-limiting structures. A small field trial by Pioneer nutritionists suggests that the low moisture and intact pericarp in this type of HMC causes it to feed much more like dry corn that typical HMC.

## ADVANTAGES OF HIGH-MOISTURE CORN INCLUDE:

1. Earlier harvest that fits well between corn silage and dry grain.
2. Increased yields of 9-12% per acre if also harvesting the cob.
3. Potential cost savings compared to harvesting dry corn and processing at the storage structure.
4. Higher ruminal starch availability compared to dry corn.
5. Additional source of digestible fiber if cobs and husk are harvested in a timely manner.

## DISADVANTAGES OF HIGH-MOISTURE CORN ARE:

1. Fermentation and feedout losses.
2. Potential for the corn crop to get overly-dry reducing digestibility and palatability.
3. Higher inventory carrying cost.
4. More inconsistent than dry grain because of changing starch digestibility over time in storage. If the corn crop gets too dry (e.g. kernel moistures <25%), problems start to mount in terms of reduced cob digestibility in earlage and snaplage, fermentation issues and potential instability in the feed bunk.
5. Due to high ruminal starch digestibility, HMC may not be the ideal compliment in high corn silage-based diets. Dry, ground corn, with a lower ruminal digestion rate, may be a better option given it has not gone through a fermentation process which solubilizes zein proteins and increases rumen bacterial access to starch granules.

## KERNEL, COB AND HIGH-MOISTURE EAR CORN (HMEC) MOISTURE CHART

| KERNEL MOISTURE | COB MOISTURE | HMEC MOISTURE |
|---|---|---|
| 26 | 48 | 28.4 |
| 28 | 48 | 30.4 |
| 30 | 50 | 32.4 |
| 32 | 53 | 34.5 |
| 34 | 55 | 36.5 |
| 36 | 57 | 38.5 |
| 38 | 59 | 40.5 |
| 40 | 60 | 42.4 |

*Source: University of Minnesota calculated assuming 12% cob.*

## HIGH-MOISTURE SHELLED CORN (HMSC) VOLUME AND WEIGHT

| HMSC MOISTURE % | BUSHELS PER TON | WET LBS PER BUSHEL |
|---|---|---|
| 22 | 32.8 | 61.0 |
| 24 | 31.9 | 62.6 |
| 26 | 31.1 | 64.3 |
| 28 | 30.3 | 66.1 |
| 30 | 29.4 | 68.0 |
| 32 | 28.6 | 70.0 |
| 34 | 27.7 | 72.2 |
| 36 | 26.9 | 74.4 |

*Source: University of Minnesota*

## VALUE OF COB AND HUSK

Earlage and snaplage energy values can vary from one operation to another due to differences in the amount of cob and husks contained in the feed. Wetter, greener hybrids usually do not harvest quite as cleanly and tend to have higher husk content which can dilute the feed and lower the energy content.

Pioneer conducted a snaplage field study to evaluate the yield and nutritional content of four hybrids harvested at four different maturities. It demonstrated that cob digestibility declined by nearly 20% from over the four week harvest window. Husk and shank also declined somewhat with increasing ear maturity, but remained relatively high across all harvest periods. Maintaining cob digestibility is yet another reason for targeting earlage or snaplage harvest at kernel moistures exceeding 28 percent (or ideally very soon after kernels reach black layer).

Snaplage is not a particularly attractive product when viewed the first time due to the presence of "stringy" husks. It is definitely more difficult to get husks in snaplage chopped as fine in corn silage primarily because only ears are feeding into the chopper. There is space between the ears and they are not held tightly against a crop mat or the shear bar. There is also no way to control which direction the ears enter the cutter head. Obtaining desired chop length is easier with silage due to the thicker crop mat and nearly all of the ears enter the feed rolls with the stalk perpendicular to the shear bar.

There are several ways the forage chopper can be modified to reduce the husk particle size:

1) set the chopping length as short as possible to slow the feed rolls down,
2) use different drum bottoms with a key stock welded every two inches perpendicular to the knives (depending on the manufacturer) to help cut the feed going through the chopper, or
3) add a re-cutter screen behind the knife drum before it enters the processor, however, this will slow down the crop flow.

## KERNEL DAMAGE

Nutritionists have learned to pay close attention to the particle size of kernels in corn silage or in dry, ground corn (corn meal). The same attention needs to be paid to particle size of high moisture corn. Typical kernel particle size goals with HMC are 800-1200 microns, with a small standard deviation desirable to prevent either excessive fines or excessive large particles. It is equally important that grain particle size be monitored in earlage/snaplage. Pioneer has developed an earlage or snaplage kernel screening method available upon request at several commercial labs which evaluates just the kernel particle size and eliminates the confounding effect of cob/husks on the final grain particle size value.

To maximize kernel shearing/damage with snaplage, it is advised to set the chop length as short as possible and that the chopper processor have relatively fine-tooth rolls (e.g. 5-7 teeth per inch) with a 1-2mm gap setting and a 50-60% differential (typically greater differential than for corn silage).



# ALFALFA

## RFV VERSUS RFQ

Relative feed value (RFV) was developed over 40 years ago as a marketing tool to help standardize quality in the buying and selling of hay. It is based on voluntary animal intake of forage digestible dry matter with a value of 100 being equal to the feeding value of full-bloom alfalfa hay.

Relative forage quality (RFQ) was developed to factor in the differences in fiber digestibility. Calculating RFQ requires a laboratory analysis for NDF digestibility (NDFD). NDFD tends to be higher in alfalfa grown in environments with cooler temperatures (especially at night). First-cutting usually exhibits the highest NDFD compared to second cuttings grown under higher heat units (See GROW section).

These two systems track quite closely for first-cutting alfalfa but tend to diverge for later harvests. Many producers measure RFV on first-cutting using a PEAQ Stick (Predictive Equations for Alfalfa Quality) and then schedule subsequent harvests based on day intervals between cuttings (e.g. 26-30 days depending upon desired quality).

Research at the University of Wisconsin shows that PEAQ can also be used to estimate RFQ of first-cutting alfalfa and that RFQ tends to be as high (or higher) than RFV estimates. However, harvest leaf losses and heat damage during storage will have a greater impact on RFQ than RFV.

## Relative Feed Value (RFV)

$$RFV = \frac{\%DDM \times \%DMI}{1.29}$$

%DDM = 88.9 - (0.779 x %ADF)

%DMI = 120/%NDF

## Relative Forage Quality (RFQ)

$$RFQ = \frac{DMI, (\% \text{ of } BW) * TDN, (\% \text{ of } DM)}{1.23}$$

**For alfalfa, clover, and legume/grass mixtures**

**DMI** = 120/NDF + (NDFD - 45) * 0.374 /1350 * 100

**TDN** = (NFC*0.98) + (CP * 0.93) + (FA * 0.97 * 2.25) + (NDFn * (NDFD/100)) - 7

**ACRONYM KEY:**

**DDM** = Digestibility Dry Matter

**DMI** = Dry Matter Intake

**ADF** = Acid Detergent Fiber (% of DM)

**CP** = Crude Protein (% of DM)

**FA** = Fatty Acids (% of DM) = Ether Extract

**NDF** = Neutral Detergent Fiber (% of DM)

**NDFCP** = Neutral Detergent Fiber Crude Protein

**NDFn** = Nitrogen Free NDF = NDF - NDFCP, or Estimated as NDF * 0.93

**NDFD** = 48 hour *in vitro* NDF Digestibility (% of NDF)

**NFC** = Non-Fibrous Carbohydrate (% of DM) = 100 - (NDFn + CP + EE + ash)

# HARVEST MATURITY

Plant maturity at harvest is the biggest driver of alfalfa yield and nutritional quality. Unfortunately, they are inversely related. If the plant is allowed to mature to the flower stage, yield is increased, but quality in terms of leaf-to-stem ratio (influencing protein levels) and digestion of the plant NDF is reduced. The recent commercialization of transgenic reduced lignin alfalfa will help reduce the negative relationship between yield and RFQ.

Field studies show that average daily increase in alfalfa yield across all but late-fall cuttings averages about 100 lbs per acre. However, yield change per day around harvest time varies considerably ranging from 0 to 200 lbs per acre per day. Yields are less in cool, cloudy weather, and in the presence of insects, disease or drought. Yield is greater with adequate moisture, high solar radiation and 75 to 85°F degree weather. Data from the Midwest shows that three harvests taken at 10% bloom will yield about 15 to 20% more than four harvests taken at the bud stage.

University of Wisconsin research shows that fiber content and digestibility of first-cutting changes at a faster rate than later cuttings. First-cutting decreases about five RFV points per day, second-cutting decreases two to three points per day and third and fourth cuttings decline one to two points per day. It appears late-fall growth changes little in forage quality during mid-to-late September and early October. RFQ will change about the same as RFV on first-cutting and then decline about 4-5 points per day on 2nd, 3rd and 4th cuttings. Factors such as drought and potato leafhopper will dramatically reduce yield but increase forage quality due to a higher leaf-to-stem ratio.

### DAILY ALFALFA FORAGE CHANGE IN YIELD AND QUALITY DURING THE GROWING SEASON

| CUTTING | YIELD (lb/day) | RFV per day | RFQ per day |
|---|---|---|---|
| | DAILY CHANGE | | |
| 1 | 100 | -5 | -5 |
| 2 | 100 | -2 to -3 | -5 |
| 3 | 100 | -2 | -4 |
| 4 | 100 | -1 | -4 |

*Source: University of Wisconsin.*

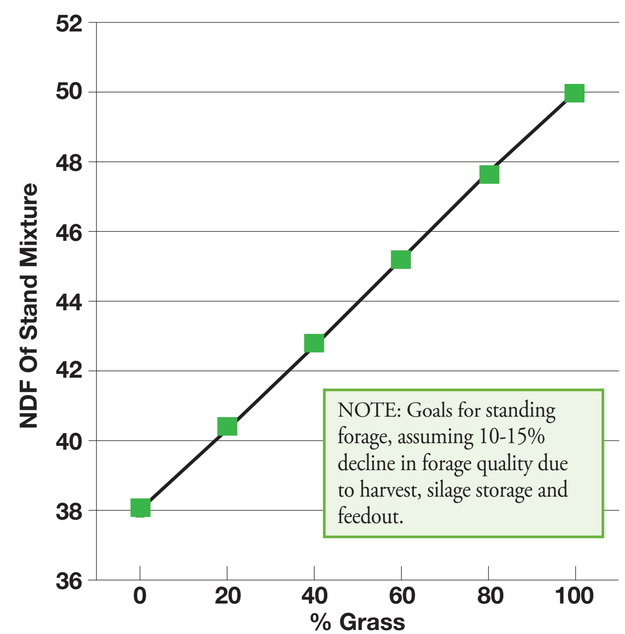
The introduction of transgenic reduced-lignin alfalfa varieties will dramatically change the traditional view of harvest management and many of the harvest maturity decision aids (PEAQ Stick, GDU targets) will have to be modified when dealing with reduced-lignin varieties. Alfalfa varieties with reduced-lignin technology have the same lignin and NDFD as conventional alfalfa varieties harvested 7-10 days earlier.

Alfalfa with reduced-lignin offers several new management opportunities for growers. One option is to continue harvesting on a typical bud stage schedule with a resulting increase in alfalfa RFQ compared to conventional varieties. A second option is to delay harvest of each cutting by 7-10 days and eliminate one cutting during the season. Summer cutting intervals could be 35 days instead of the typical 28-day schedule. By harvesting later and eliminating a cutting, alfalfa plants may have better winter survival and stand longevity. Finally, reduced-lignin alfalfa can serve as a risk reduction tool for weather or equipment related delays by maintaining higher forage quality for a longer time.

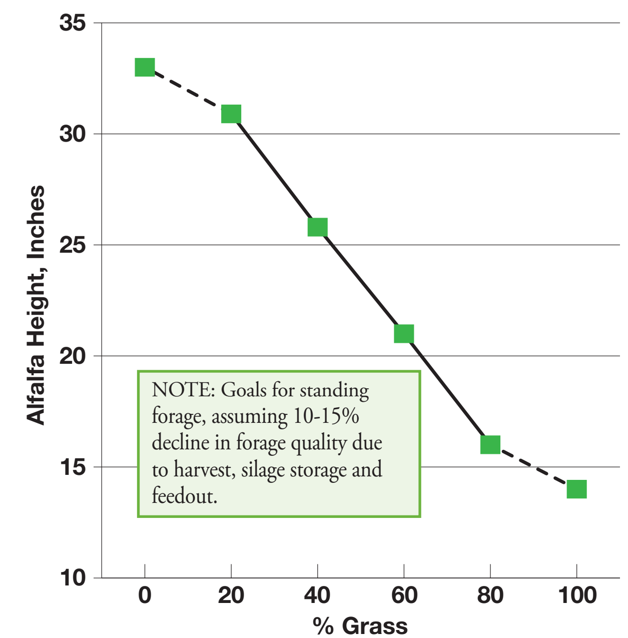
# HARVEST MATURITY OF MIXED STANDS

In mixed stands of grass and alfalfa, target harvest of grasses in the boot stage and alfalfa in the early-mid bud stage. Cornell University recommends for lactating dairy cattle to target 50% NDF in grasses and 40% NDF in alfalfa. The accompanying charts help target the optimal NDF level and conventional alfalfa height at harvest depending upon the percentage of grass in the stand.

### OPTIMUM STAND NDF IN ALFALFA-GRASS MIXTURES




### ALFALFA HEIGHT AT OPTIMUM MIXED STAND NDF



# METHODS TO MONITOR HARVEST MATURITY

Choice of maturity at harvest depends on the class of animal to which the crop will be fed, the need for quantity versus quality and agronomic considerations for the alfalfa stand such as the need to replenish carbohydrate root reserves or earlier harvest in response to leafhopper infestation. As previously noted, the introduction of transgenic reduced-lignin alfalfa varieties will dramatically change the traditional view of harvest management and many of the harvest maturity decision aids (PEAQ Stick, GDU targets) will have to be modified when evaluating reduced-lignin varieties.

It is important to set harvest goals and hope for cooperative weather. Dairy producers generally prefer alfalfa for lactating cattle in the range of 160-180 RFV/RFQ. Alfalfa stands can generally be harvested more mature to capture more yield for other classes of animals. Harvest schedules need to account for a 20-point loss in RFV/RFQ from harvest through field wilting and fermentation. If 180 RFQ is desired, harvest needs to occur when plants are close to 200 RFV/RFQ.

The moisture level to wilt the plant is primarily a storage structure and fermentation issue discussed in the STORE section of this manual.

## EXAMPLE OF RFV VS. RFQ IN ALFALFA

| SAMPLE | ADF (% DM) | NDF (% DM) | NDFD (% NDF) | RFV | RFQ |
|---|---|---|---|---|---|
| 1 | 34 | 43 | 48 | 135 | 148 |
| 2 | 34 | 43 | 58 | 135 | 174 |

Same laboratory fiber levels

High value = higher fiber digestibility

Same RFV

Clearly superior RFQ

**Leaves have less NDF, higher NDFD than stems thus harvest losses have greater impact on RFQ than on RFV.**

## EXPECTED FORAGE QUALITY VALUES AS ALFALFA ADVANCES IN MATURITY

| STAGE OF MATURITY | CRUDE PROTEIN | ACID DETERGENT FIBER | NEUTRAL DETERGENT FIBER | DIGESTIBLE DRY MATTER | RELATIVE FEED VALUE |
|---|---|---|---|---|---|
| | % OF DRY MATTER | | | | |
| Vegetative | >22 | <25 | <34 | >69 | >188 |
| Bud | 20-22 | 25-31 | 34-41 | 67 | 166 |
| Early Bloom | 18-19 | 32-36 | 42-46 | 62 | 131 |
| Late Bloom | 16-17 | 37-40 | 47-50 | 60 | 115 |
| Seed Pod | <16 | >41 | >50 | <58 | <108 |

*Source: N.P. Martin and J.G. Linn. University of Minnesota.*



# GDU METHOD

The GDU (growing degree unit) method has been employed primarily with first-cutting and begins with identifying when plants break dormancy. While corn uses a base temperature of 50°F, alfalfa uses a base of 41°F because that is the temperature at which alfalfa begins to grow. Accumulated base 41 GDU is calculated as [Maximum Daily Temperature + Minimum Daily Temperature)/2] - 41°F). GDUs are not counted until the high daily temperature hits 41°F for five consecutive days. Growers should develop their own GDU targets for their unique environments, however, in general 700 GDU is equivalent to bud stage (or about 38%NDF) and 880 approximates first flower. GDU is a preferable harvest predictor compared to using calendar dates. Research reported by W.H. Miner Institute showed the date at which alfalfa in the Northeast has reached 700 GDU was as early as May 4th (2012) and as late as June 5th (2014).

Field research has shown that NDF levels in the crop can increase as much as 0.04 points for each accumulated GDU. It is typical to accumulate 10-40 GDU/day which translates to 0.4 to 1.6 points of NDF per day. If it takes six days to harvest, the crop can increase by 2.4-9.6 points of NDF.

# SCISSOR CUTTING METHOD

Several state extension services have partnered with local forage laboratories to evaluate the fiber levels (and also NDFD) of immature plants to help stage harvest. Alfalfa sampling begins at about 14 inches of height. To facilitate rapid turnaround of data, laboratories often employ NIRS (Near Infrared Spectroscopy) using calibrations developed specifically for immature alfalfa.

# PEAQ

The predictive equation for alfalfa quality (PEAQ) is a field tool designed primarily to help determine the first harvest date by monitoring plant height and maturity. Plant height is an excellent indicator of staging harvest because RFV and RFQ decrease as the plant height increases. Research from North Dakota State University shows that the RFV of alfalfa, when growing from 20 to 40 inches in height, decreased 71 units during the late vegetative stage, 61 units during late bud stage and 53 units during the late flower stage. The PEAQ stick approach was developed using traditional alfalfa varieties so it will not apply to stands of transgenic reduced lignin alfalfa which will have higher RFV/RFQ at later plant maturities. Transgenic reduced-lignin varieties will typical have 15-20 points higher RFV than indicated by the PEAQ stick.

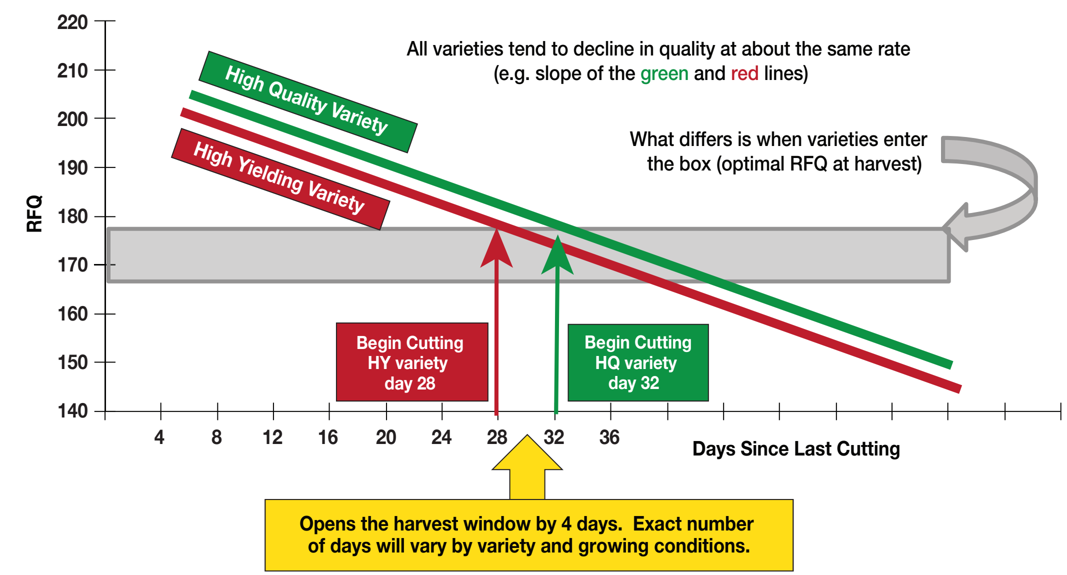
The PEAQ stick evaluation begins by sampling four to five, 2-square-foot sections representative of the entire alfalfa field while avoiding lodged or leaning areas. Determine the growth stage (vegetative, bud or flower) of the most mature stem (may not be the tallest stem). Find the single tallest stem and hold the stem up next to the stick, noting the estimated plant RFV and NDF value closest to the tip of the stem (not the tip of the tallest leaf). This method does not work well for weedy or grassy stands, or for very short (<16") or very tall (>40") stands. PEAQ is the only staging method that works relatively well across all cuttings.



# EXTENDING HARVEST WITH DIFFERENT VARIETIES

It is possible to widen the harvest window by variety selection to facilitate harvesting of extensive silage acres. The figure below shows how planting varieties selected for high quality can be used to complement high yielding varieties by entering the desired harvest window at a slightly later time.

## USING VARIETY MANAGEMENT TO "WIDEN THE HARVEST WINDOW"




# CUTTING HEIGHT

Lowering the cutter bar obviously results in higher yields of alfalfa, with the biggest effect from 1st cutting which typically accounts for 40-60% of total yearly yields. Most of the yield gain is from increased growth from stems originating from the crown rather than from axillary buds on the lower portions of the stems. Research shows that alfalfa can be cut as short as 1.5 inches and that each inch above this will result in 0.5 tons per acre reduction in annual yields. However, lower cutting reduces forage quality by lowering leaf : stem ratio resulting in about 5 points lower RFV per inch of shorter cut. Lower cutting also tends to increase the ash content from disc mowers vacuuming soil (ash) into the crop. This causes lower digestibility and the potential for increased soil-borne bacteria and clostridial spores that can also have a negative impact on fermentation.

For most producers, cutting pure-alfalfa stands at 2.5-3.0 inches seems to be a good compromise. To prevent shortened stand life in mixed stands, this should be increased to 3-4 inches if the stand includes brome-grass, orchardgrass or timothy. Alfalfa doesn't re-grow from the cut stems but rather from crown buds so cutting height has little impact on plant nutrient availability. However, grasses do not have taproots, and they regrow from the cut stems. Nutrients for the following cuttings are stored in the bottom few inches of grasses, so cut height can impact both regrowth and stand life. Many agronomists now recommend a 4-inch stubble height for cool-season forage grasses.

# WHEEL TRAFFIC DAMAGE

The old adage is that *"alfalfa doesn't die, growers kill it."* This is caused by aggressive harvest intervals not allowing the plant to adequately replenish root reserves and by punishing the stand physically with harvest or post-harvest equipment traffic. It is well known that wheel traffic soil compaction can reduce soil air permeability, water infiltration and alfalfa root development.

University of Wisconsin research shows that the largest effect of wheel traffic is breaking re-growing alfalfa stems which reduce yield at the next cutting. They recommend these management practices to reduce yield loss to wheel traffic:

1) plant traffic-tolerant varieties,
2) don't use tractors any larger than necessary,
3) limit trips across the field,
4) use wide swath to allow hay/haylage to dry faster and
5) apply manure or fertilizer (or remove dropped bales) immediately after harvest.

# HARVEST TIMING

The time of day to harvest alfalfa (am vs. pm) is an interesting topic and research results fall on both sides of the debate. The basic idea is that cutting later in the day allows the crop to deposit more sugars to improve palatability and aid in silage fermentation. Much of the positive research has been conducted on alfalfa hay harvested in Western states.

Although am vs. pm forages differ in initial composition, it is not clear that these differences persist after drying and/or fermentation. Despite the plants being cut, they are still alive and cellular respiration will reduce sugar levels at night and in the section of the window not receiving sunlight. Research in Wisconsin showed 11 of 14 alfalfa samples had higher sugars with pm-cut alfalfa; yet only one of the 14 had higher sugar levels in the stored forage.

A Miner Institute study showed no statistical difference in plant sugars, starch, NDF, or *in vitro* digestibility between am and pm harvesting. While afternoon harvested alfalfa was numerically higher in sugar and starches, the small differences either decreased or disappeared by the time the forage reached 40% DM. The alfalfa mowed in the morning was ready for silage harvest in about nine hours, while the alfalfa mowed in the late afternoon was not harvestable until after noon the following day. Many researchers in the Midwest and East Coast believe it makes more sense to harvest early in the day to maximize the hours of drying from solar radiation rather than expose the crop to delayed drying and increased weather risk.

