Agronomy Facts 18

Corn Silage Production and Management

Corn harvested for silage is an important feed crop on most Pennsylvania farms, where cropland often is limited. The crop provides livestock producers with a high-yielding, relatively consistent source of forage and the animals with a highly digestible and palatable feed. Corn silage produces more energy per acre than any other crop grown in Pennsylvania.

Corn silage serves as a high-energy forage for dairy cows. This is most important for high-producing herds and on farms experiencing problems with making or buying high-quality hay crop forage. Corn silage, with its relatively high-energy content, is also well adapted for use in low-cost rations for fattening cattle. Corn silage requires less labor per ton to produce than many other forage crops. It can extend the harvest period for the entire corn acreage and provide an opportunity for salvage of stressed or damaged cornfields. Also, corn silage can efficiently recycle plant nutrients, especially large amounts of N and K.

Corn silage has some disadvantages, however. It is difficult to market and transport very far. Corn silage can also lead to an increased potential for soil erosion and a subsequent loss in soil productivity when soil conservation practices are not a part of the production system.

PLANNING TO PRODUCE CORN SILAGE

As with all crops, a detailed plan for producing corn silage is an essential component of an efficient cropping system. The cropping plan should be based on forage dry matter requirements that take into account harvesting, storage, and feeding losses, and agronomic factors such as field selection, hybrid selection, rotations, fertility, and weed control programs.
A basic consideration for corn silage production is whether corn silage fields will be identified during the growing season or during planning. Many growers identify fields during the growing season, selecting fields that are late-planted or stressed for some reason. This approach can be effective when stresses such as drought, insects, or disease are frequently encountered. It allows growers to obtain greater yields of dry matter and energy from fields with limited potential for high-grain yields. Selecting fields for silage harvest during the season limits the opportunities to take advantage of management practices that can potentially increase silage yields and quality (hybrid selection, plant population, planting date, and fertility programs). Using these management practices to improve silage yields can result in fewer acres required to fill the silo and more corn acres available for shelled or ear corn harvest. Planting fields specifically for silage, in a cropping program where both grain and silage are being produced, will be more appropriate where the risks for acceptable grain production are minimal or where silage will be the primary use of the crop.

PRODUCTION PRACTICES

Hybrid selection

Corn hybrids selected for silage production should produce high yields of quality silage before frost. The production potential of hybrids can be obtained from silage performance tests. Unfortunately, only a limited amount of testing information is available for silage yield and forage quality. A number of studies have shown that grain yield alone is not the best indicator of a hybrid's performance for silage. To maximize corn silage yield potential, select hybrids with a relative maturity (RM) rating up to 10 days longer than a full-season grain hybrid for your area. These hybrids often have a 2 to 4 ton/acre yield advantage over standard maturity hybrids. Later-maturing hybrids are not appropriate where the crop may be harvested for grain, where early silage is desired, or where wet soils may interfere with harvest.

The maturity range of hybrids selected for a particular farm should be considered carefully. Selecting a range of maturities can cause considerable variation in moisture content at harvest, especially if fields need to be harvested in a narrow window with a custom harvester. This can result in increased variation in moisture and forage quality in the silo. Where harvest and planting are spread over a longer period, some variation in hybrid maturity is desirable to avoid harvesting silage that is too mature. In some cases, a small amount of a

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slightly later hybrid can be used when filling the top of the silo with material that has a slightly higher moisture content.

Forage quality can also vary between hybrids. Many seed corn companies are characterizing their hybrids with respect to whole plant digestibility, fiber digestibility, and starch digestibility.

Measurements of digestibility such as *in vitro* (in a test tube) or *in situ* (in the cow) digestibility appear to be the most accurate indicators of the energy value. Both systems of analysis have their pros and cons. The in vitro methods are more repeatable but may not represent actual silage as well as the in situ methods. The in situ methods tend to be much more expensive and more inconsistent between labs and methods. Both of these measures predict the energy value of the silage more accurately than other estimates such as Nel or TDN, which are based on the acid detergent fiber (ADF). Some groups have suggested that it is not only the extent or total digestibility, but also the rate of digestibility that is an important characteristic of a hybrid. However, the importance of digestion rates of various hybrids has not been well quantified yet. It should be noted that there is a standard approved for the in vitro method for feeds, but no standard in situ method has been established.

Fiber digestibility may be even more important than whole plant digestibility, since the digestibility of the fiber component of the ration limits milk production on some dairies. The total energy (digestibility) of the ration can be manipulated by increasing the amount of grain up to a point, but the digestibility of the fiber is more difficult to adjust. Fiber digestibility is probably most important on farms where corn silage makes up a significant part of the forage in the ration. The response to increased fiber digestibility appears to be greatest for high-producing cows early in their lactation due to their high energy and drymatter intake demands.

