HYBRID SELECTION FOR CORN SILAGE

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Introduction

When choosing corn hybrids for silage production, growers should consider several important factors that may impact forage yield, quality and ultimately, the animal performance derived from feeding the silage.

What criteria should growers consider when choosing a hybrid for silage? Yield and nutritional quality vary between hybrids as a result of hybrid genetics and adaptation, harvest maturity, amount of grain fill, stover digestibility and the grain-to-stover (G:S) ratio.

Perhaps the most recent and comprehensive study ever conducted on this subject is the findings of the University of Wisconsin [1] four-year (1991-95) Corn Silage Consortium that was jointly funded by several major seed companies, including Pioneer. As a result of this extended study, the University of Wisconsin recommends silage hybrid selection should start with identifying a group of hybrids that are adapted to the area in terms of maturity, standability, disease/insect resistance and drought tolerance. Once a group of adapted hybrids is identified, evaluate them on the basis of forage yield potential. The next selection criterion was grain yield potential.

The best silage hybrids tend to have high grain yields because grain is so highly digestible compared to stover. However, within the high grain-yielding group there can be differences in whole-plant yield and fiber digestibility. This reinforces the need to have silage data available because not all high grain-yielding hybrids are suitable when factoring in forage yield and fiber digestibility differences. The final consideration for hybrid evaluation should be quality according to the Wisconsin research. This is likely lower on the selection criteria list because the range in stover digestibility among commercial (non-brown mid-rib) silage hybrids is extremely narrow.

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The conclusion to this and other silage studies is that silage hybrids should first be agronomically adapted and secondly, possess the desired combination of forage yield, whole-plant digestibility and stover digestibility needed by the class of livestock to which the silage will be fed.

Variation Among Corn Silage Hybrids

Energy density (e.g. nutritional quality) of silage hybrids is determined by two primary components: (1) grain (starch and oil) content and (2) stover (neutral detergent fiber (NDF) or cell wall digestibility). Environment and crop management can also greatly influence energy density in that they affect the level of grain yield and the maturity (and digestibility) of the stover. It has been proven that agronomic characteristics, such as standability, do not significantly influence energy density or nutritional quality. However, these characteristics are important when it comes to making final decisions about hybrids especially when concerning yield potential and ease of harvest.

Yield and nutritional differences between hybrids are repeatable, provided sufficient data exists to statistically eliminate environmental growing differences. In breeding terms, this means there is no meaningful "GxE" (genetic by environmental) interaction. However, there can be a significant environmental effect on yield and nutritional value. In other words, while the absolute nutritional values may change due to different growing environments, hybrids tend to rank the same if grown across environments within their adapted geographies. This allows silage researchers to pool data from hybrids grown (side-by-side) across adapted environments and use this data to generate relative trait ratings.

Corn Silage: Two Distinct Pools of Energy

Although corn silage hybrids are selectively bred and/or characterized for high digestibility of the stover, the energy density of corn silage is highly correlated with grain yield.[(2)] Corn silage is unique and difficult to analyze in a lab or assign energy values because it contains both forage and grain. In many ways it can be thought of as a grass plant with high moisture corn attached.

Corn silage contributes "*yellow*" grain to a readily available energy (RAE) pool and "*green*" stover to a more slowly available fiber (cell wall) energy pool for rumen digestion. The important RAE pool also includes sugars found in the stover and oil found in the germ of the kernel. Largely the grain-driven RAE pool determines the energy density in corn silage.

Stover also influences energy density, but to a much lesser degree. This is especially true in early lactation cows where corn silage typically only resides in the rumen for 15-24 hours. The limited ruminal retention time (from high dry matter intakes) coupled with ruminal bacterial digestive hierarchy (utilization of RAE pools first), makes the energy contribution from stover generally less than 25% of the total energy in corn silage in early lactation rations.

An interesting finding of the UW Corn Silage Consortium was that stover is strongly influenced by both maturity and grain fill. Corn growers can expect a 1% increase in NDF and a 0.5% decrease in digestibility for each 10% decrease in grain yield. As grain fill is reduced, NDF digestibility is reduced. At the same time, stover in-vitro total dry matter digestibility increases because of non-translocated, non-structural carbohydrates (NSC), such as sugars.[(2)] This further attests to the importance of the RAE pool in improving total energy availability.

