A Partial Budget Approach to Choosing Corn Hybrids for Silage

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A partial budget approach is far superior to selection indices such as “Milk per Acre” for choosing corn hybrids for silage (see the July 2005 issue of the Michigan Dairy Review: http://www.msu.edu/~mdr/). This is because several factors that affect profitability related to corn hybrid selection vary across farms and the “best” hybrids for one farm might not be the “best” hybrids for another farm. For instance, the effect of neutral detergent fiber (NDF) concentration of corn silage on farm profits depends on many factors that vary from farm to farm such as the cost to grow, harvest, and storage corn silage and the price of corn grain used in rations. Selection indices rank hybrids the same for all farms and do not account for important differences across farms or those that change over time such as the price of corn.

To assist with the process of corn hybrid selection for silage, I’ve developed an Excel spreadsheet called CornPicker for Silage that calculates a partial budget for evaluating the effect of a change in corn hybrids for silage on farm profits. CornPicker allows you to compare a “Challenger” hybrid that you are considering growing to a “Defender” hybrid which is your current favorite (or a reference standard). The calculations include only those costs and returns that change in response to the two hybrids being compared and ignore those not affected. Input variables include data about the specific hybrids related to yield and quality, relevant farm practices, as well as prices (*e.g.* for milk, corn grain, and soybean meal). CornPicker output is an estimate of the production cost of the “Challenger” hybrid compared with the “Defender”.

Variation in yield and quality of corn silage can affect farm profits by thousands of dollars per year for every 100 lactating cows and replacements on farms (see example later in the article) and hybrid selection should be considered carefully using a partial budget. The purpose of this article is to discuss how yield and quality differences among corn hybrids should be considered for proper silage hybrid selection using CornPicker as a model of a partial budget approach.

Corn Silage Hybrid Characteristics

Hybrids differing in forage dry matter (DM) yield, seed cost, and quality traits have important effects on farm profitability. Environmental conditions change from year to year and affect rankings of corn hybrids for yield and quality traits. Therefore, the likelihood of making the best hybrid selection increases as more and more data from hybrids grown across different environments are considered in the decision. Don’t use data from just one location for this important economic decision. Corn hybrid yield and quality information can be obtained from seed companies to compare within their product lines, and from university corn hybrid testing programs such as the Michigan Corn Performance Trials (Michigan State University Extension Bulletin E-431) to compare hybrids across companies.

Yield. Forage yield of corn hybrids vary over 25% so this is an important factor affecting farm profits. Although hybrid yield must be entered on a DM basis, harvest moisture also should be similar for a fair comparison because maturity at harvest affects both yield and quality. CornPicker does not adjust for quality due to differences in DM at harvest because harvest DM is determined by management rather than by hybrid. Seed cost is calculated using cost per bag and number of kernels per bag for each hybrid.

Quality. The important quality factors that must be considered when comparing corn hybrids for silage include the concentration and *in vitro* digestibility of neutral detergent fiber (NDF), corn grain endosperm type (floury or vitreous), and the concentration of crude protein (Allen et al., 2003). The reasons for considering these factors are discussed below.

<u>NDF concentration.</u> Neutral detergent fiber is a measure of the total insoluble fiber of feeds and is related inversely to grain concentration in corn silage (*i.e.,* corn silage with a high grain concentration has a low concentration of NDF and vice versa). The NDF concentration of corn hybrids ranges from less than 38% of DM to more than 50% of DM. Concentration differences in NDF (and grain) among corn silages normally are compensated for by altering the concentration of corn grain in rations. Energy concentration of corn grain in silage is assumed to be the same as supplemented dry corn grain. Therefore, differences in energy concentration among hybrids due to differences in grain concentration can be compensated for by varying the ratio of corn grain to corn silage in rations. In the end, silage NDF concentration will not affect feed intake or milk yield as long as diets are formulated properly. Concentrations of corn silage and corn grain in different rations, and therefore the amounts of each fed annually on the farm, are directly proportional to differences in NDF concentrations of corn hybrids. Less corn silage is required (but more corn grain is supplemented) for corn hybrids with higher NDF concentrations and vice versa. CornPicker accounts for the difference in NDF concentrations between the corn hybrids being compared and how supplemental feed costs and land required for corn silage production are affected.