There also appears to be adequate sugars to support fermentation when alfalfa is harvested at typical North American moistures/maturities compared to higher moisture European forages. Hay palatability is also less of a concern in total mixed rations when cows are not given a choice of feedstuffs.



# LATE-FALL HARVEST IN NORTHERN CLIMATES

Harvesting late-fall alfalfa after a killing frost is a viable approach to increasing forage inventory without affecting winter survival or the following spring yields. The University of Wisconsin has traditionally suggested a "no-cut window" from September 1st until a killing frost (below 24°F or <26°F for 6-8 hours). This allows the plant adequate time to deposit carbohydrate root reserves to survive the winter and meet growth demands the following spring.

Midwestern research suggests that when the length of the regrowth period following harvest is more than 45 to 50 days, another harvest can be taken without much agronomic risk. Research from Quebec, Canada suggests that the weather after the final harvest is more important than the calendar date. Their studies concluded that alfalfa needs 500 GDU (base 41) between last cutting and a killing frost to build enough root reserves to successfully survive the winter. The other option to improve winter survival is to harvest when there is little chance of significant regrowth before a killing frost (~200 GDU). Stands that are aggressively cut during the year, or stressed stands are likely to benefit the most from more conservative fall harvest scenarios.

Alfalfa crowns of winterhardy varieties can withstand soil temperatures of 15°F but lower temperatures can cause winter damage. With fall harvest, it might be prudent to leave some stubble (6") or even a few strips to catch snow for improved insulation to help winter survival. Other strategies to help manage the late fall cuttings is to harvest only established, non-stressed stands, not new seedings, keep fertility high with annual fertilization and consider a late-summer or fall application of potassium fertilizer.

Inoculating late fall harvested alfalfa silage with alfalfa-specific strains of bacteria is highly recommended because most of the fermenting bacteria (epiphytes) found naturally on the crop will not survive the killing frost. Fall-grown alfalfa also contains more pentose (5-carbon) sugars compared to hexose (6-carbon) sugars produced during spring and summer growth. Pentose sugars are fermented to 1-lactic acid (3 carbons) and 1-acetic acid (2 carbons). The production of acetic acid rather than another lactic acid typically results in a higher terminal pH in fall-harvested alfalfa silage.

Feed quality should be relatively high In late fall cuttings because the growth has occurred during a period of declining solar radiation and cooler nights, although the effective fiber value of this crop will likely be very low.

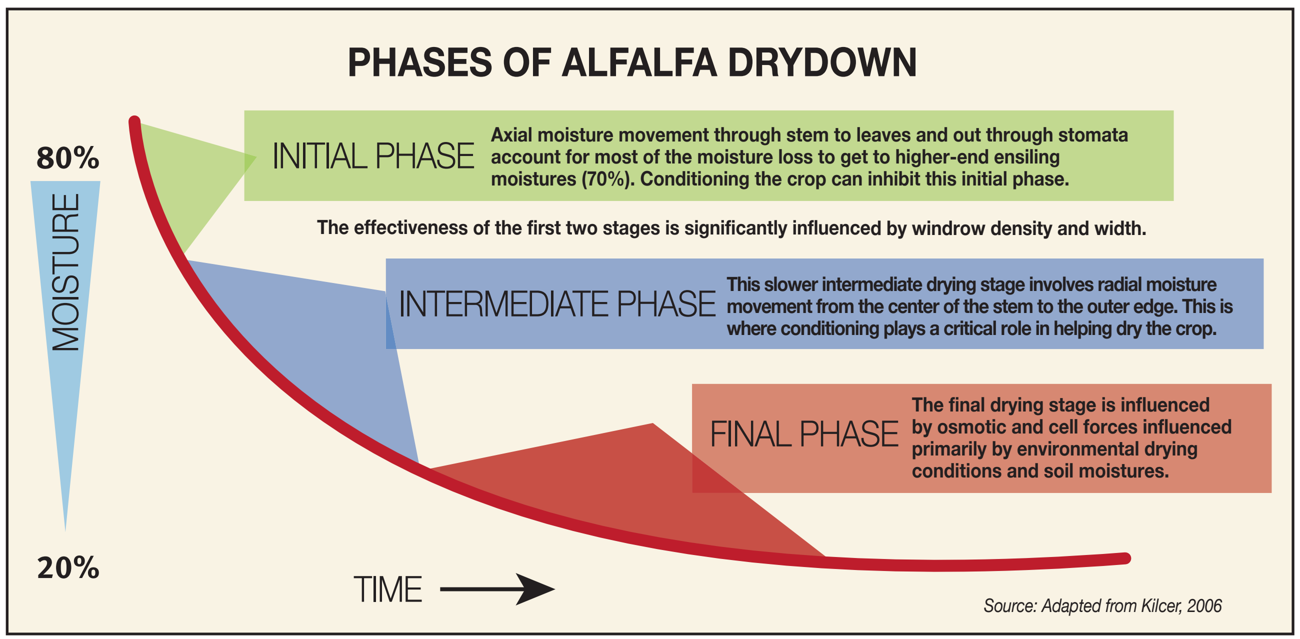
# BIOLOGY OF ALFALFA WILTING/DRYING

The primary factors that speed alfalfa wilting and drying are swath exposure to sunlight, swath temperature, air temperature, crop moisture and wind velocity. Factors which slow drying are relative humidity, swath density and soil moisture.

In an attempt to reduce weather-related harvest risk, many growers are successfully mowing alfalfa (sometimes with conditioners removed to not damage stomata) into wide swaths for faster drying, followed by merging and chopping within a 24-hour period. Not only does this reduce weather risk (e.g. rain damage leaching sugars and extending respiration losses), but preserves quality by retaining more sugars and decreases the risk of contamination by undesirable organisms such as soil-borne clostridia.

The figure below details the phases of alfalfa wilting and drying. Research from Cornell University Extension indicated that wide-swathing conditioning was of limited benefit because it interfered with moisture loss from leaf stomata.

Wisconsin researchers cite research showing conditioning with wide swathing produces the shortest time to acceptable harvest moistures and that unconditioned windrows needed to be nearly twice as wide as the conditioned windrows to produce a drying advantage. Some of this debate about conditioning centers around recommended silage harvest moistures. Producers today are targeting much dryer alfalfa silage than the 65-70% moisture that was once the norm. It appears that if producers are wide-swathing, conditioning is not as important to get down to 65+ percent moisture. However, if equipment limitations prevent adequately wide-swathing, conditioning is still recommended, especially for those wanting to ensile alfalfa in the moisture range of 55-60% to reduce clostridia (butyric acid) fermentations.





# STORE

# FERMENTATION PROCESS

Silage fermentation can be simplified into three phases. Silages experience aerobic (with oxygen) conditions during harvest and filling, followed relatively quickly by anaerobic (without oxygen) conditions which initiate lactic acid bacterial (LAB) growth and pH decline, and finally, back to aerobic conditions during feedout.

The natural microbial (epiphytic) populations that exist on the fresh crop at harvest exert a tremendous influence on the stability and feeding value of the resulting ensiled feed. Factors such as temperature, humidity, solar radiation, plant maturity, moisture, length of wilting time and soil contamination during harvest all influence the type and quantity (colony forming units or cfu/gram of forage) of epiphytes populating the crop.

The ultimate goal of ensiling is to stabilize the crop via the action of LABs. This reduces pH through the efficient conversion of sugars to lactic acid. As livestock operations transitioned to larger bunkers and drive-over piles, it created a greater need to reduce aerobic deterioration on the face of the silage during feedout.

Total epiphyte counts can vary from near zero to several million cfu/gram of fresh crop. The microflora on fresh plants are primarily gram-negative, aerobic (oxygen-loving) species. The preferred gram-positive, facultative anaerobic LAB that drives the fermentation process is very much in the minority. Furthermore, not all of the small population of LAB is desirable because many are leuconostic species which are inefficient at converting sugars, lack acid-tolerance and can't reduce pH below about 5.0. It should be noted that research on several fungicide products are in agreement that fungicides do not appear to negatively impact LAB populations or viability.

Without going into the hundreds of epiphytic populations, the ones most problematic to forage and high-moisture grain are yeast, molds and soil contaminants introduced during harvest such as gram-positive, spore-forming bacilli and clostridia. Crops such as corn silage and high-moisture corn, especially if stressed by drought or early frost, can have very high yeast counts. The proliferation of yeast in silage re-exposed to oxygen at feedout can have a negative effect on dry matter loss, heating and palatability. In the presence of oxygen, certain yeast species have the ability to metabolize lactic acid, causing an elevation in silage pH which reduces the inhibitory effect on other heat-generating spoilage organisms such as mold, bacilli and acetobacter species. Yeast and acetobacter can also produce aromatic compounds such as esters, aldehydes and ethyl acetate (smells like fingernail polish) which can significantly reduce feed palatability.

University research has shown that the impact of yeast can be minimized by proper harvest moisture, silage compaction/ feedout methods and the use of silage inoculants containing viable strains of *Lactobacillus buchneri*. Mold spores are virtually everywhere and easily survive over winter in soil and plant residues. Common field fungi (primarily Aspergillus and Fusarium spp.) are capable of producing recognizable toxins including aflatoxin, vomitoxin (DON), fumonisin, zearalenone and T-2. Estimates are that 70 to 90 percent of all mycotoxins are already on the plant prior to harvest, and no silage additive or inoculant is capable of degrading these preformed toxins. However, producers can exert management influence over storage fungi like Penicillium (toxin-producer), and non-toxin producers such as Mucor and Monila mold species. These molds do not typically infect the crop prior to harvest, but their soil-borne spores can contaminate the fresh forage during harvest. Ensuring proper harvest moisture, silage compaction and feedout methods can help reduce aerobic conditions conducive to the growth of these storage molds.

Clostridia are well-known for their ability to degrade proteins and produce butyric acid. Reducing soil contamination levels (ash) in legumes and grasses in addition to ensiling at higher dry matters such as 40-50%, reduces the chances of clostridia problems. Clostridia take a month or two to grow and establish populations, so if forced to ensile wet silages, it is best to feed them immediately before they initiate their destructive process. Producers are trending towards higher dry matter legume/ grass silages from having learned this lesson the hard way.

Researchers at the U.S. Dairy Forage Research Center showed that epiphyte counts were elevated with warmer temperatures, longer wilting times and if rainfall occurred during wilting of legume forage. While wide-swathing aids in rapid wilting of legume/grass forages, the greater exposure to solar radiation can have a negative effect on LAB counts. Finally, the process of harvesting tends to quickly raise LAB counts presumably because of the availability of nutrient-rich plant juices.

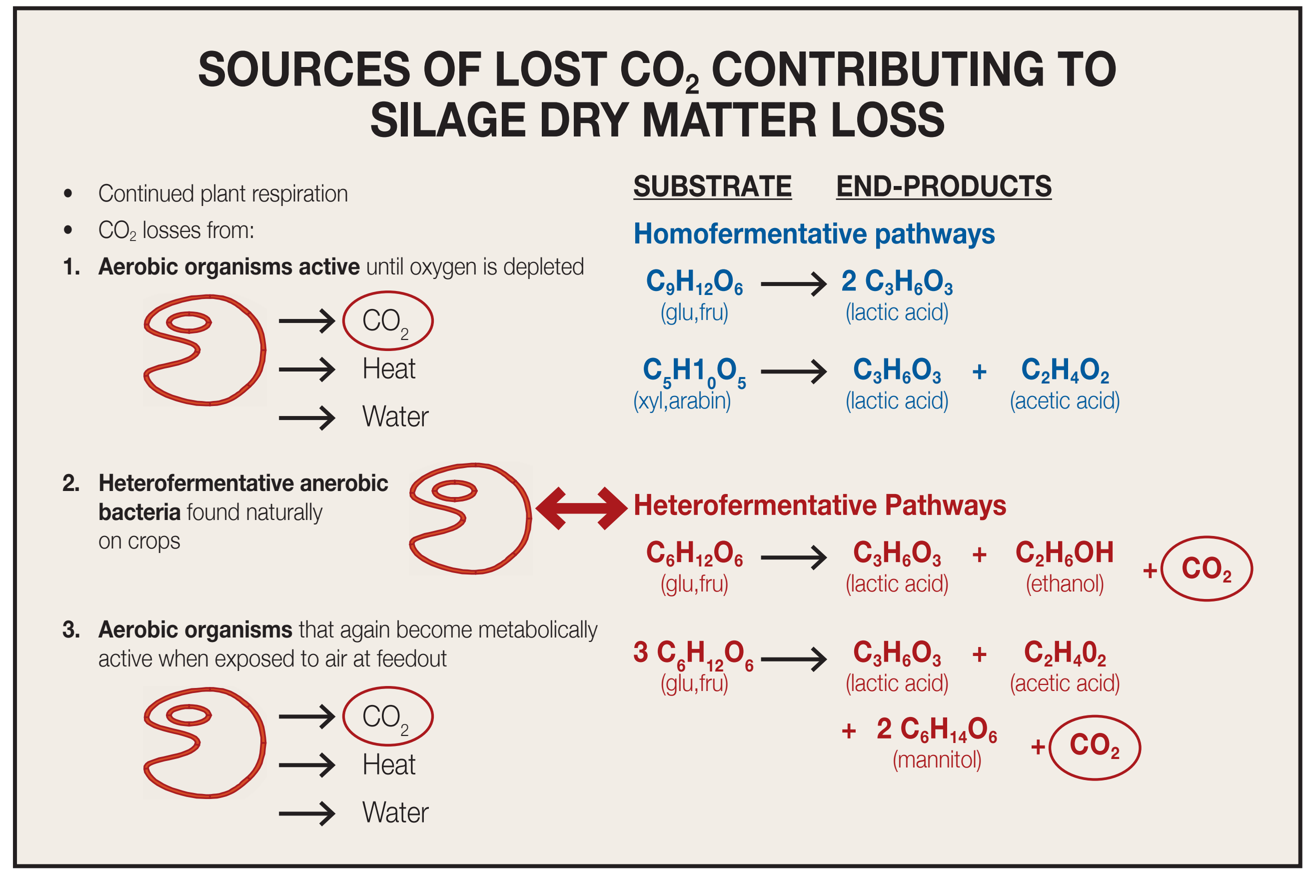
Moisture of the crop at harvest also dictates which epiphytes dominate, exemplified by clostridia preferring a high-moisture environment. You can easily observe the influence of harvest moisture on which silage microbes dominate by looking at their metabolism end-products (volatile fatty acids and ammonia-N) across different moisture ranges. In general, wetter silages undergo a more extensive fermentation, have a slightly lower pH, more ammonia-N and typically exhibit higher acetic acid levels (primarily from higher yeast and heterofermentative bacterial growth). Drier silages undergo less extensive fermentation, have a slightly higher pH, less ammonia-N and typically lower acetic and butyric acid. Silage management is critical with drier silage to minimize porosity and expose stored silage to oxygen infusion given the lack of water to fill in the air spaces.

The lower ammonia-N (soluble protein) in drier silages should be factored into diets to be sure that rumen bacteria have adequate nitrogen that used to be provided from the higher soluble protein found in wetter legume/ grass silages. The benefit of inoculation is overwhelming epiphytes with highly competitive LAB strains which dominate and direct the fermentation process to a more consistent endpoint, despite differences in harvest moisture.

Dry matter loss begins with continued plant cell respiration and growth of aerobic microflora which utilize carbohydrate sources (primarily sugar) producing water, heat and carbon dioxide ($C0_2$). It is the carbon in $C0_2$ that is lost to the atmosphere which is the cause of silage dry matter (DM) loss (commonly and incorrectly sometimes referred to as "shrink"). Wilting time and speed of harvest impact the extent of these aerobic field losses.

These processes will continue until the oxygen in the silage mass is depleted. Plant moisture and compaction play a role in reducing the length of this aerobic phase in the storage structure by reducing silage porosity.

The subsequent anaerobic phase establishes an environment suitable for domination by facultative homofermentative and heterofermentative lactic acid bacteria (LAB). There would be no DM loss in this phase if only homofermentative LAB were active because they do not produce any $C0_2$ (see graphic). However, less than 0.5% of epiphytic organisms naturally found on fresh crops are LAB and only a small proportion of



these are homofermentative. To put the loss from heterofermentative LAB in perspective, there is a 24% loss of dry matter from the heterofermentative fermentation of glucose because of the $CO_2$ production lost to the atmosphere. These anaerobic fermentation losses can be reduced by 25% or more with the use of homofermentative strains found in reputable silage inoculants.

The re-exposure of silage to aerobic conditions can be divided into two areas: top and side exposure with upwards of 20% of silage contained in the top three feet in most bunkers and drive-over piles, and face exposure during feedout. The combination of these two sources of DM loss can vary significantly due to management level with estimates of greater than 20% loss in net energy (in pure starch equivalents) reported in the literature from aerobically unstable silages. The increased use of bunkers and piles with large exposed faces (as opposed to smaller face exposure in tower silos or bags) results in significantly more DM in the aerobic, feedout phase than in the initial aerobic phase.

The fermentation of high-moisture corn (and snaplage) is somewhat unique because of the relatively low moisture and sugar content (e.g. the kernel is primarily starch, not sugar). The moisture level of the grain helps determine the length of the fermentation process and relative changes in starch digestibility over time in storage. When harvested at recommended kernel moistures exceeding 28%, terminal pH can be achieved in about two to three weeks. If the kernels get too mature/dry (e.g. <25% moisture), it can take as long as two months to fully complete the fermentation process. Inoculation with products specifically designed for high-moisture corn can be very helpful, especially those containing *Lactobacillus buchneri* for maintaining stability and palatability in a crop notorious for high yeast counts at harvest.

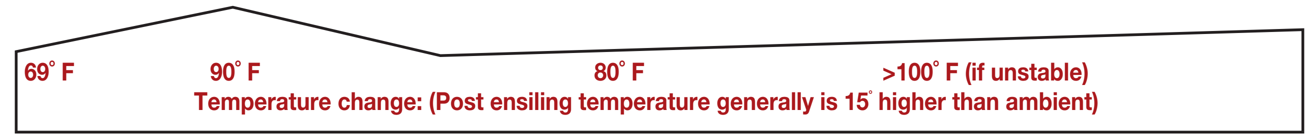
Several technologies can be employed to reduce top and face spoilage including specialized packing equipment, oxygen-barrier film, silage facers and bacterial inoculants containing *Lactobacillus buchneri* strains. The fact that *L. buchneri* is a heterofermentative LAB may lead to questions as to why inoculant manufacturers would use a LAB known to be less efficient than homofermentative strains. They are used because the metabolites of their growth inhibit yeast growth during feedout, and it is yeast which initiates the cascade of events leading to aerobic losses. In addition, most products containing *L. buchneri* also contain homofermentative LAB strains (commonly called combination or "combi" products) to facilitate both a rapid, "front-end" pH decline and stability during feedout.

# THE ENSILING PROCESS

| When fermentation losses occur | When nutrient changes occur | When aerobic spoilage losses occur |
|---|---|---|
| (sugars are lost and fiber is concentrated. About 50% DM loss occurs in Phases 1-5) | (terminal pH achieved, proteins are degraded, starch digestion increases, fiber digestion does not change) | (about 50% of total DM loss occurs in phase 6 in bunkers/piles with large faces) |
| **WSC*** | **WSC* (or Lactic Acid)** | **WSC* (or Lactic Acid)** |
| Aerobic Conditions | Anaerobic Conditions | Aerobic Conditions |
| Aerobic Bacteria → $CO_2$ + $H_2O$ + Heat | Anaerobic Bacteria → Silage Acids (mainly lactic) drop pH | Aerobic Bacteria → $CO_2$ + $H_2O$ + Heat |
| **Phase 1** (hours) | **Phase 2-5** (few days, less time with inoculants) | **Phase 6** (during entire feedout period) |

# PHASES OF SILAGE FERMENTATION AND STORAGE

| AEROBIC PHASES | | ANAEROBIC PHASES | | | AEROBIC PHASES |
|---|---|---|---|---|---|
| Cell respiration and aerobic organisms consume WSC with production of $CO_2$ heat and water. | Populations of enterobacter and heterofermentative bacteria yielding lactic acid, acetic acid and ethanol. | Transition phase with shift to more homofermentative LABs. | Primary homofermentative LAB phase. Efficiency depends on epiphytes levels, WSC, moisture and compaction. | Increases in protein solubility and starch digestibility occur during this phase. | Secondary aerobic decomposition upon re-exposure to oxygen. Highly influenced by feedout rates and face management. |





| | | | | | |
|---|---|---|---|---|---|
| Continues until all $O_2$ is consumed. High carbohydrate and protein enzymatic activity. | Acetate-tolerant bugs drop pH to ~5.0. Low pH reduces microbial activity. Lasts 24-72 hours. | Homofermentative LABs initiate more rapid and efficient drop in pH. | Longest phase lasting until run out of WSC or terminal pH inhibits growth. | Stability impacted by $O_2$ penetration residual WSC, acid profile, microbial and fungi populations. | Yeast, mold and aerobic bacteria activity causing 50% of total DM losses. |
| 12-24 hrs | 2-3 days | ← | Time to terminal pH is crop dependent related to amount of sugar and crop buffering capacity. Can range from as short as a few days with corn silage to as long as 2 months with dry (<24% moisture) high moisture shelled corn. Time can be reduced by half with a reputable inoculant. | → | |

**LAB** - lactic acid bacteria
**WSC** - water soluble carbohydrate

# SHRINK VERSUS DRY MATTER LOSS

Producers and nutritionists tend to use the terms shrink and DM loss interchangeably, however, from a calculation perspective, they are very different. Shrink loss is based on an "as fed" basis, (= lost weight, as fed basis/original weight, as fed basis) while DM loss is based on a "dry matter" basis (= lost weight, DM basis/original weight, DM basis). Measuring on-farm shrink loss can be deceiving as a small shrink loss can still result in a large dry matter loss. The difference is caused by the fact that during the oxidation of silage sugars, 60% of the original dry matter weight remains as water and water has no real nutritional value to livestock. This also helps explains why silage exits the storage structure with more moisture than when initially ensiled.

## A SMALL SHRINK LOSS CAN ACTUALLY BE A LARGE DRY MATTER LOSS WHEN MOISTURE FROM SUGAR OXIDATION ACCOUNTED FOR CORRECTLY

### We Tend to Use Shrink and DM Loss Interchangeably,

***BUT THEY ARE VERY DIFFERENT***

$$\text{Shrink Loss (\%)} = \left[\frac{\text{Lost Weight, as fed basis}}{\text{Original Weight, as fed basis}}\right] * 100$$

$$\text{Dry Matter Loss (\%)} = \left[\frac{\text{Lost Weight, Dry Matter basis}}{\text{Original Weight, Dry Matter basis}}\right] * 100$$

### Relationship of On-Farm (as fed) Measured Shrink to Actual DM Loss

(based on 65% initial silage moisture)

| DM Loss (%) | True Shrink (%) | True final % Moisture of Silage* |
|---|---|---|
| 1 | 0.14 | 65.2 |
| 5 | 0.70 | 66.5 |
| 10 | 1.40 | 68.1 |
| **15** | **2.10** | **69.6** |
| 20 | 2.80 | 71.2 |

Only if the DM on every load into storage and out of storage is accurately determined, can DM loss can be measured on farm!

Feed value is in the Dry Matter!