A 1988-89 Michigan State University study demonstrated the extent of nutritional variation between corn hybrids. In this two year study, crude protein among the germplasm tested varied by only 1-2% units, stover digestibility by 5% units, and whole plant digestibility by only 4% units.[(3)] Other researchers also have observed that stover variation is small across commercial germplasm, and its overall contribution to energy density is limited. This suggests it is primarily the grain in a hybrid that determines the overall quality and nutritional base for cattle.[(1)]

While it is important for growers interested in nutritional quality to look at the maturity and other traits associated with particular hybrids, it is the grain-to-stover (G:S) ratio that most strongly impacts the energy value of corn silage. Generally, G:S ratios across North America range (on a dry matter basis) from 30:70 (Western States) to 50:50 (Midwestern to Eastern States). Michigan State University researchers reported dry matter (DM), NDF percentages and in-vitro disappearances of various corn components (Table 1). The DM and NDF disappearance of corn grain is much greater than it is for stover components. Grain typically supplies 80% more megacalories (Mcal) of net energy for lactation (NE_L) than composite stover on a pound for pound basis. A book value for stover NE_L (1989 NRC) is 0.5 Mcal/lb DM NE_L, while that reported for corn grain is 0.93 Mcal/lb of DM.

Table 1. Composition of the Corn Plant

Part	(% Composition) % DM	% NDF	(% Disappearance) NDF	DM
Tassel	< 1	78.4	53.4	63.5
Leaf sheaths	6.1	78.1	60.3	69.0
Husk	5.8	80.5	69.5	75.4
Leaf blades	8.5	66.7	73.2	82.1
Cobs	12.1	89.3	31.9	39.2
Stalk	18.3	66.5	61.5	74.4
Grain	48.5	11.8	89.7	90.0

(Mike Allen, MSU 1995)

Ultimately, animal performance is the best way to measure one hybrid against another. A 1993 study by Hunt et.al., demonstrated that a hybrid with 6.7% units greater in-situ digestibility resulted in 850 pounds more beef per bag (80,000 seeds per bag) of corn seed planted for silage. Milk potential (pounds of milk) was predicted by multiplying pounds of beef by eight. Thus, the hybrid with the superior in-situ digestibility yielded 6,800 lbs. more milk from every bag planted.[(4)]

An understanding of the nutritional contribution of the two pools of energy in corn silage has led Pioneer breeders to advance silage hybrids for nutritional traits based first on whole plant yield and grain yield and secondly on stover digestibility. This selection hierarchy is driven by the following facts (that have been supported by various University studies): 1) grain is the biggest driver of silage energy density, 2) there is a limited range in stover digestibility among most germplasms and 3) cell contents, not cell walls provide 75-80% of the energy for rumen bacteria in the relatively short time (24-30 hrs) corn silage resides in the rumen of high producing cows.

Importance of Harvest Management

Performance of any hybrid selected for corn silage is maximized when harvested at the proper stage of maturity. New technologies like corn silage processing allows hybrids to be harvested at more advanced stages of kernel maturity. If processed correctly, growers can maximize silage yields, starch content and milk production. Corn hybrids that are not processed should be harvested at earlier maturities (68-72% moisture) to minimize nutritional starch loss from non-digested kernels passed into feces.

Pioneer research shows that at optimum silage harvest maturity (65-70% moisture), hybrids of varying test weight (and kernel texture) did not differ significantly in the force (measure with an Instrom) needed to crush the kernel. Growers should focus on a combination of plant physiological parameters (e.g. kernel milkline) and whole-plant moistures (chopping 5-10 plants and determining moisture with microwave or Koster ™ Tester) to determine optimum harvest timing. Ruminal starch availability cannot be overcome by selecting hybrids for lower test weight (and potential lowering of starch yield/acre) if the harvest window is missed by a matter of weeks, like what has occurred in the Midwest in recent years due to unusual weather patterns.

Corn Silage Hybrid Selection

Genetic differences can only be evaluated when hybrids are grown together, side-by-side (SxS), in the same plots. Statisticians within Pioneer research recommend 20 SxS silage comparisons (over multiple (2-3) years to reflect stability of yield) for making an informed genetic decision on which hybrid to plant. This number of SxS locations allows one to reduce the confounding aspects of environment (weather, soil, fertility, moisture, disease/pests and hybrid adaptability) and harvest maturity. It also helps account for the error associated with forage sampling (and sub-sampling) and laboratory analyses. Many nutritionists summarize hybrid nutritional values from their client base. These hybrid differences reflect the environmental influence, but one should not take those values as indicative of hybrid genetic difference.