The starch digestibility of hybrids can also vary; however, the potential effect is not well understood. Starch digestibility is affected not only by the kernel type, but also by maturity, kernel processing, and the length of time in storage. Also, the optimum rate of starch digestibility may vary depending on the ration—in some cases it may be desirable to have rapidly available starch in corn silage, whereas in other cases more slowly available starch may be desirable. Corn hybrids vary in the amount of hard and soft starch in the kernel, which may affect starch availability. Kernel differences among hybrids for starch will be most pronounced as the crop approaches black layer.

Hybrid types for silage

Conventional hybrids exhibit variation in dry matter and fiber digestibility. Many seed companies in our area have evaluated their existing conventional hybrids for dry matter and fiber digestibility and developed a list of hybrids recommended for silage production. It is possible to find high-yielding lines with above-average dry matter digestibility and fiber digestibility. The challenge is that little independent testing data is available. Use research-based seed company recommendations to identify the best conventional hybrids and follow up by monitoring the dry matter digestibility and fiber digestibility of your silage.

Leafy hybrids contain a gene that results in an increase in the leaf content of the silage. In one trial we conducted, the leaf content of the silage was 12 percent for a normal hybrid and 13–16 percent for the leafy hybrids. Leafy hybrids vary in their characteristics somewhat, but they tend to yield close to or better than conventional hybrids and have softer kernels that dry down more slowly. Some leafy hybrids may have less starch and more fiber than conventional hybrids. Digestibility and fiber digestibility ratings of the leafy hybrids have shown mixed results compared to conventional hybrids. There is considerable variation among the leafy genotype, so be sure to check with your seed supplier regarding specific management recommendations. Some leafy hybrids are designed for silage-only use; some have a relatively faster stover drydown rate.

Brown midrib hybrids have superior fiber digestibility, and some feeding trials have shown that use of these hybrids can increase milk production by several pounds per cow. Brown midrib hybrids have yielded about 10 to 40 percent less than conventional hybrids in our trials. This lower yield in conjunction with the high price of the seed has limited the adoption of these hybrids. If consistent 2 to 3 pound per cow increases in milk production could be achieved, this would offset costs associated with the lower silage yields of this material. The economic benefits of the BMR hybrids are maximized when this silage is stored separately and the ration is carefully balanced to take advantage of the increased fiber digestibility.

Waxy corn is grown for silage on a limited acreage in Pennsylvania. Grain of waxy corn contains 100 percent amylopectin starch (branched chain glucose molecules) rather than the 75 percent amylopectin starch in normal dent corn. Feeding trial results have been inconsistent. Some results have suggested slightly greater feed efficiencies with waxy corn and corn silage, while other trial results have not shown any differences between waxy corn and regular dent corn. Waxy hybrids can produce yields similar or slightly lower than conventional dent hybrids.

Plant populations

Desired plant populations for corn silage are dependent upon productivity of the hybrid and the soil. Generally, populations for corn silage should have 2,000 to 4,000 more plants per acre than are recommended for grain. This will often result in a desired stand of 26,000 to 32,000 plants per acre on most soils. Higher plant populations in this range are best suited on the most productive soils. A two-year trial we conducted in central Pennsylvania indicated silage yields were maximized at 42,000 plants per acre, but the estimated milk yields/acre, considering both yield and whole plant digestibility (Table 1) were maximized at 30,000 plants per acre, because of declining digestibility with higher populations. A recent study conducted at Cornell University showed a similar trend. This study showed a 1.5-ton per acre yield response when plant populations on deep, well-drained soils were increased from 26,000 to 30,000 plants per acre.

Table 1. Corn forage yield and quality response to increasing plant populations in Centre County in 1998 and 1999.

Population plants/acre	Yield Tons/acre @65%	Digestibility %	NDF %	Estimated Milk/Acre lbs/acre
24,000	23.4	66.9	47.2	30,927
30,000	24.7	67.7	46.2	35,015
36,000	25.6	64.6	50.1	27,374
42,000	26.0	65.5	48.7	30,762

Planting date

Although corn for silage responds to timely planting, it is more tolerant of late planting than is corn planted for grain. Optimum planting dates for silage are comparable to those for grain— from late April to early May in many areas of Pennsylvania. Early-planted corn destined for grain will have higher yields, less susceptibility to frosts, and lower grain moisture at harvest than will late-planted corn. In a two-year New York study, silage yields decreased by about 1 ton per week when planting was delayed after mid-May. Even so, researchers were able to produce 11-ton silage yields (68 percent moisture) with a June 27 planting date. In Lancaster County studies, we have achieved yields of more than 20 tons/acre with mid-June plantings in some years. Both studies indicate that corn silage can produce reasonable forage yields in many areas, even when planted in late June. A recent study conducted at the Southeast Research and Extension Center in Landisville has shown that energy levels are reduced in later-planted silage like this, however, presumably because of lower starch levels due to reduced grain fill.