*60% of DM loss retained as moisture

### How to Calculate True Shrink Loss and Silage Final Moisture

**A small shrink loss can still be a large dry matter loss.**

**Example: 100 lb as fed sample**

**Assume (incorrectly) that there is no moisture loss or gain**

**Shrink Loss (%) = [(35 lbs DM*0.15)/100 lbs as fed] * 100 = 5.25%**

**Final Silage Moisture (%) = (65 lbs $H_2O$ / (100-5.25 lbs as fed))*100 = 68.6%**

**Now (correctly) accounting for the fact that 60% of DM Loss is retained as moisture gain**

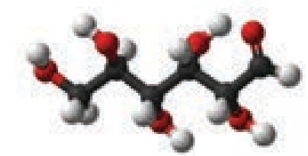
***True* Shrink Loss (%) = [(35 lbs DM*0.15*0.4)/100 lbs as fed] * 100 = 2.1%**

***True* Final Silage Moisture (%) = (65 lbs $H_2O$ + (0.6 * 5.25 original shrink) / 100-2.1 lbs as fed)*100 = 69.6%**

*Source: Dr. Brian Holmes. Professor and Extension Specialist. Biological Systems Engineering Dept. University of Wisconsin – Madison. Wisconsin Custom Operators Conference 1/25/11*



## WHAT HAPPENS WHEN SUGAR IS OXIDIZED



*$CO_2$ is lost to the atmosphere*

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O + \text{Energy}$$

Molar Mass: **180 + 192 ⟶ 264 + 108**

**(108/180) * 100 =** ***60% of original DM weight remains as water***

molar mass is defined as the mass of a given substance (chemical element or chemical compound) divided by its amount of substance.

molar mass of oxygen ≈ 32 $g \cdot mol^{-1}$

molar mass of glucose ≈ 180 $g \cdot mol^{-1}$

molar mass of water is approximately: $M(H_2O)$ ≈ 18 $g \cdot mol^{-1}$

*Source: Dr. Brian Holmes. Biological Systems Engineering Dept. Univ. of Wisconsin – Madison. Wisconsin Custom Operators Conference 1/25/11*

# TRUE COST OF SILAGE DRY MATTER LOSS

Dry matter loss in silage results in the loss of the most valuable nutrients. When silages ferment, sugars and starch are what the aerobic organisms and LAB utilize, and fiber levels are actually increased (concentrated). To understand the true cost of dry matter loss, they must be replaced with a nutritionally equivalent energy source, such as corn grain. For example, even in a relatively well-managed bunker, if management changes could reduce DM loss by 20% (from 15% to 12.5%), it would equate to a value of $1.26 per as fed ton ($7.56 - $6.30) if that energy had to be replaced with $4.00/bushel corn (see chart).

Silage producers are keenly aware of the losses from top or side spoilage. However, they may need additional convincing as to the loss in feed value in what may appear to be "normal" silage. What does not work very well for quantifying DM loss is relying on truck weights into the bunker compared against TMR weights out of the bunker. There is just too much room for measurement errors, and it does not account for the biological fact that silage comes out of the storage structure higher in moisture than when it was ensiled due to aerobic microbial activity generating moisture.

However, there are several approaches that can be used to quantify the nutritional cost

## COST OF DRY MATTER LOSS PER TON WHEN REPLACED WITH CORN GRAIN AS AN EQUIVALENT ENERGY SOURCE

Corn Cost ($/bu)

| DM LOSS | 10.0% | 12.5% | 15.0% | 17.5% | 20.0% | 22.5% | 25.0% | 27.5% | 30.0% |
|---|---|---|---|---|---|---|---|---|---|
| $3.00 | $3.78 | $4.73 | $5.67 | $6.62 | $7.56 | $8.51 | $9.45 | $10.40 | $11.34 |
| $3.50 | $4.41 | $5.51 | $6.62 | $7.72 | $8.82 | $9.93 | $11.03 | $12.13 | $13.24 |
| $4.00 | $5.04 | $6.30 | $7.56 | $8.82 | $10.08 | $11.34 | $12.61 | $13.87 | $15.13 |
| $4.50 | $5.67 | $7.09 | $8.52 | $9.93 | $11.34 | $12.76 | $14.18 | $15.60 | $17.02 |
| $5.00 | $6.30 | $7.88 | $9.45 | $11.03 | $12.61 | $14.18 | $15.76 | $17.33 | $18.91 |
| $5.50 | $6.93 | $8.67 | $10.40 | $12.13 | $13.87 | $15.60 | $17.33 | $19.07 | $20.80 |
| $6.00 | $7.56 | $9.45 | $11.34 | $13.24 | $15.13 | $17.02 | $18.91 | $20.80 | $22.69 |
| $6.25 | $7.88 | $9.85 | $11.82 | $13.79 | $15.76 | $17.73 | $19.70 | $21.66 | $23.63 |
| $6.50 | $8.19 | $10.24 | $12.29 | $14.34 | $16.39 | $18.43 | $20.48 | $22.53 | $24.58 |
| $7.00 | $8.82 | $11.03 | $13.24 | $15.44 | $17.65 | $19.85 | $22.06 | $24.26 | $26.47 |
| $7.50 | $9.45 | $11.82 | $14.18 | $16.54 | $18.91 | $21.27 | $23.63 | $26.00 | $28.36 |
| $8.00 | $10.08 | $12.61 | $15.13 | $17.65 | $20.17 | $22.69 | $25.21 | $27.73 | $30.25 |

of DM loss. One is the use of ash, pH and temperature measurements of silage on the bunker face compared to a deeper probed (e.g. 20 inches) sample. In a 2003 Idaho field study of 12 non-inoculated bunkers and piles conducted by Pioneer researchers, the average ash, pH and temperature were 0.27% units, 0.3% units and 12.9°F higher for the face compared to the deep probe sample. When the ash data was entered into an organic matter recovery equation developed at Kansas State University, it estimated a 5.6% higher organic dry matter loss in the surface silage. Totally replacing the lost organic matter with corn starch would require more than a bushel of corn for every ton of silage fed.

Another approach used by Pioneer to help producers visualize the heating caused by aerobic microbial activity is the use of thermal sensitive cameras. Silages normally heat 10-15°F above whatever the ambient temperature is at ensiling. The moisture in larger bunkers or piles retains this unavoidable (physiological) heat, which is slowly dissipated throughout the storage period. If silage is removed from the storage structure and continues to heat, this is problematic heating caused by aerobic organism growth leading to a loss in nutrient value and palatability.



# ROLE OF YEAST IN DRY MATTER LOSS

Yeasts can exert a profound impact in silage at the time of feeding by initiating the decline in aerobic stability (increased heating) and subsequent feeding value. Yeasts are naturally occurring epiphytes found on corn silage, cereal silage and high-moisture grains at the time of harvest. Yeasts can also be found in grass or legume silages, particularly when harvested at lower moisture. This may explain why producers ensiling grass/legume silages at lower moistures in an attempt to avoid butyric acid (clostridia) problems can sometimes experience aerobic stability problems.

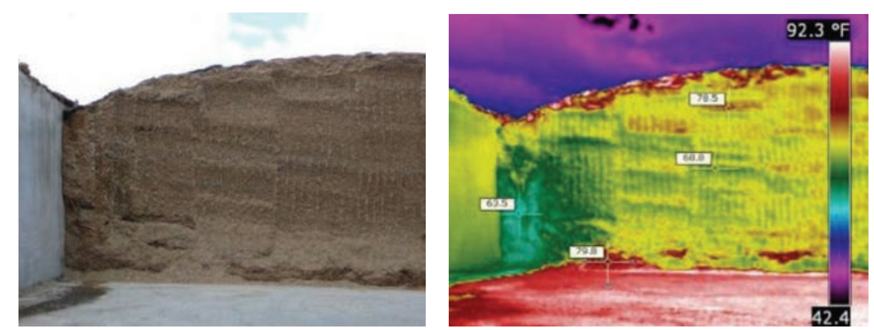
Yeast populations and the metabolites they generate shift dramatically in aerobic versus anaerobic environments. Yeasts can be categorized as fresh-crop, storage or feedout strains and are further classified as fermenters or non-fermenters. They can also be subdivided by their ability to utilize different substrates such as soluble sugar or lactic acid. The sugar-utilizers dominate during the aerobic phase at the beginning of the ensiling process and during the anaerobic conditions of storage. The acid-utilizers comprise the majority population in the presence of oxygen at feedout. At harvest, over 90% of yeasts are sugar-utilizers, but the ensiling process provides selection pressure ensuring over 90% lactate-utilizers are dominating at feedout. High counts of lactate-consuming yeasts cause aerobic stability concerns because their metabolism of lactic acid elevates silage pH creating an environment conducive to spoilage bacteria and mold growth.

Fresh-crop yeasts are usually non-fermenters and include Cryptococcus, Rhadotorala, Sporabolomyces, and sometimes Torulopsis organisms. Heat, carbon dioxide and acetic acid are the main products produced by yeasts during aerobic conditions. Heating can affect palatability and carbon dioxide contributes to dry matter loss.

Residual sugars can be utilized during storage by anaerobic, low-pH resistant, storage-type, fermenter yeasts like Sacchromyces and sometimes Torulopsis. Yeasts do not reproduce during anaerobic conditions. Although yeasts are not reproducing, they remain metabolically active producing heat, carbon dioxide, ethanol and also by-products including acetic acid, aldehydes and esters. For every alcohol that is produced, a $C0_2$ is generated which further contributes to dry matter loss. Ethanol production in silage is not entirely bad. Ethanol can help solubilize zein protein in corn kernels allowing for increased starch digestibility over time in storage.

The fermenter yeasts which are active during feedout include lactic acid-utilizing Candida and Hansula species. Yeast will reproduce during aerobic conditions (but not as fast as bacteria) explaining why overly dry, poorly compacted and slow feedout silages with high air porosity often display such high yeast (and aerobic bacillus) counts. Besides acetic acid and limited amounts of ethanol, aerobic conditions cause yeast to produce a large number of aromatic compounds depending upon the specific yeast strain and environmental conditions. As the temperature rises, more aromatic compounds are produced.

In silages, feedout yeasts are also capable of producing esters (fruity smell), ethyl acetate (fingernail polish smell), fusel alcohols (from amino acid degradation causing a harsh, solvent-type smell), aldehydes (diacetyl – butter smell or acetylaldehyde – green apple smell) and other compounds with solvent-like odors. Substrate levels also




***Lactobacillus buchneri*- containing inoculant delivering a consistent and cool silage face as pictured with a thermal sensitive (FLIR)camera.**

influence the level of by-products produced by anaerobic, storage-type sugar-utilizers. As the level of sugars and temperature increase, more aromatic esters and fusel alcohols can be produced. High level of sugars can also shift the production of alcohol to other metabolites. The production of these aromatic compounds in silages not only increases dry matter loss but can also significantly contribute to palatability problems.

From a diagnostic perspective, aerobically challenged silages usually have yeast populations that exceed 100,000 colony forming units per gram (cfu/gm) of ensiled feed. The identification of Hansula and Candida organisms usually is associated with high pH from the consumption of lactic acid, while the presence of Torulopsis usually does not have elevated pH since the organism primarily utilizes soluble sugars. Volatile fatty acid profiles will typically show a reduction in lactic acid and an increase in acetic acid levels. In contrast, samples taken deeper in the mass of well-compacted silage will typically show a more desirable pH and lactic acid level because yeast growth is limited by lack of oxygen penetration.

Higher levels of acetate should not always be considered deleterious or evidence of high yeast contamination. Elevated acetic acid levels caused by yeasts, gram-negative acetic acid producers (e.g. enterobacter sp.) or heterofermentative lactic-acid bacteria (e.g. leuconostoc sp.) may contribute to poor bunklife or intake issues. However, silages treated with bacterial additives containing strains of *Lactobacillus buchneri* also exhibit lower lactic : acetic ratios yet have been shown to reduce yeast counts and improve bunklife without exerting any negative impact on dry matter intake.

The increased availability of yeast counts and identification has caused some nutritionists to question if there is a relationship between high yeast silages and chronically low butterfat herds. While yeasts certainly contribute to the cascading events leading to unstable silage, it is unlikely that low butterfat test can be attributed to yeast or their metabolites, per se, unless the unpalatable silage is causing sorting and reducing effective fiber intake. A more likely culprit of fat test depression is underestimating the fiber or starch digestibility of forages contributing to reduced rumen pH promoting the synthesis of ruminal bio-hydrogenation lipid intermediates such as trans-10, cis-12 conjugated linoleic acid (trans fatty acid).

Short-term management of yeast-challenged silages involves approaches to increase daily removal rates to deprive them of time to grow in oxygenated environments. Proper removal techniques to preserve a densely packed and clean horizontal silo face will also help minimize yeast aerobic activity. Long-term crop planning to minimize aerobic activity from yeast in silages include properly sizing storage structures to allow aggressive feedout rates, rapid harvesting at proper maturity and moisture levels, the use of silage additives containing *Lactobacillus buchneri* and proper compaction and sealing.



Silage preservation is achieved by lactic-acid bacteria (LAB) converting sugar to lactic acid resulting in a lowering of pH to inactivate plant enzymes and inhibit detrimental microorganisms (epiphytic bacteria, clostridia, yeast, molds, etc.) that are on the plant at the time of ensiling. Lactic acid is considered the most desirable fermentation acid because it is a stronger acid than the other organic acids (acetic, propionic or butyrate) produced by silage microorganisms. An efficient and rapid pH drop diminishes the amount of sugar lost while minimizing protein degradation thus preserving/enhancing the nutritional quality of the ensiled feed.

When LAB inoculants were first conceived and commercialized, the focus was on reducing dry matter loss during the initial (front-end) fermentation by "seeding" the crop with "homofermentative" LAB, (e.g. *Lactobacillus plantarum*) which would dominate the process and efficiently convert a 6-carbon sugar into 2, 3-carbon lactic acids. It was assumed that the low pH would inhibit all the undesirable microorganism on the crop resulting in the best preservation possible. However, the first-generation of inoculants often failed when it came to preventing heating during silage feedout.

Not understood at the time was that certain lactate-assimilating yeast (e.g. *Candida* and *Hansula* species) were not inhibited by high lactic acid or low pH, but in fact, survived quite well under these conditions and then multiplied rapidly upon exposure to air during silage feedout. The yeast that utilize lactic acid as an energy source under aerobic (oxygen) conditions cause the silage pH to increase (due to loss of lactic acid) above inhibitory levels which creates an environment conducive to spoilage bacteria and mold growth. The end result is sugar, starch and protein loss and the generation of significant heat. It is now well documented that yeast populations are typically high on corn silage, grass silage and high-moisture corn (not on alfalfa) and play a key role in initiating the cascade of microbial events leading to heating in silage.

Once the yeast issue was identified, the next-generation of inoculants started to include "heterofermentative" LAB (e.g. *Lactobacillus buchneri*) which convert a 6-carbon sugar to 1, 3-carbon lactic acid and 1, 2-carbon acetic acid along with the loss of one CO2 (the ultimate cause of dry matter loss). It was originally believed that these heterofermentative LAB were undesirable as a silage inoculant strains since they did not lower the pH as low as the homofermentative LAB and lost a carbon from every sugar as CO2. However, as larger bunker and pile faces with slower feedout rates became the norm, heating in corn silage and high-moisture corn became a bigger issue in terms of nutrient loss and reduced palatability in the feedbunk. While acetic acid is not as strong of an acid as lactic acid, the acetic acid (and other compounds) produced by *L. buchneri* proved inhibitory to yeast populations.

It is widely accepted today that inoculants containing a combination of both homofermentative LAB (to efficiently drop pH) and heterofermentative *L. buchneri* (to inhibit yeast) have proven to be an effective management tool for driving "front-end" fermentation and reducing "back-end" heating at feedout. This combination of inoculant strains sometimes makes interpretation of laboratory volatile fatty acid reports confusing because in the silo, *L. buchneri* are much slower growing than the homofermentative LAB and become more active as the pH is lowered. At low pH, *L. buchneri* prefer lactic acid over sugar as their principal energy source so lactic acid levels decrease while acetic acid levels increase without altering the level of residual sugar left in the silage.

## ACETOBACTER

Recent investigations by Pioneer silage microbiologists, in well-managed corn silage, found situations where heating was occurring despite high levels of acetic acid and low yeast counts. Based on the current accepted understanding of aerobic instability, this should not be occurring. One clue to what was happening in these silages was the fact that deep core samples had higher than normal ethanol while ethanol was absent in surface samples. This suggested to our microbiologists that a microorganism able to metabolize ethanol must be present. After culturing these silages, we indeed found the newest villain in the silage stability story – acetobacter.

Acetobacter are a genus of acetic acid-producing bacteria (used in commercial vinegar production) that have the ability to preferentially convert ethanol (from yeast) to acetic acid in the presence of oxygen (at feedout). They are also capable of converting lactic and acetic acids to carbon dioxide, water and heat when ethanol levels are depleted. Acetobacter are gram-negative, strict aerobes and very acid-tolerant bacteria so low pH is not inhibitory to their survival. They are omnipresent in the environment, including soil, water and airborne and are relatively mobile in silages because, unlike LAB, they possess flagella. An easily observed attribute of both yeast and acetobacter metabolism is their ability to produce "fingernail polish" smelling ethyl acetate and ethyl lactate which may account for reduced intakes by cattle fed these silages. Under anaerobic (without oxygen) conditions, yeast produce ethanol which is converted to ethyl acetate and ethyl lactate spontaneously through an acid facilitated chemical reaction. The ethyl acetate and ethyl lactate from acetobacter occurs under aerobic conditions since that is where they have their greatest metabolic activity. In our research with acetobacter silages, we found that this "fingernail polish" aroma becomes noticeable about 24-hours before the onset of heating.

European researchers have found that the acetobacter and yeast often developed simultaneously when silage was exposed to air. While yeast are considered the main culprits of initiating heating when silage is exposed to air, researchers at the US Dairy Forage Research Center found that acetobacter initiated heating in all of their trials while yeast were significant in one-third of their trials. This suggests that the occurrence of heating during feedout due to acetobacter is more prevalent than previously thought. The lack of understanding of the role of acetobacter is also due to the fact that it is nearly impossible to enumerate acetobacter on selective media. When commercial microbiology labs report total aerobe counts, it is often incorrectly interpreted as primarily bacillus, but it likely also includes acetobacter.

Acetobacter can be found in well-managed, highly-compacted silages that have elevated ethanol levels from yeast growing in anaerobic conditions. While *L. buchneri* will not inhibit acetobacter levels, reducing yeast populations and their production of ethanol as a acetobacter substrate is helpful in reducing their negative impact. Bottom line is that producing the highest quality silage requires inoculation with research-proven products, adequate compaction and moisture to reduce porosity and excellent face management at feedout.



# FORAGE ADDITIVES

Market research indicates that bacterial inoculants account for 65-70% of all forage additives followed by acid preservatives at 20% which are used primarily on hay and high-moisture grains.

Silage producers and nutritionists are constantly looking for ways to improve forage yield and nutritional quality. When reviewing technological advances that have directly impacted forages, the inoculant industry may be among the most innovative. There have been improvements in forage genetics and equipment manufacturers have delivered significant gains with items like mergers or bunker facers. The scientific advances in microbiology have allowed the inoculant industry to deliver significant technologies over the past few decades which help:

1) reduce silage pH and conserve sugars,
2) reduce heating on increasingly large silage faces,
3) reduce dry matter loss whose energy value must be replaced with expensive grain sources,
4) improve consistency and palatability of ensiled feeds, and more recently,
5) the introduction of inoculants from Pioneer which contain a *Lactobacillus buchneri* strain capable of producing fiber degrading esterase enzymes while it grows in the silage (11CFT, 11AFT and 11GFT).

Terminal pH was historically the best assessment of inoculant efficiency with the goal of less than 4.5 for legumes and high-moisture grains and less than 4.0 for corn, cereal or grass silages. However, the problem with terminal pH is that although most silages eventually reach terminal pH, the issue is how long (and how many sugars) it took to reach a stable, terminal pH. There are tools today to better evaluate the effect of inoculation: VFA profiles, thermal camera imaging and lab methods such a Fermentrics® which allow for measuring digestion kinetics.

Pioneer has been basic in the identification and commercialization of silage bacterial strains since 1978. Pioneer silage microbiologists have developed a wide portfolio of crop-specific inoculants. Crop-specific products were a natural evolution driven by research proving not all bacteria functions the same way on every crop. If silage was thought of as bacterial growth media, consider how much difference there is between crops. Corn silage possesses high sugar with a low buffering capacity while alfalfa contains relatively low sugar levels with a high buffering capacity and is exposed to soil contaminants as it is wilted on the ground. High-moisture corn is the most difficult crop to ferment due to relatively low available water, very low sugar content and generally high yeast counts.

Inoculant product development is further complicated by the fact that Pioneer microbiologists have to individually test different strain combinations in both laboratory and animal trials. This is because bacterial strains can act differently when combined with various other strains as compared to when they are tested individually.

Inoculant technology advanced again in 2003 with the release of the first "combi" product (11C33) containing crop-specific homofermentative LAB strains in combination with *L. buchneri* to deliver rapid pH decline and significantly improved bunklife. Strains of *L. buchneri* prefer low pH for optimal growth and historically required 1-2 months of ensiling time to utilize preformed lactic acid (thus lowering lactic acid levels) and producing metabolites (acetic acid and 1,2 propanediol) which inhibit yeast growth. Feeding treated silages before 1-2 months of ensiling with older *L. buchneri* strains will present no concern, however, the bunklife may be less than expected. In 2016, Pioneer introduced "Rapid React" products containing a *L. buchneri* strain which confers excellent bunklife after only 7 days of fermentation.

Improving fiber digestibility has long been the ultimate goal for Pioneer microbiologists. Research clearly shows that adding certain enzymes to the TMR can improve fiber digestibility. The problem is that growing enzyme-producing bacteria in commercial fermentation tanks, purifying and stabilizing the enzymes and selling through distribution channels makes their use economically unviable for the silage market. Products that contain traditional fermentation bacterial strains along with enzymes have never been shown to improve digestibility beyond those containing bacteria alone. This is due to the high cost of purified enzymes prohibiting adequate inclusion rates.

Another technological breakthrough in improving fiber digestibility occurred with the introduction of a Pioneer Fiber Technology "combi" inoculant (11CFT) containing homofermentative LAB and a unique strain of *L. buchneri* capable of producing ferulate and acetyl esterase enzymes while growing in the silage mass. This enzyme helps uncouple lignin from polysaccharides in the cell wall increasing the rate of fiber digestion and generating more metabolizable energy and microbial protein yield from the silage. This allows for higher dietary forage inclusion rates and the opportunity to reduce ration costs by removing grain and protein due to the enhanced nutritive value of the forage.

Dozens of field studies have shown that the carbohydrate pools (B1, B2 and B3) as defined in the Cornell Model, have an increased rate of digestion in silages inoculated with the esterase-producing bacterial strain in 11CFT. Changing these digestion rates in ration-balancing software (like the CNCPS model) shows that the inoculated silage produces more metabolizable energy (ME) and metabolizable protein (MP) predicted milk while also yielding more microbial protein production (from rumen bacteria being able to more easily access the digestible portion of the cell wall).

It should be noted that corn silage treated with 11CFT will not act the same as feeding BMR corn silage. 11CFT-treated silage is an efficiency tool allowing for removal of some protein and energy from the diet because of faster digestion of the fiber. BMR corn silage tends to increase dry matter intake due presumably to the fragility of cell walls containing less lignin.

Nutritionists and producers have questioned the impact that silage-produced lactic and acetic acids have on that silage intake or ruminal acidosis. Lactic acid is produced by both silage bacterial species (Lactobacillus and Enterococcus) and by rumen organisms (*Selenomonas ruminantium*, *Streptococcus bovis* and *Lactobacillus species*). While lactic acid is a ten-fold stronger acid than other silage (or rumen) volatile fatty acids, the total acid (notably lactic) contribution from reasonably well-fermented silage is only a small fraction relative to the total acid load produced by rumen organisms.

Depressed intake has long been associated with silages high in ammonia, amides, and amine compounds (such as histamine) which are end-products of silage protein degradation that occurs during fermentation. If fermentation is extended, these protein degradation products typically increase in concentration similar to acid concentrations. Ammonia nitrogen (expressed as % of total nitrogen) of less than 5% typically indicates high quality silage.

Research from Europe and the U.S. shows that high levels of acetate (e.g. lactic: acetic acid ratios of near 1:1) have no negative impact on feed intake if the high acetic level was the result of silage treated with strains of *L. buchneri*. However, acetic acid produced by yeast, gram-negative acetic acid producers such as enterobacter species or heterofermentative lactic-acid bacteria like leuconostoc species may contribute to poor bunklife or feed intake issues.