Recently the authors learned a valuable communications lesson from a highly respected dairy nutritionist. The nutritionist was telling his clients that fiber digestibility should be one of the most important criteria for selecting a silage hybrid because when it was low; he was "*handcuffed*" as to how much corn silage could be incorporated into the ration. The authors were telling the same client that fiber digestibility should only account for 10-15% of a silage hybrid selection index because of the small genetic variation (4-5 percentage-points [(2)]) and the difficulty in accurately measuring the trait. The dairyman was obviously confused from the contradicting advice.

It took a meeting between the authors and the nutritionist to clarify the situation. The nutritionist was using data he had collected over several years that showed over a 15 percentage-point spread in 30-hour in vitro fiber digestibility among the various hybrids grown by his clients. His data reflected the environmental effect on the genetic potential of these hybrids. This effect is the real-world variation that dairyman and nutritionists are forced to live with. What the authors were telling the dairyman was that once the environmental, sampling and analysis effects was factored out (by SxS testing), the genetic variation in fiber digestibility between hybrids was so small that it warranted only limited emphasis (consistent with the Wisconsin findings) when selecting a silage hybrid to plant. So in effect, we were both correct; the environment plays an important role in determining fiber digestibility (we can exert limited over the environment) but when selecting hybrids (just like selecting bulls) one needs to adjust the selection pressure based on genetic differences (small in this case).

Selecting Adapted Hybrids

When selecting hybrids for silage, growers should consider hybrids that are best adapted to local growing conditions. First, growers should look at the silage comparative relative maturity (CRM) or the growing degree units (GDU) to half milkline of each hybrid. Unfortunately, industry standards do not exist for determining silage maturity, and comparing maturity and harvest moisture among corn-for-silage hybrids can be difficult.

Most seed companies have their own individual methods of assigning relative maturities to silage hybrids. For example, a hybrid with a reported need for 2,345-GDU to reach kernel blacklayer might have as much as a 6-day difference between CRM ratings depending on the company doing the rating. A conservative company may position a 97-CRM hybrid as a 100-day CRM to ensure adequate grain maturity and drydown. Another company might position the same 97-CRM hybrid as a 94-day hybrid to give the impression that it fits into shorter growing environments. Because the hybrid in the last example has a longer growing period than is reflected by the CRM, yield and stover digestibility data may make the hybrid appear to outperform other similar CRM hybrids from more conservative companies.

Pioneer silage CRM ratings are unique in the seed industry and provide a relative comparison between Pioneer® brand hybrids for rates at which hybrids reach harvestable whole-plant moistures. The silage scale is different than the Pioneer corn grain CRM and does not represent actual days from planting or emergence to harvest moisture or half milkline.

Silage growers can plan corn hybrid maturity spread based on the time it takes to plant, expected harvest dry matter change per day of CRM maturity and expected length of corn silage harvest. Slow planting due to wet soil conditions can result in a wide spread of maturities. Rapid harvest can also contribute to having a wide range of corn silage moistures at harvest, if the traditional spread out hybrid maturities are used. Pioneer silage breeders have calculated that each day of Pioneer silage CRM results in a .6% unit change in harvest dry matter. It is also not atypical to have corn silage dry matter drop as much as .75-2 points per each day of delayed harvest.

Watch out for differences between seed companies; their rating systems for days of maturity are not the same. Ask for silage specific CRM and what to expect in change of harvested silage DM for each day of CRM difference.

Selecting Agronomic Characteristics

Growers must consider the agronomic strengths of hybrid along with adaptation, yield and nutritional content. The importance of particular agronomic strengths is based upon individual customer needs, as well as environmental conditions and soil types. To maximize yield, traits that should be considered include: drought stress tolerance, brittle stalk resistance, root and stalk strength, early growth and staygreen.

Silage growers should understand that staygreen is not a trait that breeders select for….but rather a result of improved late-season plant health. An advantage to higher staygreen is improved late season standability and extended photosynthesis for maximization of kernel starch fill late in the growing season. This can be very desirable for growers wishing to allow hybrids to stay in the field longer when utilizing corn silage processing technologies. High staygreen ratings are also desirable in environments where resistance to foliar diseases is needed. However, growers should be cautious not to rely on stover staygreen to determine when to chop. The potential exists for ensiling wet forages (moisture retained in the stover) yet silage that contains advanced maturity (hard) kernels that have a tendency to pass into the feces of cattle. A lower staygreen score may be desirable in environments where grain drydown is significantly faster than stover drydown.