SOIL MANAGEMENT

Nutrient removal rates by corn for silage are higher than those by corn for grain and by most other commonly grown crops (Table 2). Consequently, on soils with low-to-optimum soil-test levels, fertilizer recommendations for corn grown for silage are 20, 30, and 115 lbs/A higher for N, P_2O_5, and K_2O, respectively, than for corn for grain with comparable yields. This results in a recommendation of 180 lbs/A N, 115 lbs/A P_2O_5, and 260 lbs/A K_2O. Because of these higher nutrient requirements, fertilizer programs can be expensive and regular soil testing is critical to monitor soil nutrient levels. The higher nutrient recommendations are made to replace nutrients removed, not because the crop will respond to higher fertilizer applications in the short term. Where the use of a corn crop is uncertain (grain or silage), lower corn for grain nutrient recommendations will suffice, provided soil nutrient levels are monitored in the future.

Table 2. Plant nutrients contained in a crop with 150-bushel corn grain per acre (25-ton silage).

Nutrient	Grain lbs/A	Silage
N	114	259
P	22	40
K	28	210
S	9	23
Zn	0.2	0.5

Since corn silage is usually produced on farms with livestock, soils often receive manure applications and are rotated with forage legume crops. This frequently results in optimum-to-high soil nutrient levels and relatively low fertilizer requirements.

The key to developing plant nutrient recommendations is to soil test and to account for manure applications and for previous crops in the rotation. This strategy will minimize fertility program costs and maintain the potential for high yields.

Corn silage production leaves little crop residue on the soil. This can lead to increased erosion and decreased organic matter levels, which can increase the potential of nitrate leaching. Soils will become less productive and more susceptible to soil compaction. To help avoid this, consider using a winter rye or ryegrass cover crop and reducing or eliminating tillage. This system combined with manure applications and avoiding soil compaction, can help to build soil quality over time. Some silage producers have found that they can grow corn silage almost continuously using this system.

WEED AND INSECT MANAGEMENT

Control strategies for weeds and insects in corn for silage are similar to those used in corn for grain. These strategies are discussed in detail in *The Penn State Agronomy Guide*. Silage yields are more sensitive than grain yields to insects or other factors that reduce stands because corn plants have difficulty compensating completely for missing plants. Poor weed control in corn destined for silage can have multiple negative effects. Where poor weed control occurs, both forage yields and quality can be reduced, and large numbers of weed seeds can be introduced into the manure.

HARVEST CONSIDERATIONS

One of the most important factors influencing corn silage quality is moisture content at time of harvest. Ideally, corn silage should be harvested at the moisture content appropriate for the type of silo used. Recommended moisture contents are 65–70 percent for horizontal silos, 63–68 percent for conventional tower silos, 55–60 percent for limited-oxygen silos, and 65 percent for silo bags.

Crop dry matter yields are maximized near 65 percent moisture (Table 3) and losses during feeding, storage, and

Table 3. Corn silage yield and quality as influenced by growth stage.

Maturity Stage	Moisture %	Yield tons/A @65%	Crude Protein %	NDF %	Digestibility %
Early dent	73	16.0	9.9	48.0	79.0
$^1/_2$milkline	66	18.0	9.2	45.1	80.0
$^3/_4$milkline	63	18.3	8.9	47.3	79.6
no milkline	60	18.0	8.4	47.3	78.6

University of Wisconsin, 1993

harvesting are minimized. Delaying harvest can reduce both the fiber and starch digestibility as the stover gets more lignified and the overmature kernels become harder and less digestible if left unbroken after ensiling.

Silage moisture at harvest is not difficult to determine and should be monitored, if possible, to prevent harvesting of the crop outside of the desired moisture range. A commercial forage moisture tester or a microwave oven can be used to determine the moisture content fairly rapidly. If silage moisture is above ideal levels then, harvest should be delayed if possible.

Corn that is ensiled extremely wet will ferment poorly and lose nutrients by seepage, which also has potential to damage the silo and if not contained, contaminate local water supplies. Silage that is too dry may result in poorly packed material, causing more mold and spoilage due to air trapped in the silage. In dry, overmature corn silage, the stover portion of the plant is less digestible and contains lower amounts of sugars and vitamin A.