As inoculants become more sophisticated in their ability to manipulate fermentation and digestibility, it may be possible to make forages higher in nutritional value than the day they were harvested; much like kernel processing improves corn silage nutritional value. Cutting-edge inoculant products should probably be viewed as more of a management tool to help improve nutritive value rather than as an insurance policy to reduce potential losses. As the inoculant industry evolves, it will be important for nutritionists to fully understand the mode of action of products because ration formulation may need to be altered to fully capture the value delivered by these products.

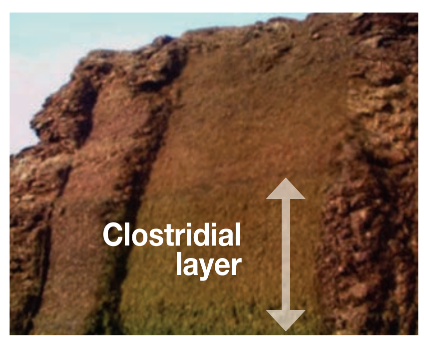
## INOCULANT APPLICATION

For inoculation to be effective in reducing dry matter loss, improving bunklife and enhancing nutrient digestibility, it is essential that the bacteria be uniformly distributed in the silage mass. Lactic acid bacteria do not have flagella and do not migrate very far within the silage mass. The most common and preferred method to facilitate distribution on the crop is liquid application applied to the silage in the accelerator (blower) of the forage harvester.

## VFA PROFILES

Practical interpretation of silage volatile fatty acid (VFA) profiles can be challenging, especially if additives containing *L. buchneri* were used and not recorded by the laboratory. Furthermore, many of the datasets from commercial laboratories are biased from the submission of problem samples. In general, a higher moisture crop equals longer fermentation and higher total acid load. It is not unusual for low dry matter grass silages to have total acid levels in excess of 10%. Typical North American silages treated with a homofermentative inoculant will have a lactic-to-acetic acid ratio much greater than 2:1. As discussed earlier, the lactic-to-acetic acid levels can approach 1:1 in products containing *L. buchneri* which metabolize lactic acid to produce acetic acid and 1,2 propanediol.

The one VFA which should be absent from quality silages is butyric acid produced by clostridia. Silages high in moisture and contaminated with soil (high ash) tend to have more problems with butyric acid. Butyric acid reduces palatability, feed intake and has the potential to predispose ruminants to ketosis. Recommendations are to limit daily intake of butyric acid to 50 grams or less for early lactation cows with levels exceeding 150 grams posing a high risk for ketosis. Ketosis risk is high at any stage of lactation when daily intake levels exceed 250 grams (see table).






### TYPICAL *L. buchneri* INOCULATED CORN SILAGE VFA PROFILE

| FERMENTATION PROFILE | |
|---|---|
| pH | 3.8 |
| Lactic Acid, % DM | 3.1% |
| Acetic Acid, % DM | 1.8% |
| Propionic Acid, % DM | 0.4% |
| Ammonia Nitrogen, % Total Nitrogen | 4.6% |

### TYPICAL HOMOFERMENTATIVE INOCULATED CORN SILAGE VFA PROFILE

| FERMENTATION PROFILE | |
|---|---|
| pH | 3.6 |
| Lactic Acid, % DM | 4.6% |
| Acetic Acid, % DM | 0.8% |
| Propionic Acid, % DM | 0.1% |
| Ammonia Nitrogen, % Total Nitrogen | 4.6% |

### BUTYRIC ACID SILAGE FEEDING THRESHOLDS

| % Butyric Acid in silage (DM basis) | mg/lb | lbs DM intake to stay below butyric acid threshold (Source: Dr. Gary Oetzel, Univ. of WI.) | | |
|---|---|---|---|---|
| | | 50g/cow/day | 150g/cow/day | 250g/cow/day |
| 0.25 | 1.1 | 44.1 | 132.2 | 220.3 |
| 0.50 | 2.3 | 22.0 | 66.1 | 110.1 |
| 0.75 | 3.4 | 14.7 | 44.1 | 73.4 |
| 1.00 | 4.5 | 11.0 | 33.0 | 55.1 |
| 1.25 | 5.7 | 8.8 | 26.4 | 44.1 |
| 1.50 | 6.8 | 7.3 | 22.0 | 36.7 |
| 1.75 | 7.9 | 6.3 | 18.9 | 31.5 |
| 2.00 | 9.1 | 5.5 | 16.5 | 27.5 |
| 2.25 | 10.2 | 4.9 | 14.7 | 24.5 |
| 2.50 | 11.4 | 4.4 | 13.2 | 22.0 |
| 2.75 | 12.5 | 4.0 | 12.0 | 20.0 |
| 3.00 | 13.6 | 3.7 | 11.0 | 18.4 |
| 3.25 | 14.8 | 3.4 | 10.2 | 16.9 |
| 3.50 | 15.9 | 3.1 | 9.4 | 15.7 |
| 3.75 | 17.0 | 2.9 | 8.8 | 14.7 |
| 4.00 | 18.2 | 2.8 | 8.3 | 13.8 |
| 4.50 | 20.4 | 2.4 | 7.3 | 12.2 |
| 5.00 | 22.7 | 2.2 | 6.6 | 11.0 |
| 5.50 | 25.0 | 2.0 | 6.0 | 10.0 |
| 6.00 | 27.2 | 1.8 | 5.5 | 9.2 |
| 6.50 | 29.5 | 1.7 | 5.1 | 8.5 |
| 7.00 | 31.8 | 1.6 | 4.7 | 7.9 |
| 8.00 | 36.3 | 1.4 | 4.1 | 6.9 |
| 9.00 | 40.9 | 1.2 | 3.7 | 6.1 |

## PROTEIN DEGRADATION

Ammonia-nitrogen ($NH_3$-N) as a percent of total nitrogen can be an indicator of the length of fermentation and/or clostridial fermentation. In general, a faster fermentation results in less proteolysis. $NH_3$-N levels (as a % of total N) should be less than 5% in corn/cereals and less than 10% in grass/legume silages.

Heat damaged (bound or unavailable) protein in silages is monitored with acid detergent insoluble nitrogen (ADIN) as a percent of total nitrogen. Levels exceeding 12% indicate excessive heating (>130°F) in forage silages and may require adjustment to the crude protein level in the ration. Pepsin insoluble nitrogen (as a percent of total nitrogen) levels greater than 20% indicate excessive heating with high-moisture earlage, snaplage or shelled corn.

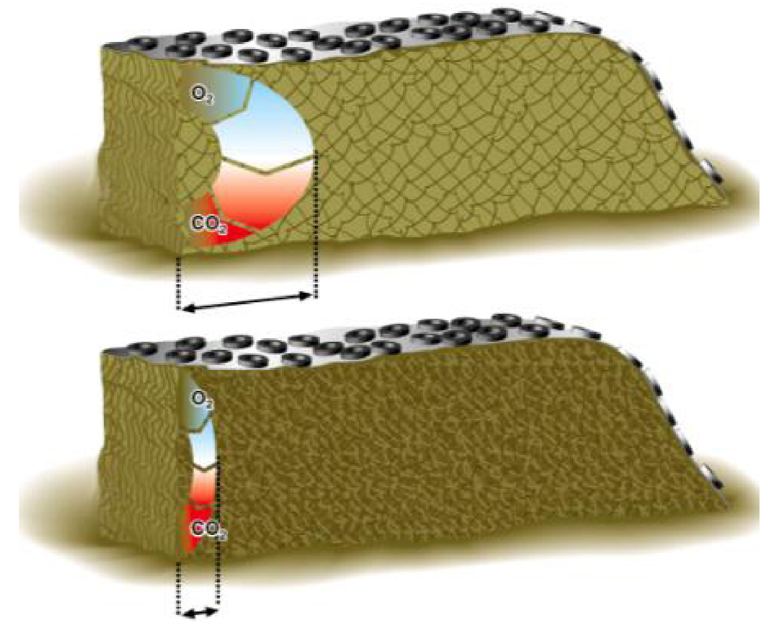
# COMPACTION AND SEALING

Packing bunkers and piles is one of the most critical elements in ensuring quality silage. Poorly packed, low dry matter silages will have extended plant cell respiration resulting in an increased loss of digestible nutrients. Entrapped air can allow the growth of aerobic microorganisms (yeasts and molds) which are detrimental to the ensiling process. Most of the silages that heat (>15°F above ambient temperature at harvest) are the result of poor compaction. Density is what is easily measured at the bunker, but it is really porosity (air movement) that management approaches are trying to reduce. Measuring density can be dangerous in large bunkers or piles with unstable faces. One of the advantages of thermal imaging is the ability to safely view the entire face with the heat signature indicative of areas with excessive porosity.

Research from Wisconsin addressed the relationship between silage bulk density and the porosity of silages. The goal is to help producers target harvest moistures which will produce porosity values less than 40% ultimately reducing oxygen penetration into the exposed face.

Two of the factors most correlated with high density (to help reduce porosity) is time spent packing per ton and depth of the individual layers being compacted. The goal is to pack in thin layers of less than six inches. When building piles, it is also important to keep a slope of approximately 30 degrees to ensure that the "tails" of the pile are not too long and shallow. It has always been recommended to build bunkers using a progressive wedge approach, rather than spreading silage out flat in thin layers. However, given the capacity to fill bunkers today, if the entire bunker can be filled in a relatively short time (1-2 days) it may facilitate easier and more uniform packing to fill the bunker in layers rather than as a progressive wedge.

Pack density should exceed 15 lbs dry matter per cubic foot for forages and over 30 lbs of




## TO MINIMIZE SILAGE POROSITY, RECOMMENDED DRY MATTER DENSITIES VARY WITH FORAGE DM

| | DM density values within the white cells do not meet recommended silage bulk density and porosity goals | | | Shaded cells in the table are recommended on-farm silage DM density to meet porosity goals based on forage DM | | |
|---|---|---|---|---|---|---|
| Bulk Density (lb as fed/ft³, kg as fed/m³) (Goal >44, 704) | 30, 480 | 35, 560 | 40, 640 | 45, 721 | 50, 801 | 55, 881 |
| Forage DM | Top number in table is Porosity - Goal is <40<br>Bottom numbers in table is recommended DM density expressed in blue as lb DM/ft³ and in black as kg DM/m³ | | | | | |
| 25% | 55.9<br>7.5, 120 | 48.6<br>8.8, 141 | 41.3<br>10.0, 160 | 33.9<br>11.3, 181 | 26.6<br>12.5, 200 | 19.2<br>13.8, 221 |
| 30% | 56.7<br>9.0, 144 | 49.5<br>10.5, 168 | 42.3<br>12.0, 192 | 35.1<br>13.5, 216 | 27.9<br>15.0, 240 | 20.7<br>16.5, 264 |
| 35% | 57.5<br>10.5, 168 | 50.5<br>12.3, 197 | 43.4<br>14.0, 224 | 36.3<br>15.8, 253 | 29.2<br>17.5, 280 | 22.2<br>19.3, 309 |
| 40% | 58.3<br>12.0, 192 | 51.4<br>14.0, 224 | 44.5<br>16.0, 256 | 37.5<br>18.0, 288 | 30.6<br>20.0, 320 | 23.6<br>22.0, 352 |
| 45% | 59.1<br>13.5, 216 | 52.3<br>15.8, 253 | 45.5<br>18.0, 288 | 38.7<br>20.3, 325 | 31.9<br>22.5, 360 | 25.1<br>24.8, 397 |
| 50% | 59.9<br>15.0, 240 | 53.3<br>17.5, 280 | 46.6<br>20.0, 320 | 39.9<br>22.5, 360 | 33.3<br>25.0, 400 | 26.6<br>27.5, 440 |

As Forage DM Goes Up

DM Density (blue Values) Must Go Up To Reduce Porosity

As bulk density (as fed) increases, porosity decreases. For a given bulk density, increasing dry matter content (decreasing moisture content) increases porosity. In the recommended range of dry matter content (30-40%) for good fermentation, the range of porosity does not change very much. However ensiling forage at higher DM does increase porosity appreciably. A porosity of 0.40 or lower appears to be a reasonable goal. To achieve this value, a 44 lbs/cu ft of bulk density is needed within the acceptable dry matter range of 30-40%. Under these conditions, the dry matter density is in the range of 13.3-17.6 lbs DM/ft³.

*Source: Holmes, B. 2009. Density and porosity in bunker and pile silos. Available on UW Extension – Forage Resources*
*Website: http://fyi.uwex.edu/forage/files/2014/01/Porosity-FOF.pdf*

dry matter per cubic foot for high-moisture grains to provide the anaerobic environment that will help improve both fermentation and feedout stability.

A good rule of thumb for the required pack tractor capacity is to multiply the tons of silage being delivered to the bunker per hour by 800. For example, if corn silage is being delivered to the bunker at 200 tons per hour, a total of 160,000 tons worth of pack tractor capacity is needed (or about four large pack tractors, not counting the push tractors).

In general, silages cannot be over-packed; except for the very top layer. It is best to level off the top and cover with oxygen-barrier film and plastic as quickly as possible. Spending hours on the top of a bunker does very little to compact the entire mass and causes problems by rupturing plant cell walls, exposing water and nutrients to aerobic spoilage organisms. The darkish layer that looks similar to "fill lines" at about 12 inches below the top of an otherwise very well managed bunker is often the result of spending hours over-packing the top layer. A migration of water and nutrients into the silage mass about 12 inches from the top allows spoilage organisms to thrive in this area.

## 800 lb RULE (total pack tractor weight required based on how much coming to the bunker/hour)

- 800 lbs worth of pack tractor is required per ton as fed delivered to the bunker per hour. Example:
  - If the chopper can deliver 100 tons as fed deliver to pile/hour * 800 = 80,000 worth of pack tractors needed (not counting push tractors) per chopper.
  - Generally requires a minimum of 2 heavy pack tractors and one push tractor per large self-propelled chopper

**MAY REQUIRE:**
- adding tractor weights
- increasing tire pressure
- using larger vehicles
- more pack tractors

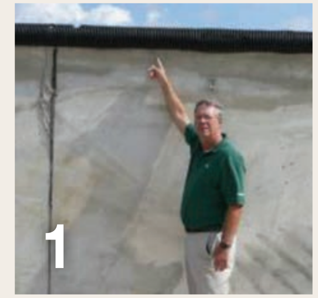
## 2.5 RULE (tons you can bring to the bunker per hour based on your total pack tractor capacity)

- 80,000 lbs total pack tractor capacity = 40 tons * 2.5 = 100 tons of as fed silage can be delivered to bunker per hour given the pack tractor capacity

Note how tractors drive over sides of a well designed pile (1:3 slope)

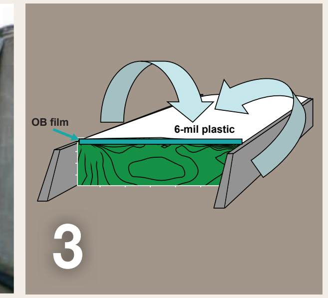


## MAKING A "BAG OUT OF A BUNKER"

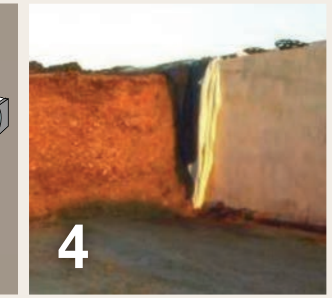



Put drainage tile on top of bunker walls so plastic will not rip when pulled over the side walls.


Secure plastic with some feed and drape it over the wall. Lay down 4-6" drainage tile behind plastic. Don't worry if it rips a little when packing; it will still serve its purpose.




Place oxygen-barrier film on the top under the plastic for added protection. Pull plastic over walls and cover silage, lapping the sheets.




Rain/melted snow runs down between wall and plastic and exits via drainage tile providing enhanced preservation for silage against the wall.

Sealing the silage mass is an important next step. This should be done as soon as possible by covering with oxygen-barrier film and 6-8mm white plastic (to reflect sunlight and reduce condensation below the plastic). Consider putting plastic down the walls of bunkers to create "a bag out of a bunker." Be sure the plastic is overlapped between sheets so moisture will drain off on top to the plastic and not into the silage. Plastic should be weighted down with pea gravel bags or tries to keep the plastic tightly secured. This is especially important on the front edge to prevent air billowing into the silage. If the bunker is sloped correctly, it is advisable to have 12-24 inches of the plastic hang over the face to shed water off the exposed face during rain events.


Pack tractors with a blade rather than a bucket (like on pay loaders) do a much better job of "feathering" out the silage into the recommended 6-inch layers. Front-wheel and front wheel-assist drive tractors (with dual wheels on both rear and front) provide extra traction, stability and allow for easier packing than with pay loaders. A 3-point lift (hitch) is advantageous to add weight to the back along with filling the inside dual tires with fluid and adding extra lights for night time packing. Having three hydraulic remotes to run the blade, a foot throttle, a left-hand reverser for clutch less shifting, plenty of rear-view mirrors (properly adjusted) and a "buddy seat" to train other drivers, rounds out the wish list for the ideal pack and push tractor.

# MANAGING DRIVE-OVER PILES

Drive-over piles are becoming increasingly popular for several reasons:

1) faster to fill and feedout,
2) better understanding of the proper shape/slope and
3) less spoilage on the tails due to the technologies of oxygen-barrier film and *L. buchneri* inoculants.

A good drive-over pile starts with a solid base of gravel, compacted lime, asphalt or concrete. Once a manageable pile height is set (determined by the maximum height the bucket or tele-handler can reach), the width is determined by the proper side slope. The maximum recommended side slope is 1:3 or 1 foot of rise for each 3 horizontal feet. So if the pile is 10 feet tall at the top, a 1:3 side-slope results in 30 feet of silage on each side, or a 60 foot wide pile. A 30% maximum slope is critical because if the slope is any steeper it is dangerous for pack tractor drivers, and the silage doesn't get adequately packed on the sides. Silage pile ends should have the same slope as the sides so the entire pile can be driven over from any direction.

## HOW NOT TO MAKE A DRIVE-OVER PILE

- Slope too steep
- Did not drive pack tractor over all sides
- Tires holding plastic slip off or don't really weight down the plastic
- Air being billowed into the silage mass along sides where tires slid off

# BALEAGE

For many smaller producers, baleage offers more flexibility than harvesting dry hay. Baleage is best harvested between about 35-70% moisture to ensure adequate fermentation. Baleage stored at 20-30% moisture is generally less successful due to moisture limiting an acceptable fermentation.

University of Wisconsin researchers recommend using a cutter on the front of the baler to cut the hay into 4-inch lengths for greater packing density, easier use in a TMR mixer, and less feed lost when fed in a feeder. They suggest wrapping baleage within 24-hours of harvest with a minimum of at 6mil, preferably 8mil, of plastic wrap. This can be accomplished by wrapping 6 times with 1ml plastic or 4 times with1.5 mil plastic. Research with 4mils of plastic showed that oxygen leaked through the plastic resulting in microbial growth and spoilage. Total plastic thickness, not the number of wraps appears to be the most important factor to resist oxygen from reaching the feed.

Wrapping is a preferred storage method but long-term storage might be aided by the use of an inoculant or acid, if adequate distribution of the products can be achieved at the baler. Silage bales should be stored on a smooth, dry surface where ripping of plastic and rodent damage can be minimized.




# FEED

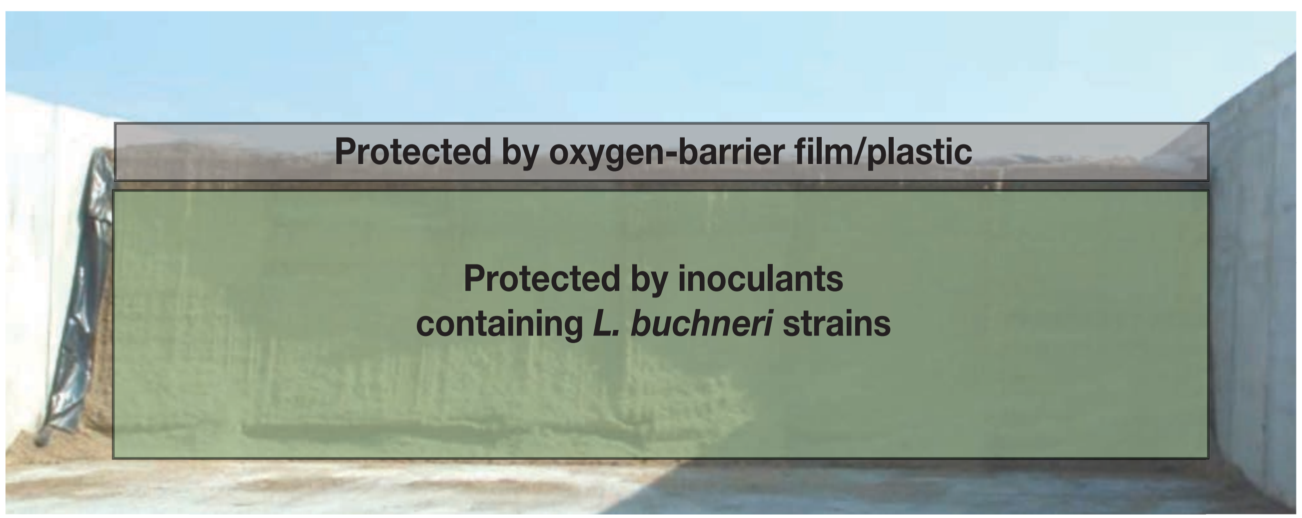
# FEEDOUT MANAGEMENT

Proper silage feedout management is essential to maintain consistent and high quality ensiled forages and high-moisture grains. Research shows that poor face management can easily double dry matter losses. Besides the financial loss associated with these losses, feed quality and consistency can vary dramatically and may contribute to livestock production and health problems. As mentioned earlier, porosity is the enemy so proper moisture (to fill in the air spaces), particle size, compaction (density) and sealing methods are also the key to maintaining anaerobic conditions. It is also advisable to remove and dispose of visibly moldy feed from the sides or top of the storage structure and not to allow loose, aerated silage to pile up for extended periods of time before feeding.

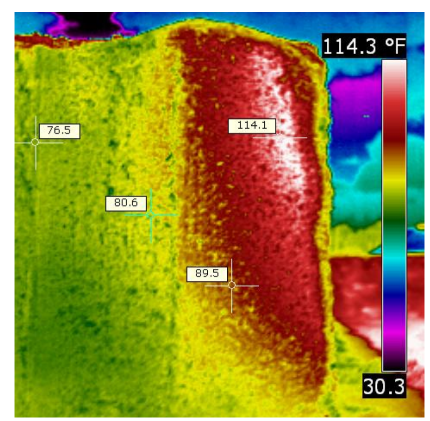
Proper feedout practices are especially important during warm periods of the year because the biological activity of aerobic bacteria and yeast organisms increases twofold for every 10°C increase in temperature. Consequently, it becomes challenging to stay ahead of aerobic instability during the spring and summer. It is also common to have bunklife problems with harvested forages that have been rained on before chopping and ensiling. Rain can leach crop sugars and splash soil-borne bacteria and fungi (mold) onto the crop, effectively "seeding" the silage with spoilage organisms awaiting the chance to grow if provided the opportunity. Crops stressed by drought, insect or hail damage will generally possess elevated fungal counts dictating that proper management be followed when ensiling these stressed crops.

The first criterion for stable silage is achieving a low terminal pH producing a hostile environment to inhibit the propagation of spoilage microorganisms such as aerobic bacteria, yeast and molds. Inoculants containing *L. buchneri* strains have been a tremendous benefit by inhibiting the growth of yeast. A second criteria for stable silage is the maintenance of an anaerobic, or "oxygen free" environment for as much of the silage as possible.