Selecting for Yield and Nutritional Traits

Once a hybrid is selected for area of adaptability and agronomic strengths, silage producers can then turn their attention to silage yield and nutritional ratings. What follows is a discussion of the nutritional traits analyzed and reported by

Pioneer. Growers should make inquiries from their seed supplier as to the companies testing and analytical commitment to the corn silage market.

Pioneer rates silage hybrids on a scale of 1 to 9, with 1 being the poorest rating and 9 the most outstanding. This system provides a broad view of hybrid performance across many different environments. The ratings are based on multiple comparisons with other Pioneer hybrids (not competitive hybrids) and on overall performance across their area of adaptation under normal conditions. While absolute values from local plots are often shared with growers and nutritionists, Pioneer catalogs and sales literature includes these general ratings to give growers the opportunity to easily compare relative differences among hybrids recommended for silage.

The database used to determine Pioneer silage ratings (and NIR calibrations) contains thousands of silage samples collected over several years from large planned plots and side-by-sides harvested across North America. Typically, the Pioneer Livestock Nutrition Center analyzes about 7,000 samples from over 100 Pioneer hybrids grown in over 1100 (SxS) locations. Another 7,000 samples from experimental hybrids years away from potential commercialization are also submitted to our laboratory by Pioneer Research Stations across North America.

Yield Ratings

While energy density is important, silage economics still demand high whole-plant yields. This is especially true among expansion dairies where corn silage in the ration is on the increase. A 1.0 point difference (in Pioneer's 1 to 9 rating scale) in yield approximates a 1.0 to 1.5 ton per acre difference in wet (70%) silage yield.

The impact of special silage traits (e.g. high digestibility, brown mid-rib, leafy, high oil, modified amino acids) on animal performance is tempered by a single agronomic trait…. silage yield. Corn silage yield per acre is important because it may (economically) offset any response in animal performance [11].

Silage Digestibility Ratings

Whole plant digestibility ratings from Pioneer are based on the results of several different methodologies recognizing that there are inherent flaws in any single method (i.e. grind size, sample size, exposure time, rumen-based conditions versus purified enzyme methods).

Hybrids score higher for whole plant digestibility if they are low in fiber while also exhibiting higher starch content, digestible cell wall (dNDF) and in-vitro-cellulose whole plant digestibility. All of these traits are predicted by near infrared reflectance spectroscopy (NIRS) from calibrations developed by Pioneer researchers and NIRS spectroscopists. This allows a sample to be profiled for multiple traits in a matter of 90 seconds so thousands of data points can contribute to the trait ratings for any individual hybrid.

A 1.0 point difference in whole plant digestibility approximates a 1.0% to 1.5% unit difference in in-vitro digestibility, a .02% units difference in ADF, a 2-3% difference in whole plant starch and/or a .02% unit change in adjusted net energy for lactation (NE_L). In terms of animal production, a 1.0 point difference in digestibility ratings approximates enough extra energy to produce 3 lbs. beef gain or 25 lbs. more milk from every ton of (as fed) corn silage fed to cattle.

Because there is no industry standard used in analyzing or reporting digestibility data, it is easy for corn growers and dairy producers to become confused. As a result, Pioneer is active in a Midwest NIRS Consortium of Midwestern Universities and commercial forage labs in an attempt develop more standardized methods that the corn silage industry can adopt when publishing silage quality information. [7]

RAE Ratings

Readily Available Energy ratings from Pioneer primarily reflect grain content and are based on total starch, sugar (in kernel and stover), and oil content of hybrids harvested at silage maturity. High oil corn would have higher RAE due to the elevated oil in the germ of the kernel. High RAE is generally indicative of a higher grain-to-stover ratio hybrid. A 1.0 difference in RAE approximates a 1-1.3% unit difference in whole plant RAE levels.
Given the same digestibility score, a higher RAE score would be desirable by dairy producers feeding high production cows with fast rumen passage rates. Beef producers might desire a lower RAE score, as rumen passage rates are slower in these animals.

Fiber Digestibility Ratings.

Pioneer also provides information on the digestible neutral detergent fiber (dNDF) of all the hybrids that are recommended for silage growers. This trait addresses the contribution of the cell wall pool to the energy potential of the hybrid. The dNDF method measures the enzymatic degradability of NDF from whole plant corn silage based on a 24-hour rumen retention time and is predicted by a NIRS calibration developed by Pioneer. The 24-hour time point was chosen to be reflective of the rates of passage in high producing animals. Growers must be sure they are comparing "*apples to apples*" when comparing company ratings for fiber digestibility. Not only can the methods be very different but also if one company uses a longer time exposure to rumen fluid or enzymes (e.g. 48-hours vs. 24-hours), the extent of fiber digestibility will naturally appear higher.