Moisture content cannot be determined accurately using the kernel milkline, because of variations due to weather and hybrids. Moisture content should be measured rather than estimated.

One strategy for timing corn silage harvest is to chop a sample at the full dent stage, just as the milkline appears, and determine the moisture content. Then estimate the harvest date by using a typical drydown rate of 0.50 to 0.75 percentage units per day.

Harvest considerations should also focus on obtaining the correct particle size distribution and the need to process the crop. Processing silage refers to putting the chopped material between two rollers that are installed in the harvester to crush the harvested material as it passes through. Kernel processing units are becoming more popular on corn silage harvesters in Pennsylvania. Kernel processing has the advantage of crushing cob slices and kernels and can increase the starch availability by about 10 percent in the silage. The current data show no clear nutritional advantage to processing silage unless it is overly mature with hard kernels. In some cases this has resulted in increased milk production compared to unprocessed silage. A good general recommendation for the theoretical length of cut for processed silage is $^3/_4$ inch with a 1–2 mm roller clearance.

For unprocessed silage, an average theoretical length of cut should range from $^3/_8$ to $^3/_4$ of an inch. Particle size of corn silage should be monitored during harvesting because it can change as crop moisture content varies. The Penn State Particle Size Separator can be used to estimate the particle size distributions for harvested corn silage.

Table 4. General recommendations for corn silage particle size distributions on the three sieves and bottom pan in the Penn State Particle Size Separator.

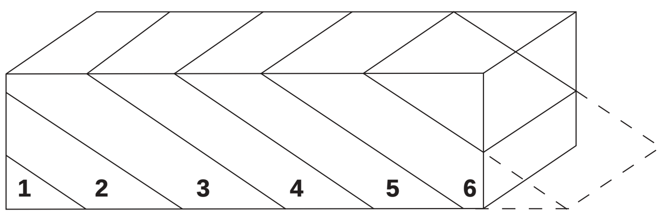
Screen	%
Top (>0.75in)	2–8
Second (0.75in–0.31in)	60–80
Third (0.31in–0.46in)	20–30
Bottom (<0.46in)	1–4

Figure 1. The Penn State particle size separator can be used to monitor silage particle size.

Once harvesting has begun, fill the silo as rapidly as possible and continue until it is filled. Continue to evaluate processed corn throughout the harvest season. Kernels should be broken into multiple pieces and cobs should be broken into thumbnail-sized pieces or less. As the crop matures after half milkline, it may be desirable to have more kernel breakage so that much of the grain is in the bottom pan of the particle size separator.

The most desirable method of packing bunker silos is the progressive wedge method, where silage is continually packed on a 30–40 percent grade. This minimizes the surface area exposed to the air that can result in DM and forage quality losses. If this is not possible, the silos should be packed by spreading relatively thin layers of silage (6 inches deep) and packing it well. If packed well, the density of the silage should be about 14 pounds of dry matter per cubic foot.

Figure 2. Technique for ensiling forage in bunker silos.



Frosted corn

Corn is occasionally damaged or killed by frost before it reaches the desired maturity for ensiling. If the frost is early and green leaves remain on the plant, the crop will continue to accumulate dry matter and should be left in the field until it reaches the appropriate moisture content. Plants that are killed and still immature will likely contain too much moisture for immediate ensiling. These plants will dry slowly and dry matter losses will increase as the dead plants drop their leaves in the field and sugars leach from the frosted leaves. The best option is to leave the crop in the field to dry to an acceptable level (at least 72 percent moisture for a horizontal silo), unless it appears dry matter losses are becoming too high or harvesting losses will increase dramatically.

Drought-stressed corn

When corn is so drought stressed that it may not resume growth, it should be ensiled. Corn in this condition usually has few ears and has leaves that have turned brown and are falling off. Be careful not to harvest prematurely because corn with ears and some green leaves may still grow and accumulate dry matter later in the season. Often corn in this stage will be higher in moisture than it appears. If this is the case, delay harvest. The net energy content of drought-damaged corn often is 85–100 percent of normal, and it sometimes contains slightly more crude protein. Drought-stunted silage often contains high fiber digestibility, so when it is supplemented with additional grain, it can be an excellent forage and sustain high milk production.

One concern with drought-stressed corn is the potential for high nitrate levels in the silage. High nitrate levels are found most frequently where excessive nitrogen rates were applied and when a drought-stressed crop was chopped within three days following a rain. Ensiling crops that are suspected to have high nitrate levels is preferred to green chopping, because fermentation will decrease nitrate levels by about 50 percent. When in doubt, obtain a forage analysis with nitrate determination before feeding the questionable forage. Then take appropriate precautions in feeding this silage.