Silages should ideally be removed from bunker and pile faces by mechanically shaving the silage face from top to bottom or peeling the silage horizontally with a front-end loader bucket. This is preferred to lifting the bucket from the bottom to the top. Lifting creates fracture lines in the silage mass allowing oxygen to enter which promotes aerobic activity. Even when removing the desirable 6-12 inches daily from the silo face, oxygen can still penetrate several feet into the stored mass. This facilitates heat-generating aerobic activity which may not fully dissipate from the face. Use of inoculants containing *L. buchneri* allow for reduced feedout rates while maintaining aerobic stability. Research shows that the stability of the entire TMR can be maintained, as well as acid-based TMR products, when at least 14 lbs forage dry matter was treated with Pioneer's *L-buchneri*-containing silage inoculant and included in the TMR. Silage facers are becoming increasingly popular. They "blend" feed across the entire face and cleanly remove silage without disrupting compaction, which is often the result with improper use of front-end loader. Blending of silage also averages the variation in feed quality due to field-induced differences (e.g. water-holding capacity, nitrogen fertility etc.).




The accompanying pictures show normal and thermal imaging of a well-managed bunker which was being mechanically faced. This bunker was split down the middle as it was excessively wide and feedout rate was a concern. However, the thermal image clearly shows by the reddish-white colors that oxygen is penetrating the exposed side resulting in aerobic activity and nutrient loss. When bunkers are inoculated with reputable products containing *L. buchneri*, it is recommended to feed across the entire face, even if only removing 2-3 inches per day, rather than splitting the bunker and prolonging oxygen exposure on the exposed side.




# FEEDOUT SAFETY

Reported incidences of silage avalanches are increasing at an alarming rate. These cause machinery damage (front-end loader windows) and worker injury or death. It is imperative to think about safety while taking forage samples from bunker/pile faces, measuring density, removing spoiled feed or simply operating buckets or facers. Several companies forbid employees to approach silage bunkers or pile faces due to the liability concern.

Dangerous way to sample silage due to potential for silage avalanche

Be careful of pack tractors if near the storage structure during filling

# SILAGE STORAGE SAFETY REMINDERS

- A second individual should always be present at the bunker when sampling feed, removing top-spoilage or testing bunker densities.
- Obtain representative forage samples at the mixer wagon and not at the silage face.
- When standing on the top of a bunker, stay at least 15 feet behind the face and do not approach if the integrity of the face is questionable.
- Be extremely careful removing top-spoilage or moving tires and cutting back plastic. Consider implementing a fall-prevention harness cabled to a post secured a distance from the face.
- Do not stand in front-end loader or skid-steer buckets to procure samples from higher heights.
- Be cautious of avalanches in silages, especially when observing a layer of dry silage between two moist layers.
- Be careful walking around bunkers and piles that have visible silage leachate and slippery wet conditions.

**Unsafe removal of top spoilage due to potential for silage avalanche**

# SILO GAS

Caution should be exercised when working around silages within three weeks of harvest due to the potential for lethal nitrous oxide silo gases with the aroma of bleach. When tower silos were the norm, it was a common practice to run the blower for at least 15 minutes before entering a recently filled silo. Silo gas is heavier than air and can exist around bunker, pile or bagged silages, especially near the ground where there is minimal air movement.

Silo gas is common in all silages but more so in forage crops such as corn and sorghum that accumulate nitrates from exposure to stress situations including drought, hail, frost, cloudy weather and fertility imbalances. Nitrates accumulate in the lower portion of the plant when the crop yield is less than the supplied nitrogen fertility level. Nitrates are responsible for lethal silo gas when they combine with organic silage acids to form nitrous oxide. The nitrous oxide decomposes to water and a mixture of nitrogen oxides including nitrogen oxide (colorless), nitrogen dioxide (reddish-brown color) and nitrogen tetraoxide (yellowish color). These forms of nitrogen are volatilized as a brownish gas in the atmosphere. This gas is heavier than air and very lethal to humans and livestock.

## NITRATE LEVELS IN FORAGES FOR CATTLE

| NITRATE ION % | NITRATE NITROGEN PPM | RECOMMENDATIONS |
|---|---|---|
| 0.0-0.44 | <1000 | Safe to feed under all conditions |
| 0.44-0.66 | 1000-1500 | Safe to feed to non-pregnant animals. Limit use for pregnant animals to 50% of total ration on a DM basis. |
| 0.66-0.88 | 1500-2000 | Safe to feed if limited to 50% of the total DM ration. |
| 0.88-1.54 | 2000-3500 | Feeds should be limited to 35-40% of the total DM in the ration. Feeds over 2000 PPM nitrate nitrogen should not be fed to pregnant animals. |
| 1.54-1.76 | 3500-4000 | Feeds should be limited to 25% of total DM in the ration. Do not feed to pregnant animals. |
| Over 1.76 | >4000 | Feeds containing these levels are potentially toxic. DO NOT FEED. |

*Adapted from: Cornell University. To convert % nitrate ion ($NO_3$) to ppm Nitrate-Nitrogen divide %$NO_3$ by 4.4 to obtain %$NO_3$-N and multiply %$NO_3$-N x 10,000 to obtain ppm $NO_3$-N.*



# NITRATES

Similar to silo gas, the potential for high nitrate levels occurs when crops such as corn, sorghum, and some grasses are exposed to stress situations including drought, hail, frost, cloudy weather and fertility imbalance. Immature corn that undergoes these stressors accumulate toxic nitrate concentrations in the lower portion of the stover when crop yield is less than the supplied nitrogen fertility level and due to reduced plant biochemical functions impeding nitrogen from being converted to crude protein in the kernel. If it rains, three days should be allowed before resuming harvest as plants that recover from stress will eventually convert nitrates to a non-toxic form. Nitrates are not only responsible for lethal silo gas but when fed to animals, they induce symptomatic labored breathing due to interfering with the blood's ability to carry oxygen.

If the crop has been stressed or shows a marked reduction in grain content, a forage nitrate analysis is advised. As a general recommendation, feeding programs should be modified if the only source of post-fermented feed contains more than 1,000 PPM of nitrate-nitrogen. It is best to feed stressed crops as silage rather than fresh, green-chop because fermentation typically reduces plant nitrate levels by approximately 40-50 percent. When feeding ruminants non-fermented, droughty corn stalks as a major source of their diet (e.g. wintering beef cows), producers need to closely monitor nitrate levels.

Drought or stressed silages that have not been inoculated should ferment a full three weeks before feeding. If a sorghum or corn crop is inoculated with a reputable product, nitrate levels should be reduced by 40-50% in a matter of a few days. Ruminants can be fed higher nitrate feeds if the rumen bacteria are given time to adapt by gradually increasing the volume of high-nitrate feed in the ration and if cattle are fed more frequently than normal. Problems also can be reduced by diluting the stressed silage with other feeds and avoiding the use of non-protein nitrogen sources, such as urea or ammonia.

It is a common recommendation to leave a higher stubble (e.g. 12") when chopping drought-stressed corn to reduce the nitrate accumulation that occurs in the lower portions of the stalk. However, most growers are in need of forage inventory during drought conditions. Therefore, it is acceptable to chop at normal heights (4-6") to increase forage inventories given that the fermentation process will degrade 40-50% of the nitrates and if the silage in question will not be the sole forage. For example, nitrate-N levels of up to 2000 ppm are acceptable if the post-fermented feed if limited to 50% of the entire diet. This means that the pre-fermented crop could have levels upward of 3500-4000 ppm nitrate-nitrogen.

# PRUSSIC ACID

Prussic acid (or HCN, hydrogen cyanide) can be produced in forage and grain sorghums, johnsongrass, white clover, vetch seed, shattercane and to a lesser degree in sudangrass. Sorghum-sudangrass hybrids are intermediate but also a potential threat. The leaves of cherry trees. Young, upper leaves and new shoots (especially those produced after a frost) contain more prussic acid than stems, seeds or lower leaves.

Prussic acid does not occur in healthy plants. It is when plant tissues are damaged by drought, cool and cloudy weather, wilting, freezing, chopping or chewing (or released by rumen bacteria) that enzymes come into contact with plant cyanogenic glycosides and produce prussic acid.

Prussic acid symptoms can occur within 15-20 minutes of consumption and death an be rapid if not treated (typically with intravenous sodium nitrite and sodium thiosulfate). Prussic acid interferes with cellular oxygen use and can cause asphyxiation and death in just a few minutes. Difficulty breathing, muscle tremors/convulsions and bright red colored blood are common characteristics.

Frost and drought bring on the greatest potential for prussic acid production. University of Nebraska recommends not to graze or green chop for several days after a killing frost because frozen plants can release high concentrations for several days. After wilting, prussic acid release from plant tissue will decline. Dead plants have even less free prussic acid. When only plant tops have been

| HCN, ppm (DM basis) | EFFECT ON LIVESTOCK |
|---|---|
| 0 - 500 | Generally Safe |
| 600 - 1000 | Potentially toxic, should not be the sole source of feed |
| > 1000 | Dangerous to cattle, DO NOT FEED |

*Source: Dairyland Labs, Arcadia, WI*

frosted, new shoots may regrow at he base of plants and be very high in prussic acid. University of Nebraska recommendations are not to graze frosted plants until regrowth of shoots are over 15 inches tall or until several days after the entire plant and shoots are killed by a subsequent frost.

Drought-stricken plants are composed primarily of leaves and have a high potential to produce prussic acid. This is particularly a problem when new growth is brought on by rain following a drought. Grazing drought-stressed stunted plants is the most common cause of prussic acid poisoning.

Sorghum hay and silage can loose upwards of 50% of the prussic acid but problematic levels may still exist should the forage had extremely high levels at harvest.

Dairyland Labs is among several labs that offer prussic acid analysis. Their recommendation for sampling include: 1) obtain fresh samples during late morning or early afternoon as levels decrease in the late afternoon and evening., 2) collect random samples from several pasture locations or cores from several bales, 3) seal in plastic bag and store in dark, cold (not frozen) environment and 4) deliver to lab quickly and do not ship samples that may take multiple days to arrive at the lab.




# MANAGING MOLDS AND MYCOTOXINS

Mold contamination in silage poses a significant risk to livestock health and farm productivity. Molds can enter corn during various stages of growth and persist through harvest and ensiling. They may produce mycotoxins, which are harmful compounds that can severely impact the quality of silage and cause adverse health effects in animals. Understanding the types of molds, the conditions that favor their growth, and effective management strategies is crucial for maintaining high-quality silage and ensuring animal health.

## FIELD MOLDS

Field molds originate from spores that are omnipresent in the environment. These spores can survive winter in soil and plant residues, making reinfestation of crops during the next growing season highly probable. Fungi typically enter corn plants through the roots during the seedling stage, via silk channels during pollination, or through wounds caused by environmental stressors such as wind, hail, or insect damage. Aspergillus and Fusarium are two of the most common field fungi that affect corn and are capable of producing dangerous mycotoxins, such as aflatoxin, vomitoxin (DON), fumonisin, zearalenone (ZEA), and T-2 toxin.

While fungi responsible for smuts or foliar rust diseases generally do not produce mycotoxins that are harmful to livestock, ear molds can lead to potential contamination with toxins. Plant stressors, including drought, insect damage, or inadequate pollination, can weaken plant defenses and create ideal conditions for the development of ear molds. It is estimated that 70–90% of all mycotoxins found in silage are already present on the plant before harvest and ensiling. However, visible ear mold does not always correlate with mycotoxin contamination, and the absence of visible mold does not guarantee toxin-free silage. The absence of visible mold also does not guarantee that silage is toxin-free. Proper hybrid selection plays a key role in mycotoxin prevention: dual-purpose hybrids typically accumulate less DON than BMR hybrids, making them a better choice for silage when mycotoxin risk is a concern.

### REDUCING MYCOTOXIN RISK FROM FIELD MOLDS:

1. **Select resistant corn hybrids –** Choose hybrids with resistance to fungal diseases like Fusarium and Aspergillus.
2. **Rotate crops –** Regular crop rotation helps prevent mold buildup in the field.
3. **Apply fungicides at key growth stages –** Use fungicides strategically during vulnerable growth stages to reduce mold infections.
4. **Harvest at optimal moisture –** Timely harvesting at the right moisture level minimizes mold growth.

## Environmental and Physiological Factors Influencing Mold Growth

Mold growth and mycotoxin production are influenced by environmental and physiological conditions. Fusarium, for example, thrives in humid conditions (>70% humidity) and in climates where days are hot, and nights are cool. This temperature fluctuation increases the likelihood of toxin production. Fusarium species can grow at temperatures of 25–30°C without producing mycotoxins, but oxidative stress, often induced by plant infection, triggers the production of toxins like DON. Specifically, the production of DON has been associated with oxidative stress within the host plant, which promotes peroxide synthesis, subsequently triggering mycotoxin production.

While low oxygen and low pH conditions during ensiling are not conducive to Fusarium growth, the mycotoxins that have already been produced in the field, such as DON, remain stable throughout the ensiling process. Recent research indicates that DON levels may increase during ensiling. This increase could be attributed to the conversion of conjugated forms of DON, such as DON-3-glucoside (DON-3G), back into DON during fermentation. Inadequate packing or delayed fermentation that allows oxygen to infiltrate silage may also contribute to elevated DON levels. Monitoring DON levels 30 days after harvest gives a more accurate picture of the contamination status, as the fermentation process typically stabilizes within this timeframe.

## Key Field Mycotoxins and Their Impacts

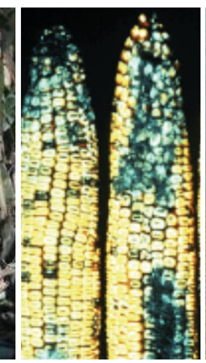
The most concerning mycotoxins produced by field molds include DON, T-2 toxin, fumonisin, and ZEA, all synthesized by Fusarium species. It is important to note that some publications group DON and T-2 toxin under trichothecenes, a class of mycotoxins produced by several fungal genera, including Fusarium. Each of these mycotoxins poses serious health risks to livestock, particularly cattle:

| TOXIN | INTERPRETATION | FIELD VS STORAGE | ANIMAL HEALTH ISSUES |
|---|---|---|---|
| Deoxynivalenol (DON) | Fusarium graminearum<br>Fusarium culmorum | Field | Gastrointestinal issues, reduced performance |
| Zearalenone (ZEA) | Fusarium graminearum<br>Fusarium culmorum | Field | Reproductive issues, hyperestrogenism |
| Fumonisins | Fusarium verticillioides<br>Fusarium proliferatum | Field | Liver and kidney damage, reduced performance |
| T-2 Toxin | Fusarium sporotrichioides<br>Fusarium poae | Field | Gastroenteritis, immunosuppression |
| Aflatoxins | Aspergillus flavus<br>Aspergillus parasiticus | Field and Storage | Liver disease, decreased milk quality, immunosuppression |
| Ochratoxin A (OTA) | Aspergillus ochraceus<br>Penicillium verrucosum | Storage | Kidney damage, immunosuppression |
| Roquefortine C | Penicillium roqueforti<br>Penicillium paneum | Storage | Reproductive disorders, mastitis, lack of appetite |
| Mycophenolic Acid | Penicillium roqueforti<br>Penicillium paneum | Storage | Immunosuppression |

- **DON (Deoxynivalenol):** Although ruminants are relatively resistant to DON, exposure to high levels can lead to reduced feed intake, decreased weight gain, and lower milk production. DON also has the potential to alter rumen microbial activity, which may impact digestion efficiency.
- **T-2 Toxin:** T-2 is a type of trichothecene that is particularly toxic and can have severe health impacts on cattle. Symptoms include gastrointestinal lesions, decreased feed intake, immune suppression, and in severe cases, hemorrhages in the digestive tract. T-2 can also lead to reduced reproductive performance and poor weight gain.
- **ZEA (Zearalenone):** ZEA is an estrogenic mycotoxin that mimics natural estrogen, potentially causing reproductive issues such as reduced conception rates, infertility, abortions, and mammary gland enlargement in cattle. Chronic exposure can lead to long-term reproductive challenges within the herd, especially among heifers.
- **Fumonisin:** Fumonisin is linked to kidney and liver damage in cattle. Although ruminants are generally more tolerant of fumonisin than other species, high levels can cause reduced milk production and potential damage to liver function. Fumonisin can also negatively impact immune function, making animals more susceptible to infections.

Conditions that increase mold and mycotoxin proliferation include delayed harvesting, poor compaction, and compromised silo covers. Additionally, Aspergillus and Penicillium species, common in silage, are known to produce aflatoxins and other dangerous mycotoxins, especially under conditions of high temperature and moisture.

**Fusarium graminearum Spp.** (also called Gibberella zeae or Gibb)



**Penicillium Spp.**

**Gibberella Ear Rot**

**Fusarium** (moniliforme) **stalk rot**

**Fusarium verticillioides** (F. moniliforme) **ear rot**

**Aspergillus Spp.**

**Gibberella Stalk Rot**

## MOLD GROWTH REQUIREMENTS

| | ASPERGILLUS | FUSARIUM MONILAFORME | FUSARIUM GRAMINEARUM |
|---|---|---|---|
| Temperature | Optimum > 33°C (90°F) | Optimum 27-29°C (80-85°F) | Optimum 20°C (68°F) |
| Moisture | Grain-fill drought stress | Early drought, then humidity | Wet during flowering |
| Insects as vectors | Important | Very important | Less important |

# STORAGE MOLDS IN SILAGE

Field fungi do not typically thrive in the anaerobic, low pH conditions of well-managed silage. However, when silage is aerobically challenged—due to low harvest moisture, poor compaction, or improper feed-out techniques—these fungi can grow and produce additional toxins. Silage crops with high levels of yeasts, especially Candida and Pichia (formerly Hansenula), are at higher risk for aerobic spoilage. These yeasts consume lactic acid, thereby increasing the silage pH and allowing oxygen to penetrate, which facilitates the growth of molds in high-pH silage. The most common mold species isolated from silage and high-moisture grains are Aspergillus, Penicillium, and Monascus. These molds typically do not invade the crop before harvest but are present as soil-borne spores on forage during ensiling.

### Major Storage Mold Species and Their Risks

- **Penicillium:** This bluish-green mold is of particular concern because of its ability to survive low-pH environments. It produces a wide array of mycotoxins, including PR toxin, patulin, citrinin, ochratoxin, mycophenolic acid, and roquefortine C. These toxins can have severe consequences on animal health, especially in poorly compacted silage that is prone to aerobic spoilage.
- **Aspergillus**: Aspergillus flavus is of particular concern due to its ability to produce aflatoxins, which are potent carcinogens. Aflatoxins are less common in silage than other mycotoxins but can be present in poorly managed silage, particularly when using corn infected by ear rot diseases.
- **Monascus:** This red-colored mold, along with Mucor and Monilinia, is generally non-toxigenic but still undesirable due to its negative impact on the nutritional quality, bunk life, and palatability of silage. While these molds do not produce harmful mycotoxins, their presence can degrade silage quality.

### Conditions Favoring Storage Mold Growth

Storage molds flourish in conditions where silage is exposed to oxygen. The most effective way to prevent their growth is through proper silage management, ensuring that the crop is compacted adequately, the silage pile is sealed promptly, and feed-out is performed carefully to maintain anaerobic conditions. Yeasts like Candida and Pichia are particularly adept at consuming lactic acid and elevating the pH, creating an environment conducive to mold growth.

**REDUCING MYCOTOXIN RISK FROM STORAGE MOLDS:**

1. **Ensure proper silage compaction –** Compacting silage tightly reduces oxygen and prevents mold growth.
2. **Seal silage quickly and effectively –** A tight seal prevents oxygen from entering the silage pile, limiting mold activity.
3. **Monitor moisture levels closely –** Keep silage moisture within the recommended range to prevent spoilage and mold growth.
4. **Feed out silage properly –** Minimize exposure to air during feed-out to reduce the risk of mold development.

# IDENTIFYING AND MANAGING MYCOTOXIN RISKS

Nutritionists often suspect mycotoxin issues when they observe symptoms such as spoiled silage, digestive upsets, erratic intake, and diseases linked to compromised immune systems. It is important not to dismiss a potential toxin issue based solely on the appearance of the silage. Mycotoxins can be present in silage that appears normal, while moldy silage may not necessarily contain detectable toxin levels. Confirming mycotoxins as the cause of production or health issues can be challenging due to the difficulty of obtaining representative samples from the contaminated portion of the crop. A practical sampling approach is to compare analyses of spoiled or moldy samples with normal-looking silage. For a more accurate toxin estimate, samples should be taken after blending the feed in a TMR (total mixed ration) mixer, providing a more homogeneous sample than random subsamples taken from the storage structure.

Mycotoxins are often underestimated in livestock agriculture because they can exist in conjugated forms, primarily with sugars, which may escape laboratory detection. These undetected toxins can still exert toxic and immunosuppressive effects once disassociated in the digestive tract. One challenge in managing mycotoxins is the frequent co-occurrence of multiple toxins in the same feed, which can complicate their interpretation. While we often have "toxic" limits for individual mycotoxins, it's common for livestock feed to be contaminated with more than one mycotoxin at a time, and we don't always fully understand how these multiple toxins might interact synergistically. For example, toxins like DON and ZEA frequently co-occur in silage, and their combined effects could be more harmful than when considered individually. This makes it difficult to determine the true risk based on the presence of a single mycotoxin. Therefore, testing for multiple mycotoxins and understanding their potential combined impact is important for better managing livestock health.

### Analytical Methods for Mycotoxin Detection

Various methods are available to test for mycotoxins, including ELISA (enzyme-linked immune stimulant assay), HPLC (high-performance liquid chromatography), GC (gas chromatography), and TLC (thin-layer chromatography). ELISA tests are often used as rapid and inexpensive toxin screens, especially for grains, but they may result in false positives when used on forage samples. Labs that use proper "clean-up" methods can improve the accuracy of ELISA testing for mycotoxins in forage. For more reliable detection, techniques like HPLC, GC, or TLC are often preferred. However, it's important to recognize that the precision of these analytical methods may not outweigh the impact of sampling error. Research shows that over 75% of the total variability in mycotoxin analysis is due to sampling error, with only 16% attributable to sample preparation and just 8% to analytical testing variability. This suggests that even using more precise assays like HPLC or GC may not lead to more accurate results if the sampling process is flawed. In fact, multiple tests using less expensive methods may offer a better overall assessment of mycotoxin levels than relying on fewer tests with high-precision assays. To minimize sampling error, it is recommended to collect multiple small subsamples from various, evenly distributed locations throughout the silage pile. Although this discussion focuses primarily on corn silage, other feed ingredients like corn grain and distiller's grains can also contain significant levels of mycotoxins. These are often "field toxins" like DON and can contribute to the overall toxin load consumed by animals.