Crude Protein Ratings

One characteristic upon which corn silage growers should probably place reduced emphasis is crude protein. Crude protein contribution from corn silage is relative minor compared to foodstuff such as alfalfa, and the amino acid profile in zein protein (found in the endosperm of the kernel) is of low biological value. A 1.0 point difference in crude protein (whole plant) approximates a 0.3% unit of change in whole plant crude protein. Producers should select corn silage hybrids for their energy contribution and rely on alfalfa as their main source of forage protein.[(2)]

Rating Hybrids for Silage Using Production Indexes

Many silage growers prefer an overall index to sort hybrids according to their unique needs for yield versus nutritional quality. Suppliers of seed genetics should have this conversation with all silage growers to be sure their needs are being met. As a starting point for dairy producers, Pioneer suggests they consider spreading 100 index points in this fashion: 60 points on forage yield, 30 points on RAE (starch + sugar+ oil) and 10 points on fiber digestibility. The limited selection pressure on fiber digestibility acknowledges that environment and management can cause large differences, but genetically there is a very small range between silage hybrids.

A more advanced index (MILK95) was developed and published by researchers at the University of Wisconsin. The MILK95 spreadsheet determines potential milk yield a hybrid could deliver per ton and per acre by combining yield and forage quality information. [(5)]

Pioneer Hi-Bred slightly modified this calculation for its North American hybrid comparisons by using an in-vitro cellulose method as a co-variant to adjust ADF values used in the calculations. What this means is that if a hybrid is determined to have higher whole plant digestibility from various in vitro methods, the ADF is adjusted down so when ADF is put into common NE-L regression equations, the resultant NE-l estimates appear higher. This helps overcome the limitation in commonly used NE-L equations that employ only one variable (ADF) and erroneously assume all ADF is equally digestible.

A 1.0 point difference in Pioneer corn silage ratings for "Milk Per Acre" approximates about 1,000 pounds in milk per acre advantage as determined by the modified MILK95 formula. One drawback to MILK95 is its inability to correctly compare unique genetics such as high-oil corn silage.[(6)]

University of Wisconsin researchers Shaver and Schwab recently released an updated version of MILK95 entitled MILK2000. MILK2000 enhancements allow for the use of forage analyses (crude protein, neutral detergent fiber (NDF), *in vitro* NDF digestibility, starch, and non-fiber carbohydrate) to estimate energy content using a modification of the NRC (2001) [(12)] summative approach and dry matter intake from NDF and *in vitro* NDF digestibility to predict milk production per ton of forage dry matter (DM). In MILK2000, the intake of energy from forage for a 1350 lb. milking cow consuming a 30% NDF diet is calculated and the cow's maintenance energy requirement (proportioned according to the percentage of forage in the diet) is then subtracted from energy intake to provide an estimate of the energy available from forage for conversion to milk (NRC, 1989). [(13)] Forage DM yield multiplied by the milk produced per ton of forage DM provides an estimate of the milk produced per acre and combines yield and quality into a single term.[(14)] Pioneer is in the process of updating milk per acre ratings with the new MILK2000 equations.

Summary

To maximize milk and meat production per acre of corn silage, growers should select hybrids with the agronomic characteristics adapted to their unique growing environments. Superior hybrids must also demonstrate high forage yields. Silage hybrids that return the most profit usually produce the most grain without compromising whole plant tonnage. A silage hybrid should be assessed RAE (starch+sugar+oil) content and stover (cell wall, NDF) digestibility. Individual producers can determine their own index weightings or use equations such as MILK2000 to arrive at single term comparisons of production potential based upon yield and quality data.

While differences in corn silage hybrids are evident from the standpoint of morphology, nutrients and in vitro digestibility, animal performance differences are more difficult to measure (especially on farm). In addition, inherent traits of these silages may be neutralized by environmental and management factors. Management factors such as whole plant maturity, kernel moisture, kernel size, silage particle size and associative feeding effects further influence animal response.(11)

Silage growers today should be able to select high-quality silage genetics based upon reliable trait information provided by reputable seed suppliers. Future hybrid selection will be simplified once industry standards are established for the quality ratings of hybrids. In addition, growers will benefit by on-going research into the effect of growing environment and stages of harvest maturity on the yield and nutritional value of individual hybrids.

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