Silage preservatives and inoculants

Most preservatives and inoculants are aimed at promoting lactic acid production, reducing dry matter losses during storage, reducing heating, and increasing bunk life. In some cases, one or more of these benefits has occurred in controlled studies, but not in all trials. Likewise, some improvement in milk production has been found in some studies, but not in others.

Research has included organic acids, such as propionic or acetic-propionic mixtures or their salts, certain enzymes alone or in combination with antioxidants, as well as silage inoculants containing one or more types of bacteria. When used, these products should be added according to the manufacturer's directions. The products cannot, however, overcome poor practices for ensiling, harvesting at the proper dry matter, packing, feeding, or managing silos.

Transferring corn silage

Occasionally, it is desirable to transfer corn silage from one silo to another. This often can be done with a minimum of risk, if silage is well preserved, as indicated by pH or smell and bunk life. The transfer should be made during cool weather and done as quickly as possible. Packing is important when transferring silage. Drier silage often has much greater losses when transferred, and transferring marginal quality silage is not recommended.

Evaluating corn silage

Once the silage has undergone an adequate fermentation, usually in 3 weeks, a sample should be obtained for forage analysis to develop a feeding program. This analysis can also provide feedback to those involved in the silage production process. Some target values for corn silage nutrient values and possible causes of problems are listed in Table 5.

Evaluation of the silage pH and fermentation acids can provide feedback on whether the fermentation occurred under ideal conditions. Fermentation acid levels, pH, and ammonia levels were surveyed recently in a large dataset provided by a commercial feed-testing laboratory. These data indicated that dry matter influenced the fermentation characteristics, with wetter silages having lower pH values, higher fermentation acid levels, and higher ammonia levels.

Table 5. Typical corn silage nutrient values and causes for values outside the normal range.

Nutrient	Concentration	Desired range	Possible cause to be outside range.
DM (%)	33.0	(30–40)	Harvested too early or too late
CP (%)	8.8	(7.2–10.0)	Underfertilization, N losses from heavy rain, or weed competition can cause low protein.
Protein solubility (%)	48.0	(31.9–52.8)	
ADF (%)	28.9	(23.6–33.2)	High ADF or NDF levels can be caused by low grain in silage due to crop stress, immaturity, or hybrid differences.
NDF (%)	49.0	(41.3–54.1)	
TDN (%)	68.0	(66.8–70.9)	Related to ADF levels. High fiber levels result in low TDN.
NEL (%)	0.69	(0.67–0.75)	Related to ADF levels. High fiber levels result in low NEL.
NSC (%)	35.1	(23.1–43.7)	Stress or immaturity that reduces starch and sugar concentrations can reduce NSC levels.
Ca	0.25		Low pH soil. High Ca can result from weed contamination in silage.
P	0.23		
Mg	0.18		
K	1.20		K levels above 1.0 are generally an indication of high soil test K.
S	0.13		
Mn	34		
Cu	5		
Zn	0.04		
Se	0.41		

In general, pH values for corn silage should be in the 3.5 to 4.3 range, lactic acid levels should be in the 4–6% range, acetic acid 2% or less, propionic acid 0–1%, and butyric acid less than 0.1%. Ammonia N levels should be less than 5%.

Other factors that can be used to evaluate the silage include temperature, smell, and the appearance of the silage. Silage temperatures should generally be within 15 to 20^{0}F of the ambient temperature. Higher temperatures indicate that oxygen is penetrating into the silage and resulting in aerobic decomposition. The silage should also not have a rancid odor, associated with clostridial fermentation in wet silages. A vinegar odor can also be associated with wet silages that have high levels of acetic acid. An alcohol odor is associated with fermentation by yeast, which results from slow feedout rates and air penetration in the silage face. There should also not be any visible mold in the silage, which is often an indication of high dry-matter content at ensiling or poor packing and sealing practices.

Table 6. Fermentation acid profiles collected from numerous corn silage samples from the mid-Atlantic region.

	Dry matter		
	<30 % DM	**30–35%DM**	**>35%DM**
Samples[1]	421	550	591
pH	3.9	4.0	4.2
Lactic Acid	5.59	4.87	4.09
Acetic Acid	3.79	2.50	1.72
Propionic Acid	0.56	0.41	0.33
Iso Butyric	0.62	0.53	0.44
Butyric Acid	0.39	0.39	0.31
NH3-N	5.1	3.9	3.9

[1] Not all analyses were performed on all samples.

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