## FDA CENTER FOR VETERINARY MEDICINE FEEDING RECOMMENDATIONS FOR MYCOTOXIN-CONTAINING FEEDS IN TOTAL RATION

| MYCOTOXIN | RECOMMENDED MAXIMUM CONCENTRATION IN TOTAL RATION | TYPE OF LIVESTOCK |
|---|---|---|
| Aflatoxin | 20 ppb | Dairy Cattle and Calves |
| | 100 ppb | Breeding Cattle, Breeding Swine and Mature Poultry |
| | 300 ppb | Finishing Cattle and Swine |
| Vomitoxin (DON) | 5 ppm | Ruminating Beef, Feedlot Cattle and Chickens |
| | 0.5 ppm | Swine: Feeder pigs and prepubertal gilts |
| | 1 ppm | Swine: Finishing pigs, breeding herd and boars |
| | 1 ppm | Veal Calves |
| | 2 ppm | All other animals |
| Zearalenone | 0.3 ppm | Breeding Swine, Young Swine |
| | 0.5 ppm | Young Males (Intact) |
| | 0.5 ppm | Feeder Swine |
| | 2.0 ppm | Older Boars and Finishing Pigs |
| | No acceptable levels | Layer Chickens |
| | 10 ppm | Broiler Chickens |
| | No FDA guidelines, <12ppm suggested by Iowa State University. | Lactating Dairy Cows |
| | 5 ppm | Beef Feeder Cattle |
| | 0.5 ppm | Cattle (dairy and beef); Virgin Heifers |
| | No information | Bulls |
| T-2 Toxin | 0.1 ppm | Young Swine (both sexes), replacement swine (no data) |
| | 0.3 ppm | Adult Breeding and Older Feeder Swine |
| | 0.5 ppm | Dairy Cows and Feeder Cattle |
| | 0.5 ppm | Layer Hens |
| | 0.75 ppm | Broilers |
| | No acceptable limit | Ducks, Turkeys and Geese |
| Fumonisin | 5 ppm | Horses |
| | 10 ppm | Swine |
| | 50 ppm | Cattle |

*Source: Mycotoxins in Feeds: CVM's Perspective http://www.fda.gov/AnimalVeterinary/Products/AnimalFood-Feeds/Contaminants/ucm050974.htm*

## Parts Per Million (ppm)

1 milligram/kilogram (mg/kg) = 1 ppm
1 milligram/liter (mg/l) = 1 ppm
1 microgram/gram (µg/g) = 1 ppm
0.0001% = 1 ppm

**1 ppm** ANALOGIES

1 inch in 16 miles
1 minute in two years
1 second in 11.5 days
1 car in bumper-to-bumper traffic from Cleveland to San Francisco
8.34 pounds/million gallons

**1 ppm = 1,000 ppb = 1,000,000 ppt**

## Parts Per Billion (ppb)

1 microgram/kilogram (µg/kg) = 1 ppb
1 microgram/liter (µg/l) = 1 ppb
1 nanogram/gram (ng/g) = 1 ppb

**1 ppb** ANALOGIES

1 silver dollar in a roll stretching from Detroit to Salt Lake City
1 sheet of toilet paper stretching from New York to London
1 second in nearly 32 years
1 pound/120 million gallons of water

**0.001 ppm = 1 ppb = 1,000 ppt**

## Parts Per Trillion (ppt)

1 nanogram/kilogram (ng/kg) = 1 ppt
1 nanogram/liter (ng/l) = 1 ppt
1 picogram/gram (pg/g) = 1 ppt

**1 ppt** ANALOGIES

1 square inch in 250 square miles
1 second in nearly 32,000 years
1 ounce in 7.5 billion gallons of water

*Source: Adapted from: http://www.llojibwe.org/drm/environmental/content/concentrations.pdf*

# REMEDIATION AND PREVENTION

### Fungicides

Fungicide use has the potential to improve overall silage quality and yield, but its impact on mycotoxin levels is less consistent. Cultural practices like hybrid selection and crop rotation are commonly used to manage mycotoxins, while fungicides serve as an additional tool. Some studies have indicated that fungicide applications can reduce ear rot diseases, such as those caused by Fusarium and Gibberella, potentially leading to a reduction in associated mycotoxins like DON and fumonisins.

However, the impact of fungicides on mycotoxin levels varies significantly depending on environmental conditions and disease pressure. Trials conducted during high disease pressure years have demonstrated that certain fungicide applications can lower mycotoxin levels and increase silage yield. In these cases, fungicides applied at specific growth stages showed improved silage tons per acre. Conversely, during years with low disease pressure, fungicides often show minimal effects on mycotoxin levels.

This variability highlights the need for more conclusive research regarding the consistent effectiveness of fungicides. While they can contribute to improved plant health and yield, relying solely on fungicides to reduce mycotoxin concentrations is not advisable. Instead, they should be considered as part of an integrated mycotoxin management approach.

### Mycotoxin Binders and Deactivators

One method to mitigate the effects of mycotoxins is through the use of binding agents, which work by adsorbing toxins and reducing their bioavailability in the gut. The majority of commercial binders are clay-based, including hydrated sodium calcium aluminosilicate (HSCAS) and montmorillonite, which are commonly used for adsorbing aflatoxins. These clay minerals effectively trap mycotoxins like aflatoxin B1 due to their structure and unbalanced electrical charges. However, it is important to note that clay binders are typically poor or at least highly variable in their effectiveness against DON (Deoxynivalenol), one of the most common mycotoxins found in corn silage. Producers should be cautious when being sold a clay-based binder for a DON problem, as its efficacy may not match expectations.

In addition to traditional clay-based binders, mycotoxin deactivation products (MDPs) offer an alternative approach to mitigating mycotoxin impact. Unlike clay-based binders that primarily adsorb toxins, MDPs use a combination of adsorption, biological transformation, and immune support. They often contain components like bentonite to adsorb aflatoxins, as well as specific bacterial and yeast strains capable of transforming non-adsorbable mycotoxins, such as trichothecenes and zearalenone, into less toxic forms. These products may also include plant and algae extracts that support organ function, particularly the liver, and enhance immune response.

While these binders and deactivators can be valuable tools, it's crucial to understand their potential drawbacks. For example, clay-based binders may interfere with mineral absorption, particularly for trace minerals such as zinc, copper, and selenium. As a result, some nutritionists choose to increase the levels of trace minerals in diets to compensate for potential reduced absorption, often as a precautionary measure, even though it can be difficult to determine if this adjustment is truly necessary.

Additionally, binders and MDPs can be expensive, so evaluating their return on investment (ROI) is essential. It is important to assess the level of mycotoxin contamination in the feed and whether it reaches a threshold where binders or deactivators are genuinely needed. Producers should not rely solely on the claims made by salespeople—consulting with unbiased, trusted advisors is recommended to ensure that these products are necessary and cost-effective. Moreover, the positive effects sometimes attributed to binders could be due to the additional components often found in these products, such as vitamins and organic trace minerals, which can independently improve animal health. Therefore, it's important to consider the entire formulation and whether these added ingredients may be responsible for the observed benefits.

### Feed Management

Once toxins are detected or strongly suspected, nutritionists must develop practical strategies to mitigate their impact. Unfortunately, remediation options are limited, but some effective approaches include:

- **Segregation of Spoiled Feed:** Removing visibly moldy or spoiled feed to prevent further contamination.
- **Dilution of Contaminated Feed:** The most common and effective strategy is the principle of "dilution is the solution," where contaminated feed is mixed with uncontaminated feed to reduce the overall toxin concentration. This method is most feasible on farms with multiple storage options to separate problematic silages. However, as livestock today consume significantly more dry matter than in the past, dilution must be carefully managed to avoid excessive toxin intake.

## SMUT

The most common types of smut that infect corn are common smut, caused by *Ustilago maydis* (or *Ustilago zeae*) and head smut, caused by *Sphacelotheca reiliana*. This fungal pathogen attacks leaves, stalk or ear and can survive on crop debris and in the soil. It can infect any tissue of the plant by entering through wounds and forming characteristic smut galls. The fungus can also enter through the silks, causing gall formation on the ear tip. Most of the time the disease starts in corn kernels, growing through the kernel and eventually forming a large gall. The term smut is derived from the powdery, dark brown to black, soot-like mass of spores produced in the galls. The gall robs the other kernels of nutrients, and while smut doesn't dramatically affect overall yield it limits grain production on affected plants.

Smut is generally known as one of the dry season diseases. It also occurs from mechanical injury to plants such as machinery, hail, blowing sand or herbicide injury. Smut usually occurs where hail or driving rains occur in earlier stages of growth and is more common in soils with high nitrogen levels, particularly following manure applications. Optimum growing temperatures are 80-93°F. Maintaining well-balanced soil fertility is a major control measure.

Feeding smut infested corn silage may appear visibly unappealing, however there is no known mycotoxin associated with smut, although that does not preclude other fungi being present on the plant which is capable of producing toxins. Feeding smut-infested corn won't hurt animals and sheep studies have shown no negative impact on palatability. In fact, smut is considered a delicacy in Mexico and is sold commercially as huitlacoche.

- **Boosting Immune Function:** Supplementing rations with higher levels of energy, protein, vitamins, and organic trace minerals (selenium, zinc, copper, manganese) can help boost the immune system, reducing the impact of mycotoxins on livestock health.

Effective management of molds and mycotoxins in silage requires a combination of pre-harvest, harvest, and post-harvest strategies. In-field prevention through good crop management practices is critical for reducing mycotoxin contamination before silage is even harvested. During storage, proper silage management, including optimal moisture levels, thorough compaction, sealing, and controlled feed-out, is essential to preventing aerobic spoilage and mold growth. Finally, regular monitoring and testing for mycotoxins, along with targeted remediation strategies, can help ensure that silage remains a safe, nutritious feed source for livestock.

## MOVING SILAGE

The ability to move silage from one structure to another (e.g. from bags to emptied tower silos to facilitate feeding systems) is a relatively common question among producers. Unfortunately, very little research has ever been published on the subject. It is difficult to give broad-based recommendations because the success or failure of moving silage is dependent on the condition of the silage in the original storage structure. Factors influencing the success of moving silage are fermentative acid profile, contamination level with spoilage bacteria/ fungi, residual sugar levels, and buffering capacity, and whether or not an inoculant was used at initial ensiling. Field experience suggests that well-ensiled, stored silage can be successfully moved if the following conditions are met:

- Inoculate the silage at harvest with a combination inoculant product containing *L. buchneri* strains.
- Move the silage as quickly as possible into the new storage structure.
- Move in the coldest time of the year to minimize the potential of fueling bacterial/fungal growth.
- Manage the move to prevent as much oxygen penetration into the silage mass as possible.

If the silage was initially inoculated at ensiling, it is generally not recommend to inoculate again at the move. If the fermentation is directed as desired, the fermentative acid profiles should allow for movement of silage with relatively few problems.

# GOALS FOR STABLE SILAGE

## LOW pH

The pH for relatively high sugar-containing crops such as corn silage, cereals and grass silages should be 3.8-4.2. The pH for crops with relatively less fermentable sugar and high buffering capacities such as legume silages should be 4.0-4.5. The pH for high-moisture corn which contains minimal sugars should be 4.0-4.5. The pH will be lower for wetter silages. Terminal pH is not indicative of how much sugar it took to arrive at pH. The more efficient the pH decline, the more water soluble carbohydrates will be conserved in the silage mass. Water soluble carbohydrates are essentially 100% digestible and contribute significantly to the overall energy value of the silage.

## PROPER SPECTRUM OF FERMENTATION ACIDS

Historically, the goal for silage was a 2:1 ratio of lactic acid (LA) to acetic acid (AA). Inoculation with homofermentative lactic acid bacteria will increase the LA: AA ratio to closer to 3-4:1. It is important to note if a *L. buchneri* product was used on silage before attempting to interpret silage fermentation reports. Inoculant products containing *L. buchneri* strains can result in a LA: AA ratio closer to 1:1 due to the *L. buchneri* metabolizing lactic acid and producing more acetic acid which is inhibitory to yeast growth and subsequent silage heating. Higher levels of acetic acid can also be the result of uncontrolled growth of yeast or leuconostic species. The problem often encountered with high lactic acid silages is they are more prone to heating and aerobic stability issues given that lactic acid is not inhibitory to yeast growth. This is due to high residual sugar levels coupled with the lack of volatile fatty acids (acetic) which inhibit growth of yeast and spoilage organisms. Elevated level of butyric acid is an indication of clostridial fermentation. Butyric acid silages typically have higher pH, higher ammonia nitrogen levels and are unpalatable. Although unpalatable, these silages will be very stable due to the microbial inhibition of butyric acid.



## TEMPERATURE

Silage temperature should be no greater than 15-20°F above ambient temperature at the time of ensiling. Large storage structures retain heat longer than smaller storage structures. Water is an excellent heat-sink so wetter silages retain heat longer than drier silages. Temperatures should be monitored by inserting a thermometer at least two to three feet into the silage mass due to heat dissipating from the surface. If silage is faced and heating continues to increase it is an indicator of excessive aerobic fermentation due to poor compaction, improper face management, slow feedout or failure to inoculate with *L. buchneri*.

## MINIMUM MICROBIAL/ FUNGAL ACTIVITY AT FEEDOUT

In general, aerobes (such as Bacillus species), molds (such as Mucor, Monilia, Aspergillus and Penicillium species) and yeast counts should all be less than 100,000 colony forming units/gram of silage (as fed). While total counts are helpful, detailed identification of individual species and actual mycotoxin loads are much more instructive as to the source, prevention and necessary remediation.

## MINIMAL PROTEIN DEGRADATION

A faster fermentation typically results in reduced plant and microbial proteolysis. Measuring ammonia nitrogen as a percent of total nitrogen is a good indicator of the extent of proteolysis. Values should be less than 5% in corn/cereals and less than 10% in grass/legume silages. Pepsin insoluble nitrogen as a percent of total nitrogen of over 20% indicates excessive heating in high-moisture ear or shelled corn. Heat damage (unavailable protein from the Maillard Reaction) is measured by acid detergent nitrogen as a percent of total nitrogen. Levels exceeding 12% are indicative of excessive heating which may require adjustment to the crude protein level of the feedstuff.

# SAMPLING SILAGES

It is critical that feedstuffs be sampled correctly. Assuming a "normal" fermentation, it is recommended to sample forages at harvest. Pre-fermentation sampling allows the nutritionist to have the analysis "in hand" so rations can be balanced for that particular forage immediately as the silage is removed from the storage structure.

Statistics indicate that 10-12 samples need to be taken in order to be 95% confident of correctly characterizing a feedstuff. When obtaining samples from the face of a bunker or pile, it is best to select 10-12 locations and mix the silage together in one pile. Then use the quartering procedure to obtain a reasonably sized sub-sample for submission to the laboratory. Another, more convenient and safer approach is to sample the feedstuff from the discharge chute after it has been mixed in a TMR mixer. Do not sample "problem" silage as removed from a TMR mixer or an upright silo unloader chute so as not to mask the "trouble spots" with normal silage. It helps to have comparative samples from both good and poor silage to help troubleshoot the relative extent of the problem.

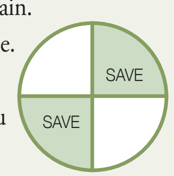
When making a field call with suspected silage problems, it is best to come prepared with equipment for evaluating the situation and sampling the silage. A moisture tester such as a Koster® Tester, an electronic moisture tester or a 600-700 watt microwave and battery-operated scale are essential to evaluate silage moisture. Some nutritionists prefer the slower Koster Tester because it allows time to query the producer about management practices. It is also useful to have litmus paper or a pocket pH meter to probe silage to determine if the pH is uniform or if pockets of clostridial growth are the reason for elevated pH. A thermometer (or infrared camera) to measure silage temperatures is also helpful when assessing bunklife or heat damage problems. Remember to bring plastic bags and a permanent marker to identify and store 1-2 lb samples. An insulated cooler with reusable ice packs is required if samples are to be sent to a laboratory for volatile fatty acid or microbial identification analysis. If sending to a laboratory for microbiological profiling, do not freeze the sample. Freezing can disrupt the cells of spoilage organisms leading to erroneous laboratory results.

## QUARTERING PROCEDURES

Allows reduction of the sample size while maintaining a representative sample

Thoroughly mix material to be sampled (e.g. by rolling back and forth on a piece of plastic), then pour into a uniformly shaped pile on a clean surface.

1. Divide sample into four equal parts (quarters), using a drywall joint knife, trowel or any straight-edged tool.
2. Discard two opposite quarters and save the other two.
3. Combine the two saved quarters into a pile and then quarter again.
4. Be sure to collect fine material at the bottom of the saved sample.
5. Discard two opposite quarters and repeat step 3.
6. Continue to do this until you have a pile that is the amount you want to submit for laboratory analysis




*Source: Dairyland Labs, Inc.*

# SILAGE MOISTURE DETERMINATION

Not only does nutrient content of forages vary with field and cutting, so does harvest moisture. Silages should be monitored at least weekly for moisture content and ration adjustments made when moisture changes by more than 2-3% points. Snow, rain soaking feed on the bunker face and differing harvest moistures from diverse fields can all lead to variation in moisture content of the feed. This is especially critical when weighing silage into TMR mixers where ingredients are added by weight and more or less water in the feed can alter the nutrient profile and forage: concentrate ratio of the final diet.

Technology is rapidly evolving in the area of on-farm moisture testing. Options range today from rapid, handheld NIRS (Near Infrared Spectroscopy) testers with photodiode array or narrow band filters, industrial NIRS like the John Deere HarvestLab™ that can be taken off the chopper and used in the farm shop, forced air approaches like the Koster Moisture Tester or food dehydrators and the microwave approach.

Research from the late-90s at the University of Wisconsin, before the introduction of handheld NIRS approaches, showed that the residual moisture found in samples when using the microwave or Koster drying methods was about 2% units higher that laboratory oven methods when conducted in a lab setting and 3-6% when conducted by various operators on-farm. Their conclusion was that the microwave method was more variable than the Koster drying method was, while the laboratory oven method was least variable.

Small errors in determining silage harvest moisture can have significant impact on determining actual dry matter yields for paying custom growers. A 2% unit mistake in moisture determination does not translate to 2% of the yield. If the actual yield was 34 tons/acre at 30% dry matter (70% moisture), then the actual dry matter yield would be 10.2 tons/acre. If a poor sample or poor moisture measuring technique gives a value of 28% dry matter (72% moisture), the incorrect value would be 9.5 tons of dry matter. In this example, our 2-percentage unit error in dry matter determination represents a 7.3% error in yield.

Determining the number of samples that need to be collected requires finding the balance between what is practical and what is statistically valid. It is not practical to collect and analyze enough samples to determine with certainty that moisture content is within +/- 1% unit. The accompanying generic chart

## SILAGE DRY MATTER ADJUSTMENTS DONE CORRECTLY

| SILAGE DM % | DESIRED LBS OF SILAGE DM IN EACH TMR BATCH | PRODUCER VARIES THE LBS OF AS-FED SILAGE ADDED TO EACH TMR BATCH DEPENDING UPON SILAGE DM |
|---|---|---|
| 30% | 1000 | 3333 |
| 35% | 1000 | 2857 |
| **40%** | **1000** | **2500** |
| 45% | 1000 | 2222 |

*Source: University of Wisconsin*

## DM ADJUSTMENTS NOT DONE CORRECTLY SIGNIFICANTLY ALTERS THE DIETARY FORAGE:CONCENTRATE (F:C) RATIO

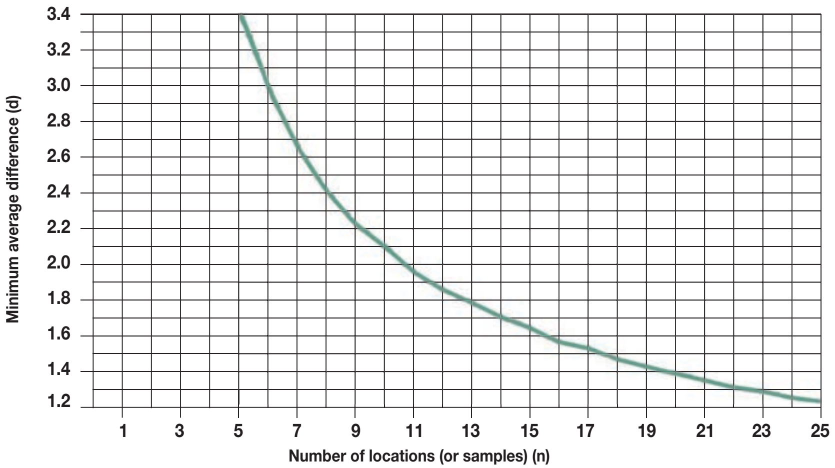
| SILAGE DM% | AMOUNT OF AS FED SILAGE ADDED TO EACH TMR BATCH WITHOUT CONSIDERATION OF CHANGING DM | ACTUAL LBS OF SILAGE DM ADDED TO THE TMR BATCH (F:C RATIO) |
|---|---|---|
| 30% | 2500 | 750 (43:57 F:C) |
| 35% | 2500 | 875 (46:54 F:C) |
| **40% (Assumed DM)** | **2500** | **1000 lbs DM desired in the TMR batch (50:50 F:C)** |
| 45% | 2500 | 1125 (53:47 F:C) |

*Source: University of Wisconsin*

## IMPACT OF MOISTURE DETERMINATION ERRORS ON ASSESSING SILAGE YIELDS

| | ACTUAL | 2-UNIT ERROR | 4-UNIT ERROR | 6-UNIT ERROR |
|---|---|---|---|---|
| **DM** | **30%** | 28% | 26% | 24% |
| **Wet (as fed) Yield** (T/a) | **34** | 34 | 34 | 34 |
| **DM Yield** | **10.2** | 9.5 | 8.8 | 8.2 |
| **Adjusted Yield** (T/a @ 70% moisture) | **34** | 31.7 | 29.5 | 27.2 |

## MINIMUM AVERAGE DIFFERENCE (d) IN TRAITS WHICH CAN BE DETECTED WITH A GIVEN NUMBER OF LOCATIONS OR SAMPLES (n)




Source: D.A. Sapienza, Ph.D.

estimates the number of samples that should be taken to be 95% confident that a given difference exists for any particular nutritional trait (e.g. moisture, NDF etc.). Some assumptions were made in developing this curve concerning the representative nature of the sample and the coefficient of variation (CV) of the analytical method. Poor sampling in the field or poor analytical practices in the lab will increase the CV and thereby the number of samples required.

The way to use the chart is to establish the acceptable measurable difference on the Y-axis (vertical) and then go across the chart until you intercept the curve. Dropping down to the value on the X-axis (horizontal) indicates the approximate number of samples that should be taken. For example, if you want to be 95% confident in a 2% unit moisture difference (e.g. 70% + / - 1% unit) to base silage grower compensations, then you would need 11 samples. If you want this level of confidence in a truck load, then you need to sample the truck 11 times. If you want to be 95% confident in a (reasonably uniform) field (same hybrid, uniform soil types etc.) in which the chopper capacity is delivering 22 truckloads per hour to the silage pit, then you would collect 1 sample from every other truck and be somewhat confident that the sample taken from each truck is truly representative of the entire truckload. If you want to be 95% confident in each truck during each hour of silage delivery, then you would need 11 samples from each of the 22 trucks for a total of 242 samples; which would be unmanageable and expensive to test. The issue then becomes: 1) what is the population ("within an individual truck" or "within the number of trucks per hour" or "within a field"), 2) what is the acceptable level of confidence required for that trait and 3) what can be agreed to by the grower and buyer (including the lab or method chosen to determine moisture and other parameters such as starch).



A practical approach from a relatively large field might be the following:

1. Every other truck from a particular field will be sampled at the silage pit using an agreed upon sampling protocol.
2. That sample will be delivered to the scale operator.
3. At the conclusion of harvesting the field, the scale operator will empty the sample bags from trucks delivering from the same field into a 5-gallon bucket.
   a. This composite sample will be mixed and sub-sampled into 2 zip-lock bags and labeled with the time and field.
   b. One sample will be kept in the refrigerator until the end of the day when it will be presented to the lab for moisture testing.
   c. The other sample will be frozen and held until the lab results are returned for its paired sample.
4. Upon receipt of the moisture results from the lab, moistures for that field will be averaged and applied to all loads weights delivered from that field.

# MICROWAVE OVEN AND GRAM SCALE MOISTURE DETERMINATION METHOD

Silage, haylage, or hay moisture content can be evaluated in a microwave oven. This technique is fast, easy to perform, and relatively accurate in determining the moisture content of any forage. The major drawback with this system is an electrical power source is required, which is not always convenient for testing forages. In addition to a microwave oven, a small gram scale, paper plate for each sample and glass of water are needed.

1. Place the paper plate on the scale and note how many grams it weighs. A good suggestion is to write this weight on the edge of the plate. Re-weight the plate each time it is used.
2. Weigh 50 to 100 grams of chopped forage onto the plate on the scale. Cored samples do not need further chopping.
3. Spread the sample evenly over the plate and place it in the microwave with a half-filled glass of water in the back corner. Silage samples, estimated to be in the 50 to 75 percent moisture range, can be heated initially for four minutes. Hay samples with less than 30 percent moisture should only be heated for three minutes.
4. Weigh and record the weight, then stir the forage on the plate and place it back in the oven for one additional minute.
5. Repeat procedure #4 again, but only run the microwave oven for 30 seconds this time. Continue drying and weighing until the weight becomes constant. Be careful not to heat the forage to the point of charring. If this occurs, shorten the drying intervals.
6. To calculate the moisture percentage, subtract the last dry weight from the original weight and divide this number by the wet weight. Now multiply by 100. This is the moisture content of the sample.

**Example:** Original wet weight was 90 grams. Dry weight is 60 grams.
**90 - 60 = 30 30/90 X 100 = 33.33%**

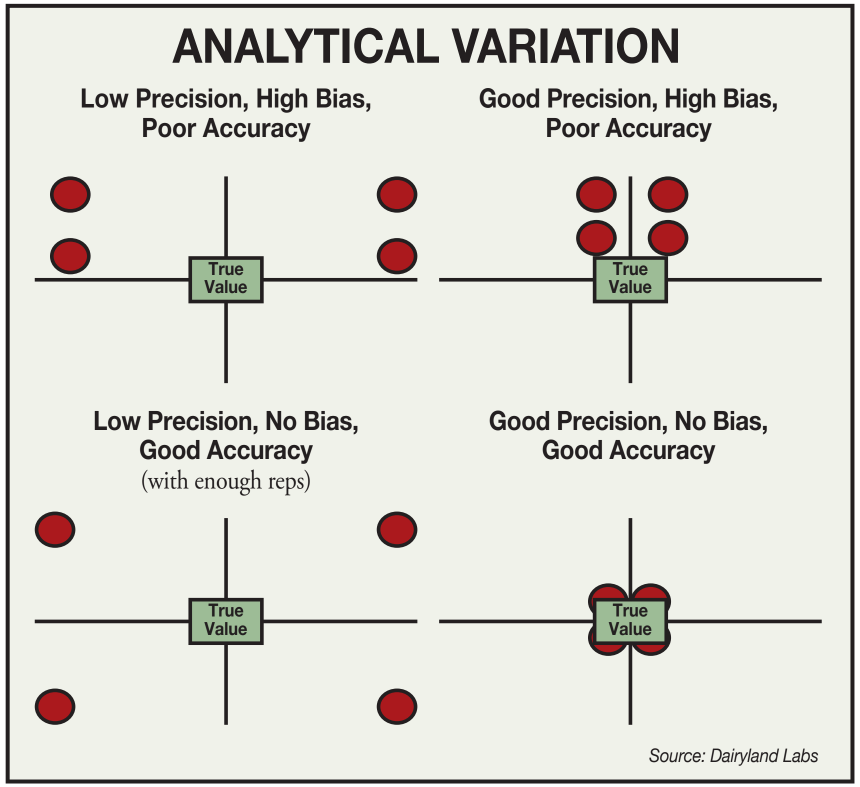
**Easy Method:** If exactly 100 grams of forage was weighed onto the plate, the final dry weight (minus the paper plate weight) subtracted from 100 is moisture content. Alternatively, the final dry weight is the dry matter percentage.

**Example:** Original wet weight=100 grams. Final dry weight=55 grams.
**100 - 55 = 45% moisture content or 55% DM**

# ANALYTICAL ERRORS

Forage analysis is important for balancing diets and for gaining insight into the impact of management practices on forage quality. Sampling error at the farm can certainly affect how representative the sample is compared to what is being fed. Similarly, there are factors which affect analytical variation in the values being reported on laboratory reports. These factors are bias, precision and accuracy.

Bias is defined as a systematic error introduced into sampling or testing. Precision references the ability of a measurement to be consistently reproduced while accuracy is whether the reported value is correct.




# NIRS VERSUS WET CHEMISTRY

Wet chemistry refers to the more laborious, bench top chemistry conducted in the laboratory. Near Infrared Spectroscopy (NIRS) is another analytical approach valued for repeatability and rapid turnaround of data.

A major advantage to NIR over wet chemistry is cost savings. It is possible to analyze more samples, more often, for the same but compared to more expensive wet chemistry. This helps producers manage feedstuff nutrient variation through more frequent analysis. It is a common recommendation to only use wet chemistry analyses, especially following a typical growing season. However, that is not necessary with laboratories that use diverse samples to frequently update their NIR calibrations. If the lab is a reputable lab willing to share calibration statistics, NIRS is the best way to stretch analytical dollars.

NIRS had been discussed in the literature since 1939 but it was not until 1968 that Karl Norris and co-workers at the Instrumentation Research Lab USDA-Beltsville proved that absorption of specific wavelengths could be correlated with chemical analysis of other grains and forages.

Early in 1978, John Shenk and his research team developed a portable instrument for use in a mobile van to deliver nutrient analysis of forages directly on-farm and at hay auctions. This evolved into the university extension mobile NIRS vans in Pennsylvania, Minnesota, Wisconsin and Illinois. In 1978, the USDA NIR Forage Network was founded to develop and test computer software to advance the science of NIRS grain and forage testing. By 1983, several commercial companies had begun marketing NIR instruments and software packages to commercial laboratories for forage and feed analysis.

NIRS is based on the interaction of the physical matter of feeds with light in the near infrared spectral region (700-2500nm). Vibrations of the hydrogen bonded with carbon, nitrogen or oxygen cause molecular "excitement" responsible for absorption of specific amounts of radiation of specific wavelengths. This allows labs to relate specific chemical bond vibrations (spectra) to the concentration of specific feed components (e.g. starch) determined by traditional wet chemistry methods. NIRS is possible because molecules react the same way each time they are exposed to the same radiation. Sample preparation and presentation to the NIR instrument varies widely. Though dried, finely ground samples are often employed, whole grains or fresh, unground can also be scanned. Instruments are increasingly coming to the market that are rugged enough to work in mobile applications such as on-board silage choppers.

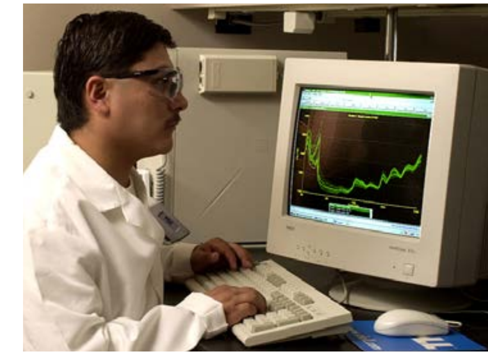
NIRS is a rapid, secondary method based on the mathematical relationship (regression) with the accepted wet chemistry method. Consequently, a NIRS value can never be more accurate than the traditional method. Sophisticated software packages are used to perform the mathematical calculations necessary to associate the NIR-produced spectra of specific reference samples with the actual wet chemistry of those samples. These mathematical relationships are termed "prediction models" or "calibrations."

The robustness of a NIRS calibration is primarily determined by the number of samples, how well they represent the diversity of the feedstuff and the typical variation observed for the trait being measured. For example, if the goal is to develop a calibration for crude protein in corn grain, samples of corn from diverse genetic and environmental backgrounds must be included in the reference samples being analyzed by wet chemistry. When a particular wet chemistry method does not exist (e.g. prediction of ethanol yield from corn), laboratories may develop an entirely new wet chemistry method upon which to base the NIR calibration.

Recently there has been a multitude of hand-held NIR instruments hitting the market. Portable instrument will never replace the need for the accuracy of a laboratory but there are many occasions where a handheld instrument is useful, particularly at harvesting for quick decision or when a lab is far away. The current technology of portable instruments is such that users should expect increased errors with undried, unground silage or TMR samples of about 50 % compared to laboratory NIR (dried, ground) results. For example in corn silage, laboratory NIR errors are less than 2% units for dry matter and 3% units for NDF. Users should also investigate the type and spectral range of hand-held instruments because many are only capable of predicting dry matter and not all the constituents typically required for forage evaluation or pricing.

As routine users of NIR values, producers and nutritionists should feel comfortable asking laboratories or equipment manufacturers about their NIR statistics. This will help instill confidence in these values similar to the way statistics (e.g. P-values) determine the confidence in research trial results. Listed below are three NIR statistics that reputable NIR laboratories should be able to provide:

1. Number of samples in the calibration set (N) - influenced by the typical variation in the trait of interest. The narrower the range in sample differences, the more difficult it is for NIR (or wet chemistry) to detect those differences. Typically 80-100 samples are required for developing an initial calibration with up to hundreds of samples in a "mature" calibration.
2. Standard error of calibration (SEC) - defines how well the NIR calibration predicts the wet chemistry values that are used to build the calibration. Low SEC values are desired. For example, if the wet chemistry value is 30 and the SEC is 3, this means approximately 66% of the NIR values should fall within the range of 30 +/- 3 (e.g. 27 to 33).
3. Regression coefficient ($R^2$ or RSQ) - the "best fit" line when NIR values are plotted against the wet chemistry values. High $R^2$ values are desired. An $R^2$ of 1.0 means 100% of the sample variation is being explained by the calibration.



# PROXIMATE ANALYSIS

Proximate analysis is a chemical scheme for describing feedstuffs that was developed in Germany over 100 years ago. It relies on destructive laboratory methods to determine:

- Dry matter (DM)
- Ash (minerals)
- Crude Protein (CP)
  - Kjeldahl process measures nitrogen (N) content
  - N x 6.25 = % CP
- Ether Extract (fat)
- Carbohydrates (CHO)
  - Crude Fiber
- Nitrogen Free Extracts
  - Mostly sugars and starch but may contain some fiber
  - Determined by difference (100-all other analytes), not by direct analysis

Proximate analysis was a starting point for determining the nutritive value of feeds but failed to provide information on feedstuff digestibility, nutrient adequacy, palatability or toxicity.

# DETERGENT SYSTEM

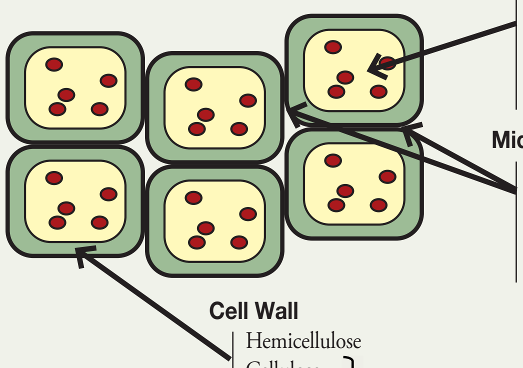
Forage laboratories continue to use many of the proximate analysis methods. However, the relatively poor state of laboratory feed analysis in the 1960s triggered the research program of Peter Van Soest to develop the Detergent System of feed analysis. The detergent system replaced crude fiber (CF) and N-free extract with:

- neutral detergent solubles (NDS)
- neutral detergent fiber (NDF)
- acid detergent fiber (ADF)
- lignin

Over a number of years, Van Soest convinced the scientific community to replace the proximate analysis system with the Detergent System making it possible to explain nutritional responses in terms of feed digestibility and intake. As with the crude fiber procedure, ADF isolates primarily cellulose and lignin, but not hemicellulose. This made ADF unsuitable as a measure of total structural fiber. When the NDF analysis procedure was first published in 1967, ADF began a slow, steady decline in the U.S., although it remains commonly used in many areas of the world. While NDF has largely replaced crude fiber among scientists, crude fiber continues usage because NDF is not a government-approved method for legal trade in many countries.

In the 1980s, David Mertens (Ph.D. student of Peter Van Soest) started efforts to standardize NDF analysis among laboratories in the U.S. Mertens realized the only way to reduce error among laboratories was to prescribe a single NDF method. Martens' efforts resulted in recommendations that all feeds be amylase treated (to remove starch), sodium sulphite be used (to remove plant and microbial protein) and that NDF be reported on an ash-free basis (e.g. "om"). The resultant value would be designated aNDFom. The only methodological variation considered was that feeds with greater than 100 grams of fat/kg be pre-extracted with a suitable solvent. Acceptance of the NDF method by the AOAC was a protracted process, but was finally approved in June, 2002.

## PLANT CELL STRUCTURE



**Cell contents**
Organic acids
Sugars
Starch
Fructans
Oil

**Middle Lamella**
β-glucans
Pectic substances *(ferments like starch but won't produce lactic acid, 6-15% in alfalfa, >20% beet and citrus pulp)*

**Cell Wall**
Hemicellulose
Cellulose
Lignin

Cellulose and Lignin: **A**cid **D**etergent **F**iber
Hemicellulose, Cellulose and Lignin: **N**eutral **D**etergent **F**iber

### FIVE TYPES OF FORAGE TISSUES

1. Vascular bundles containing phloem/xylem.
2. Parenchyma bundle sheaths surrounding vascular bundles.
3. Sclerenchyma patches connecting vascular bundles to epidermis.
4. Mesophyll cells between the vascular bundles and epidermal layer.
5. On the surface a single layer of epidermal cells covered by a protective cuticle.

*Source: Mary Beth Hall, University of Florida*



# DIGESTION TRIALS

Digestion trials are used to determine how much of a nutrient or feedstuff is digested and available to the animal for maintenance, growth and production.

Digestion trials consist of:

- Proximate analysis of the feedstuff
- Feeding an animal a given amount of feed
- Collecting feces (sometimes urine, too)
- Proximate analysis of the feces
- The difference is the "apparent" digestibility of the feed. For an individual nutrient, the difference equals the digestion coefficient for that nutrient.

Given all the nutritional acronyms, it is understandable that confusion abounds regarding certain terms. For example, the confusion surrounding apparent and true digestibility defined mathematically as:

Apparent Digestibility = 100*[(intake)–(feces)]/ (intake)

with feces = (undigested + any endogenous loss)

True Digestibility = 100*[(intake)–(undigested)]/ (intake)

True digestibility is typically greater than apparent digestibility. Apparent digestibility does not discount the endogenous production of protein and fat from either sloughed cells or rumen microbes that appear in the feces or in residues from *in vitro* (laboratory) trials. True digestibility equals apparent digestibility when there is no endogenous loss as with NDF digestibility because the animal is not producing any NDF.

*In vivo* (in live animal) digestibility measurements are generally understood to be apparent digestibilities. *In vitro* dry matter disappearance (IVDMD) is measured dry matter disappearance during test tube or *in situ* incubations and calculated as: IVDMD = 100 – undigested dry matter %. IVTDMD (*in vitro* true dry matter disappearance) is calculated as 100 – [(NDF/100) x (100-NDF digestibility)]. IVTMD is an estimate of the amount of material that was truly digested based on Van Soest's suggestion that 98% of cell contents are truly digested, so virtually all the undigested material must be unfermented NDF. Alternatively, it can be calculated as IVTDMD = cell solubles + digested NDF.

The *in vitro* dry matter digestibility (IVDMD) or apparent digestibility analysis in a commercial laboratory consists of the classic two-stage Tilley & Terry procedure. The first stage is 48-hour incubation in rumen fluid and buffer followed by a second 48-hour digestion in pepsin and HCl. The *in vitro* true digestibility (IVTD) consists of the same 48-hour incubation in rumen fluid, however, the second stage substitutes an NDF extraction for the pepsin and HCl. The NDF extraction more completely removes bacterial residues and other pepsin insoluble material yielding a residue free of microbial contamination.

Confusion also surrounds the difference between nutrient digestibility (or digestion coefficient) and digestible nutrient. Nutrient digestibility is expressed as a percentage of the nutrient with a capital "D" suffix (e.g. NDFD, as a % of NDF). Digestible nutrient is the proportion of dry matter that is digested nutrient. The common format for representing this is a lowercase prefix "d" (e.g. dNDF, as a % of DM). Nutrient digestibility and digestible nutrient are not interchangeable terms, even though the concepts are related.

## How a Lab Calculates uNDF, dNDF and NDFD:

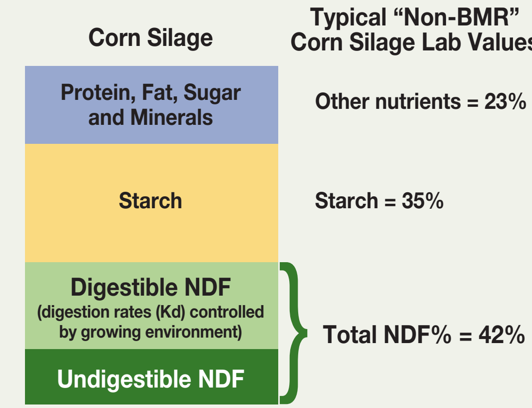
Assuming the lab starts with 20 grams of corn silage dry matter that was 42% NDF, you have 8.4g of starting NDF (20*42%).
If after 24 hours of rumen fluid incubation there are 5.7 grams of residue containing 71% NDF, you have 4g of final NDF (5.7*71%).
If after 240 hours of incubation there are 3 grams of residue containing 90% NDF, you have 2.7g of final NDF (3*90%).

**uNDF (24 hour, % of DM)** = 4/20 = 20%

**uNDF (240 hour, % of DM)** = 2.7/20 = 13%

**dNDF (24 hour, % of DM)** = NDFD*%NDF = 52*42 = 21

**NDFD (24 hour, % of NDF)** = $(NDF - uNDF_{24hr})/NDF$ = (42 – 20)/42 = 52%



## ENERGY SYSTEMS

Total digestible nutrients (TDN) are a measure of feedstuff energy from the organic compounds in feed expressed as % or pounds. TDN uses nutrient values from laboratory proximate analysis multiplied by standard digestion coefficients from digestion and is calculated as follows:

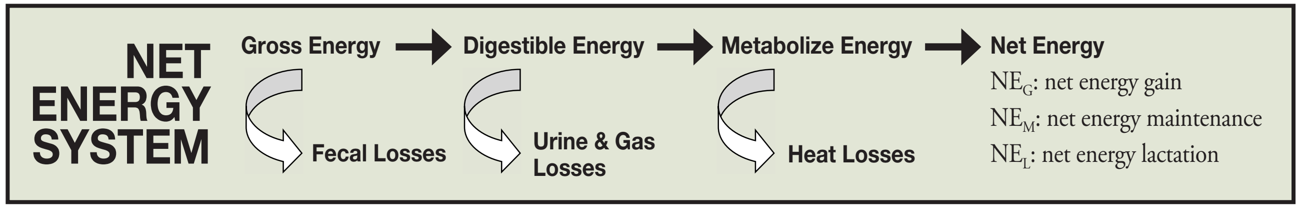
%TDN = % digestible crude protein
+ % digestible crude fiber
+ % digestible nitrogen free extract
+ (% digestible ether extract x 2.25)

The primary limitation of the TDN system is chemical analysis of feed and manure does not relate well to animal metabolism. TDN ignores important losses such as urine, gas and especially heat.

These limitations led to the development of the Net Energy System where the units of energy are expressed in terms of Megacalories (1,000 kilocalories or the amount of heat to raise the temperature of one gram water from 14.5°C to 15.5°C).

A summative energy equation approach has been used by most commercial labs to calculate the Net Energy of Lactation (NEL) since it was published in the Seventh Revised Edition (2001) of the NRC Nutrient Requirements of Dairy Cattle. The summative approach utilizes values for crude protein, fat, non-fiber carbohydrate (NFC) and NDF, along with corresponding digestibility coefficients for these nutrients.

A modification of the summative approach was used in the development of the University of Wisconsin MILK2006 approach to assigning milk per acre and milk per ton values to alfalfa and corn silage.




## DIGESTION RATES

Effective nutrient degradability as defined by the Orskov equation is Kd/ (Kd + Kp) where Kd is the rate of digestion (e.g. 2-7%/hour for fiber) and Kp is the rate of feed passage from the rumen (e.g. 5%/hour for high producing dairy cow). Effective nutrient supply can then be calculated as dry matter intake * (Kd / (Kd + Kp)).

Laboratories can provide estimates of Kd values for NDF with published equations from Cornell University. It utilizes a single time point NDFD value (e.g. 24, 30 or 48-hour), NDF, lignin and an assumed digestion lag value (e.g. six hours).

More recently, a gas production system named Fermentrics® became commercially available allowing for the direct measurement of digestion rates for both fast (primarily starch) and slow (primarily fiber) pool nutrients. Curve peeling techniques and published equations that are used to estimate the carbohydrate pool Kd values (e.g. CHO $B_1$ and $B_3$) allow for measured rates to be used for feedstuffs rather than relying on book values.



# PLENISH® HIGH OLEIC SOYBEANS

The nutritional issue affecting butterfat yields in dairy cows begins with the germ of a corn kernel which contains about 60% linoleic fatty acid (C18:2). Corn grain and corn silage are the foundation of most dairy diets. The combination of corn grain and corn silage can add to high ruminal linoleic loads, which has been clearly linked to milk fat depression. Conventional soybeans contain about 22% oleic acid (C18:1), 55% linoleic acid. In contrast, Plenish soybeans contain 75% oleic acid and only 7% linoleic acid. The high oleic and low linoleic fatty acid content of Plenish soybeans allows for higher dietary inclusion levels than commodity soybeans This transgenic soybean innovation provides nutritionists with a high-energy (~20% fat) and high-protein feed option containing a desirable fatty acid profile that can replace expensive fats like palm oil (C16:0) and/or commercial ruminally protected fats thus reducing feed cost and/or improving butterfat yields. Depending upon dietary needs, Plenish soybeans can be fed in all stages of lactation but likely have most benefit to energy-deficit transition and high-producing cows. They can also be fed year round and may help minimize declines in milk fat typically seen in hot weather

All Plenish soybeans must be fed on-farm or delivered to an approved processor for oil extraction. There are several ways to access Plenish soybeans or high oleic oil for use in dairy cow diets. Producers (or contract growers) can sign on-farm feeding agreements to grow Plenish soybeans on their farm. Alternatively, producers can access Plenish soybeans from approved grower/processors. Finally, certain approved crush plants are marketing Plenish soybean meal containing 7-9% high oleic oil versus only 1-2% oil in commodity soybean meals.

Soybean protein is naturally high in rumen solubility. Roasting soybeans can double the escape protein from the rumen thus increasing rumen undegraded protein (RUP, bypass protein). Heating soybeans to effective levels will denature urease (thus allowing for urea use in diets) and denature trypsin inhibitor (not a concern in mature ruminants). Feeding rolled or quartered soybeans is preferred to whole. Research has shown that extremely fine grinding may not be justified and due to increased surface area, may reduce the RUP of the soybeans. Raw and ground Plenish soybeans can be fed successfully in herds not requiring additional RUP and not feeding urea, however, Michigan State University research suggests

inclusion rates should be lower than for roasted Plenish soybeans.

Roasting typically costs $25-$35 per ton. Losses by open flame roasting are near 12% as water and pods/hulls. Losses when using electric or hot air are mostly water. Roasting too hot or too long can decrease protein value by binding them with sugars (Maillard reaction). Low roasting temperatures will reduce RUP and may fail to denature urease. Steeping the roasted soybeans (~30 minutes) to allow time for heat to penetrate is also required. The protein dispersibility index (PDI) laboratory method can be used to evaluate roasting effectiveness. A PDI value of between 9-11 indicates optimal roasting and steeping.

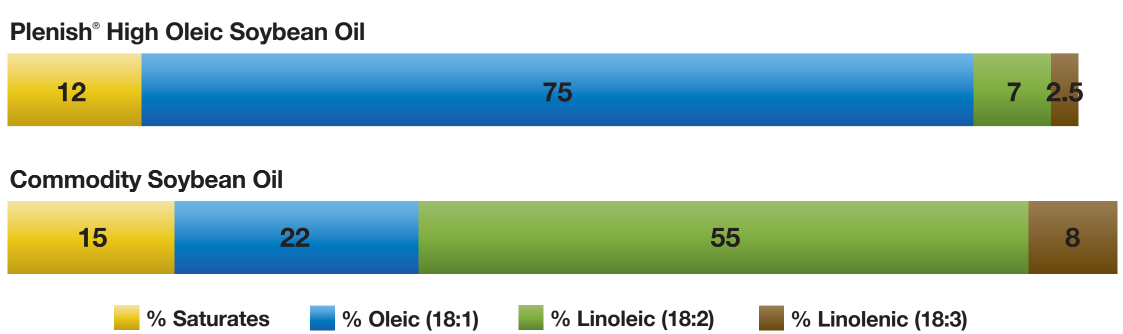
There is limited published data on recommended grind size for feeding Plenish soybeans, but recent University trials have ground beans to around 800 microns. Field surveys indicate some dairies feeding a coarser grind (>1000 microns) while others grind very fine (300 microns). It has been historically recommended not to fine grind commodity soybeans as the linoleic acid could lead to ruminal upsets and milk fat depression. Dairies feeding fine ground Plenish soybeans do not report these problems; however, fine grinding will decrease RUP, reducing the benefits of proper roasting given that small particle proteins are more likely to degrade rapidly in the rumen than larger-particle proteins.

Most dairies/nutritionists are feeding an average of 4-5 pounds of full fat roasted Plenish soybeans/cow/day but can range from 2 to 10 pounds; although at the lower levels, positive results may not be readily observed. Levels as high as 16 pounds/cow/day of roasted Plenish soybeans were fed in Michigan State University research studies without compromising milk or butterfat yields. Inclusion rates ultimately depend upon individual herd dietary needs as well as availability, local commodity prices, any premiums required to grow Plenish soybeans and cost of transportation, processing, and storage.

Field reported responses include increased milk fat, increased milk volume and potentially increased milk protein. Herds that respond in milk fat typically see the response in about a week; those that respond in milk volume due to the energy provided see an almost immediate, overnight response and herds that see a protein response typically observe the impact within 2-3 weeks. The most predictable response comes from removing/diluting linoleic acid in the diet. Research has shown that milk fat % is increased by about 0.2% units for every 100g/day reduction in dietary linoleic acid. Depending on the base diet and individual herd nutritive requirements, positive cow responses have also been observed without changing linoleic acid levels due to the increased energy supplied from the soybean oil and/or the rumen undegradable protein (RUP, bypass protein) gained from the roasting process

The range in feeding responses is likely due to the nutritive profile of the original diet benefitting from what Plenish. soybeans can provide (other than high oleic acid). This may be from providing additional (oil) energy or filling a gap in certain amino acids. Other factors may be how the Plenish soybeans were processed on different farms (not over or under-roasted) and/or differences in particle size when fed (ranging from 300 microns to over 1000 microns). Some herds have seen responses increase over time due to cows maintaining better body condition, peaking higher and/or maintaining more persistent lactation curves. When a cow response is less noticeable, it is frequently associated with diets that previously included more expensive ingredients of which Plenish may offer a lower cost alternative. It is difficult to have a valid controlled, on-farm comparison so it is important to work with a nutritionist to identify other factors which may influence a feeding response.

## TYPICAL FATTY ACID PROFILE OF PLENISH AND COMMODITY SOYBEANS






# COMMON FORAGE ANALYSIS TERMINOLOGY

The following compilation of forage analysis terms and descriptions is provided for convenience of the reader. It should be noted that most commercial laboratories will have analyte definitions and their unique analytical procedures described in more detail on their respective websites.

**Dry Matter (% DM):** DM is the resulting feedstuff after 100% of the water has been removed by drying (100% - moisture). Drying causes delay in analysis turnaround so some labs dry to a certain moisture and then use a NIR scan to account for any residual moisture. Feed analysis reports typically report nutrients on an "as fed" or wet basis and on a "DM" basis. All dairy and beef nutrition is based around DM values due to the large variation in moistures in ruminant feedstuffs. Monogastric diets are typically based on "as fed" values.

**Crude Protein (% CP):** Calculated by multiplying the total nitrogen in the feed by 6.25, based on the assumption that 100% protein contains about 16% nitrogen (100/16=6.25).

**Adjusted CP %:** A calculated value, sometimes referred to as available protein, used for forages to discount the total crude protein level based upon the amount of heat damaged (bound, caramelized) protein resulting from the condensation of carbohydrate degradation products with protein forming, dark-colored, insoluble polymers poorly digested by ruminants. It is sometimes calculated by subtracting ADF bound CP (ADF-CP or ADICP) from CP. ADF-CP is calculated by multiplying acid detergent insoluble nitrogen (ADIN, sometimes called ADF-N) by 6.25. Alternately adjusted CP is calculated on a proportional basis depending on ADFCP level such as when ADIN (% of N) is greater than 14%.

**Ammonia: (NH3):** A pungent, colorless, gaseous alkaline compound of nitrogen and hydrogen which is very soluble in water. An indicator of non-protein nitrogen content.

**Ammonia-N (NH3-N, %CP):** Ammonia-nitrogen expressed as a percent of crude protein as an indicator of excessive protein degradation in silage.

**Nitrates (%N0$^3$ or ppm N0$^3$-N):** The nitrogen concentration expressed as nitrate. To convert % nitrate ion (N0$^3$) to ppm Nitrate-Nitrogen divide %N0$^3$ by 4.4 to obtain %N0$^3$-N. Multiply %N0$^3$-N x 10,000 to obtain ppm N0$^3$-N.

**Soluble Protein, %CP:** A chemical (Borate-Buffer) test typically reported as % of crude protein which measures the amount of protein rapidly degraded to ammonia to supply rumen bacteria nitrogen requirements.

**Soluble Protein (Microbial), %CP:** A microbial analysis available on Fermentrics® reports calculated as the amount of crude protein degraded in three hours of sample incubation divided by the total crude protein of the sample.

**Rumen-Undegraded Protein (RUP, %CP):** Portion of the protein that is not degraded in the rumen. Sometimes called bypass protein, escape protein or undegraded intake protein.

**Rumen-Degraded Protein (RDP, %CP):** Portion of total protein which is degraded in the rumen; sometimes referred to as degraded intake protein. Commonly determined using a Streptomyces griseus (SGP) enzymatic digestion method developed at Cornell University.

**Acid Detergent Insoluble Crude Protein (ADICP, %CP):** Sometimes called heat damaged protein or unavailable protein. It quantifies the unavailable protein resulting from the condensation of carbohydrate degradation products with protein forming, dark-colored, insoluble polymers poorly digested by ruminants. It is an input in ration balancing programs using Cornell Model logic.

**Neutral Detergent Insoluble Crude Protein (NDICP, %CP):** Protein associated with the residue remaining after performing a NDF analysis. It is an input in ration balancing programs using Cornell Model logic. It is sometimes referred to as (Neutral Detergent Insoluble Protein) or NDP (Neutral Detergent Protein). It could also be expressed in terms of Nitrogen or "N," a component of crude protein and called Neutral Detergent Insoluble Nitrogen (NDIN) or just Neutral Detergent Nitrogen (NDN). The NDIN value can be calculated by dividing the NDICP by 6.25.

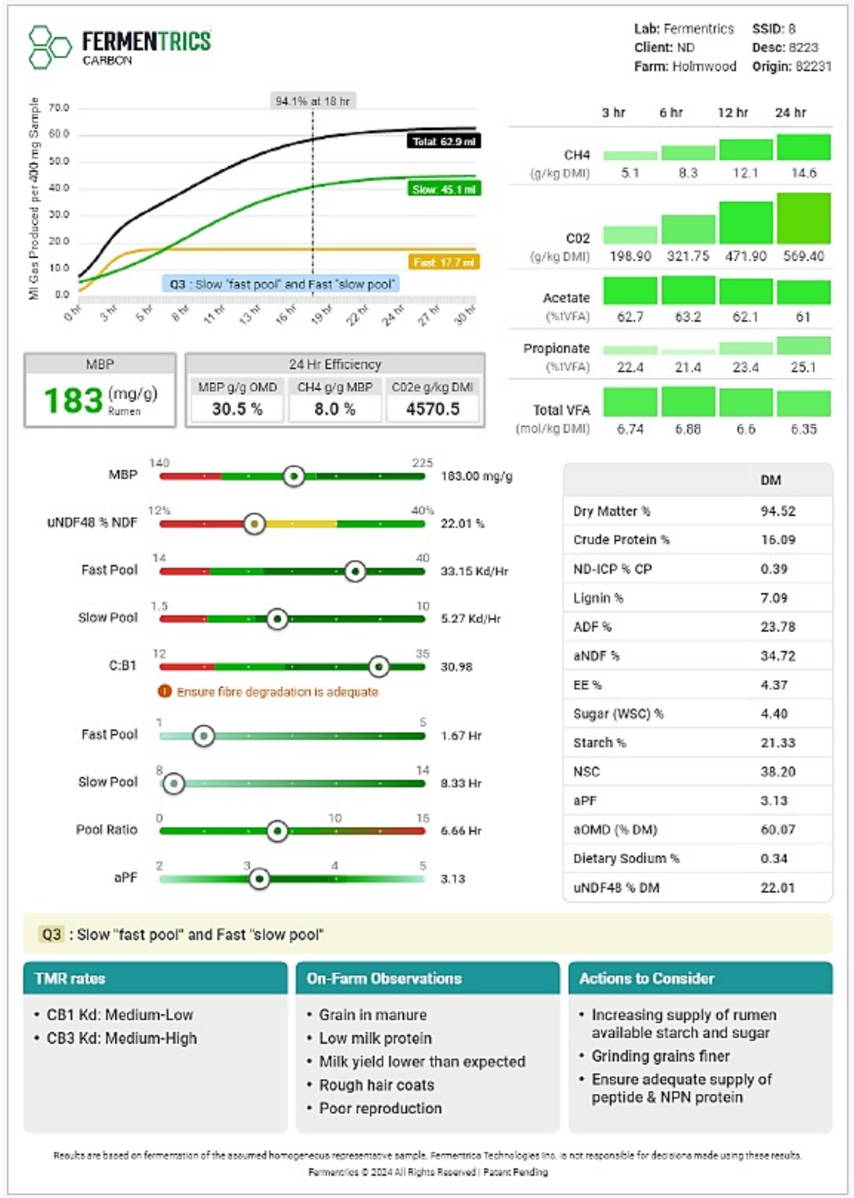
**Prolamins:** Prolamins are proteins such as zeins, and other proteins (albumins, globulins, glutelins) encapsulating corn kernel starch granules to protect starch from premature hydration prior to germination. Corn prolamins tend to be in higher concentrations in the vitreous (glassy) endosperm (high in flint hybrids) than in the more centrally-located floury endosperm of dent hybrids.

**Microbial Biomass Production (MBP, mg/g):** A value reported on Fermentrics® reports measured directly by analyzing the substrate that remains after 48-hour incubation with a NDF analysis (without amylase or sodium sulfite). The difference between the weight of the substrate before and after NDF analysis is the microbial biomass yield of the rumen fluid incubated sample. If the dry matter intake (DMI) of the diet is known, the estimated grams of rumen microbial protein produced are calculated with this equation: MBP x 0.41 x 1.3 x Kg of DMI. The 0.41 is the assumed amount of microbial protein contained in the biomass being measured, 1.3 is an adjustment factor accounting for about 30% of the rumen bacteria existing in the liquid phase thus not measured in the biomass value. Using an actual TMR example with 160 mg/g MBP and an average cow DMI of 23.5 kg, equates to 2004 grams of microbial protein produced. The total contribution of microbial protein plus any RUP provided in the diet is what will contribute to the total protein supply utilized for milk production.

**Starch Digestibility (STRD, % starch):** *In vitro* rumen fluid (or enzymatic) starch digestibility. Sample grind size (e.g. 1-4mm) and incubation time (e.g. 2-10 hours, but most commonly 7 hours) differ by laboratory. This is only ruminal starch disappearance and does not account for post-ruminal starch digestion to determine total tract starch digestion.

**Fecal Starch, %:** measurement of the % starch on a DM basis found in manure. Composite samples of fresh manure from 10-12 cows are submitted to the lab for starch analysis. Levels less than 3% fecal starch indicate excellent total tract (rumen + intestinal) starch digestion.

## EXAMPLE OF A TMR FERMENTRICS® REPORT




**Carbohydrate Digestion Rates (Kd, %/hour):** Carbohydrate pool digestion rates (Kd) are maximum rates of degradation per hour for the $B_1$ (starch), $B_2$ (soluble fiber) and $B_3$ (NDF) carbohydrate pools as defined by models like CNCPS or CPM. Some laboratories publish Kd values for the B3 (NDF) pool by employing published equations from Cornell University utilizing single time point NDFD values (e.g. 24, 30 or 48-hour), NDF and lignin quantity and an assumed digestion lag value (e.g. six hours). Fermentrics™ reports use gas production methods to directly measure digestion rates for both fast (primarily starch) and slow (primarily fiber) pool nutrients. Curve peeling techniques and published equations are used to estimate the carbohydrate pool Kd values.

**Sugar, %:** Sometimes called water soluble carbohydrates (WSC). Sample incubated with water in a 40°C bath extracting simple sugars and fructan. WSC determined after acid hydrolysis with sulfuric acid and colorimetric reaction with potassium ferricyanide.

**Starch, %:** A polysaccharide consisting of a long chain of glucose units.

**Nonfibrous Carbohydrate (% NFC):** An estimate of the rapidly available carbohydrates (primarily starch and sugars). Calculated from one of the following equations: NFC = 100% - (CP% + NDF% + EE% + Ash %) or, if corrected for NDICP, NFC = 100% - [CP% + (NDF% - NDICP %) + EE% + Ash%]. Since NFC is calculated by subtraction, the result includes the additive errors of each component, particularly the NDF procedure. NFC and nonstructural carbohydrates (NSC) are not interchangeable, especially in forages, with much of the difference being pectins and organic acids found in NFC but not NSC.

**Nonstructural Carbohydrates (%NSC):** An enzymatic method where all constituents are analyzed to estimate the sugars, starch, organic acids, and other reserve carbohydrates such as fructans. It is a lower value than NFC because NFC contains compounds other than starch and sugars. NFC and NSC are not interchangeable, especially in forages, with much of the difference being pectins and organic acids found in NFC but not NSC.

| FEED | NFC | NSC |
|---|---|---|
| Alfalfa silage | 18.4 | 7.5 |
| Corn silage | 41.0 | 34.7 |
| Beet pulp | 36.2 | 19.5 |
| High-Moisture Corn | 71.8 | 70.6 |
| Soy hulls | 14.1 | 5.3 |
| Ground corn | 67.5 | 68.7 |

**Acid Detergent Fiber (% ADF):** Residue remaining after boiling sample in acid detergent solution. ADF contains cellulose, lignin and silica, but not hemicellulose.

**Neutral Detergent Fiber (%aNDF):** The NDF value is the total cell wall comprised of the ADF fraction plus hemicellulose. It is the residue left after boiling sample in neutral detergent solution. If amylase and sodium sulfite are used during the extraction (recommended procedure), the fiber fraction should be called amylase-treated NDF (aNDF) to distinguish from original method. If reported on an ash-free basis it is termed $aNDF_{om}$. As NDF increases, dry matter intake generally decreases.

**Undigested Neutral Detergent Fiber ($uNDF_{240}$, %DM):** uNDF is the neutral detergent fiber (cell wall or lignin + cellulose + hemicellulose) that is not digested after x-number of hours incubated with rumen bacteria. uNDF is reported as a % of DM (not as a % of the NDF) with typical rumen retention times of either 24, 30, 120 or 240 hours. uNDF improves predictions of dry matter intakes and rumen function (e.g. rumen microbial yield).

| | uNDF 240h, % of DM | |
|---|---|---|
| FEED TYPE | GOAL | AVERAGE |
| Alfalfa hay or haylage | < 13 | 18 |
| Corn silage | < 7 | 9 |
| Sorghum, sudan or small-grain hay or silage | < 9 | 14 |

*Source: Dr. Rick Grant, W.H. Miner Institute*

**NDFD, as %NDF:** A measurement of the NDF digestibility typically measured by *in vitro* incubations with rumen fluid and buffers or *in situ* by hanging samples in fistulated animals. Grind size of sample (finer grind will generate higher values) and incubation times (12, 24, 30, 48-hour) vary by laboratory. Some labs report dNDF which is the portion of the neutral detergent fiber digested by animals at a specified level of feed intake, expressed as a percent of the dry matter. NDFD = dNDF/NDF x 100.

**Physically Effective NDF (peNDF, %DM):** An estimate of the coarse portion of the fiber believed effective in stimulating chewing activity and salivary buffer production to increased rumen pH. It is calculated by dry sieving the sample for ten minutes and taking the proportion of the dry matter retained on a 1.18mm sieve (termed the pe factor) multiplied by the NDF content of the sample.

## NDF DEFINITIONS

| | NO amylase NO Na sulfite | amylase NO Na sulfite | amylase Na sulfite | amylase Na sulfite Ash free |
|---|---|---|---|---|
| | **NDF** | **NDR** | **aNDF** | **aNDFom** |
| High Grain Corn Silage | 37.7 | 38.1 | 36.0 | 35.2 |

*Source: Dave Mertens, Pioneer Symposium at the 2002 Cornell Nutrition Conference*

**Lignin:** Sometimes called acid detergent lignin (AD-lignin). It is the indigestible plant component (chain of phenyl propane units), giving plant cell walls strength and water impermeability. High levels of lignin tend to reduce digestibility within a plant species. There are two methods of measuring lignin in acid detergent fiber: sulfuric acid lignin and permanganate lignin. Permanganate lignin is a larger value than sulfuric lignin for most feeds.

**Total Tract NDF Digestibility (TTNDFD, %NDF):** An *in vitro* method that measures NDFD and uNDF (at 24, 30 and 48 hours) in standardized rumen fluid with incorporating rate (Kd) of fiber digestion, the amount of potentially digested NDF (pdNDF), rate of feed passage (Kp) in high-producing dairy cows and hindgut fiber digestion to provide a total tract estimate of NDF digestibility.

**Potentially digestible NDF (pdNDF, % DM):** a measure of the potentially digestible NDF calculated by subtracting $uNDF_{240}$, % DM from total NDF, %DM in the original sample.

**Potentially digestible NDF yield (pdNDF yield, % DM):** a measure of potentially digestible NDF yield per acre calculated by multiplying DM yield of silage/acre times pdNDF, %DM.

**Crude Fat, %:** An estimate of the fat content of feeds determined by ether extraction; sometimes termed ether extract (EE). Crude fat contains true fat (triglycerides) as well as alcohols, waxes, terpenes, steroids, pigments, ester, aldehydes and other lipids.

**Ash %:** the residue remaining after burning sample at 550°C as an estimate of total mineral content.

**Minerals:** Macro minerals (e.g. calcium, phosphorus, potassium, magnesium, sodium, sulfur) are reported as a percent and trace minerals (e.g. copper, iron, manganese, zinc) are reported as parts per million (ppm).

**Corn Silage Processing Score (CSPS, %total starch):** Analysis of dried corn silage sample to assess level of kernel damage at harvest. Sample is separated by particle size using sieves and then analyzed for percent starch on coarse (> 4.7 mm), medium (1.18 to 3.35 mm) and fine screens (0.6 mm or less). Scores above 70% indicate optimum kernel processing; 50-70 indicate average processing and scores less than 50% indicate under processed samples.

**Relative Feed Value (RFV):** An index that combines factors affecting forage intake and digestibility allowing for relative comparisons of legume, grass and legume/grass forages (not corn silage). RFV Is used to determine the relative value for marketing purposes. It is calculated as: RFV= (DMI, % of body weight) * (DDM, % of DM) / 1.29 where: DMI is dry matter intake (% of body weight) calculated as 120/ (NDF, %DM) and DDM is digestible dry matter calculated as 88.9–(0.779 x ADF, %DM)

**Relative Feed Quality (RFQ):** An index which incorporates NDFD to more accurately compare potential animal performance when fed legume, grass and legume/grass forages (not corn silage). It is based on the digestibility of the forage dry matter and how much the cow can eat based on filling capacity. It is calculated as: RFQ = (DMI, % of BW) * (TDN, % of DM) / 1.23. See page 95 for calculation examples.

**Milk per Ton, lbs/ton:** A corn silage or alfalfa index that estimates the pounds of milk produced per dry matter ton of forage based on the University of Wisconsin MILK2006 decision aid.

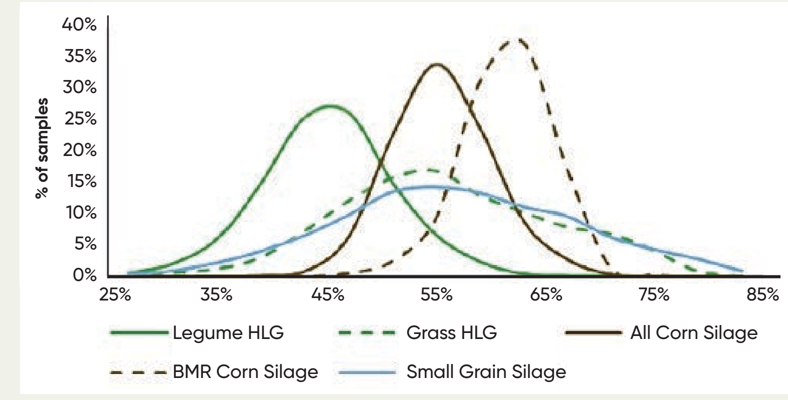
**Milk per Acre, lbs/acre:** A corn silage or alfalfa index that estimates the pounds of milk produced per acre from the total yield of forage dry matter based on the University of Wisconsin MILK2006 decision aid.

**Energy Calculations:** Most labs report calculated values for total digestible nutrients (TDN, %), net energy lactation (NEL, Mcal/lb), net energy maintenance (NEM, Mcal/lb), net energy gain (NEG, Mcal/lb). There are several different equations that can be used for each of these energy values, so it is best to source the equations being used from the individual laboratories.

**Fermentation Profiles:** Typical silage fermentation analysis will include levels of volatile fatty acids (acetic, propionic, 1,2 propanediol, isobutyric, butyric) along with pH, lactic acid, and occasionally ammonia-N and ethanol.

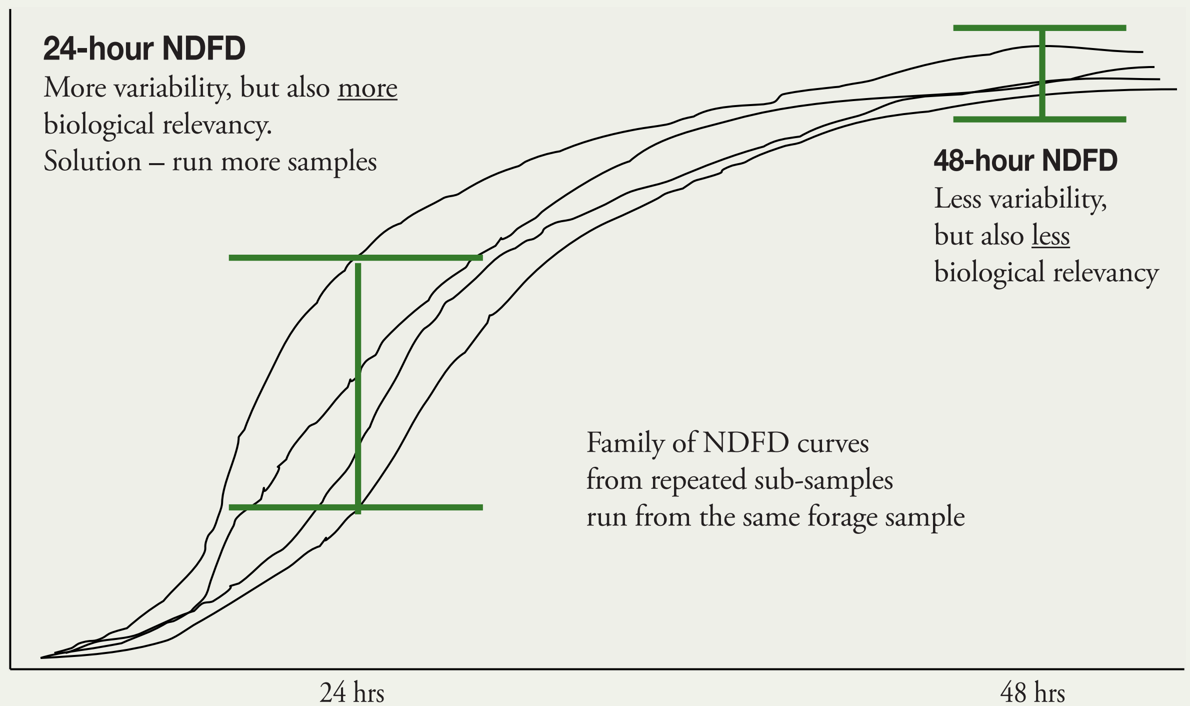


## TYPICAL RANGES IN NDFD (30-HOUR)




*Source: Dairyland Labs, 2018. Data from 140,964 samples*

## THE 24-HOUR VERSUS 48-HOUR NDFD INCUBATION TIME DEBATE



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