<u>Forage NDF digestibility.</u> Greater forage NDF digestibility significantly increased DM intake (DMI) and milk yield across a wide range of forages (Oba and Allen, 1999). A one-unit increase in forage NDF digestibility was associated with a 0.55 lb increase in 4% fat-corrected milk yield. Normal commercial corn hybrids vary by about 5 percentage units of *in vitro* NDF digestibility (IVNDFD) when averaged over many growing environments; for the brown midrib hybrids this variation is increased by about another 5 percentage units increasing the total range to about 10 percentage units. These relatively small differences in IVNDFD can have large effects on animal performance. Assuming corn silage is the only forage fed, a 5-percentage unit difference in IVNDFD between two corn hybrids should result in a difference in 4% FCM yield of 2.75 lb /cow per day. CornPicker accounts for the effect of forage NDF digestibility on milk yield and feed intake when evaluating corn hybrids for silage.

Starch. Corn grain contains about 70% starch, so corn silage starch concentration, like grain concentration, is related inversely to concentration of NDF (i.e., if NDF concentration is high, starch concentration is low). Starch is located in the endosperm of corn grain, and endosperm type (floury or vitreous) affects starch digestibility. Proportions of vitreous and floury endosperm vary among corn hybrids and by maturity at harvest. Floury endosperm is easily seen as a fine white powder when dry corn is ground. Vitreous endosperm (sometimes called "flinty" endosperm) is observed as yellow grits when ground. Starch in vitreous endosperm is resistant to digestion, so extent of starch digestion is related negatively to the vitreousness of the endosperm. Increasing maturity at harvest increases endosperm vitreousness and decreases starch digestibility.

For corn grain in silage, starch digestibility increases over time in the silo as the proteins in vitreous endosperm are dissolved. Corn hybrids with highly vitreous endosperm are more likely to have lower starch digestibility, especially during the first several weeks after ensiling. Currently, there is no quick, inexpensive way to measure starch digestibility in the laboratory, so this important hybrid trait cannot reliably be included in a partial budget until more information becomes available. However, it should be considered for hybrid selection. Information about endosperm vitreousness of corn hybrids should be available from individual seed companies and can be observed visually.

Crude protein (CP). Corn silage is normally supplemented with high-protein concentrates, such as soybean meal, to increase protein concentration of ruminant diets. Corn hybrids with higher CP concentrations require less supplemental protein, which can lower feed costs. The CP concentration of whole-plant corn varies by approximately 1.2 percentage units across corn hybrids, and CornPicker accounts for this variation by adjusting amounts of supplemental CP (e.g., using soybean meal as a standard in the spreadsheet). The rumen degradation of CP is assumed to be similar for corn silage and soybean meal [ruminally undegraded protein (RUP) for both is 35% for DMI at 4% of BW and 50% forage diet (NRC, 2001)].

The Calculations

Corn silage required. A partial budget analysis for corn hybrid selection needs to account for all corn silage consumed by different groups of animals on the farm. CornPicker calculates corn silage intake for up to three lactating cow groups (e.g., fresh, higher producing, lower producing), up to two dry cow groups (e.g., far-off, close-up), and up to two heifer groups (e.g., less than 12 months, greater than 12 months). Within a group, total corn silage intake depends on the number of animals in the group and the corn silage intake per animal. CornPicker calculates corn silage intake per animal considering farm-specific inputs such as DMI, forage NDF concentration of the diet, the proportion of forage NDF from corn silage, and the NDF concentration of the corn hybrids being compared. Forage NDF concentration is used to calculate the corn silage concentration in diets because forage NDF limits feed intake and diets normally are formulated to the same or similar forage NDF concentrations. CornPicker calculates the total corn silage that must be grown and harvested for all animals in the farm by adjusting the corn silage intake for DM losses throughout harvesting, storage and feeding. Minimum storage losses likely will be 12 to 15% but can be much greater in some cases. Feed refusals (weighback) also must be considered and can be 5% or more of the ration DM fed.

Land required for corn silage. The amount of land required for corn silage production per year is calculated as the amount of corn silage DM required as described above, divided by the DM yield of the corn hybrids. Because the NDF concentration of corn silage directly affects the amount of corn silage required, it has profound effects on the land required for forage production. For instance, a corn hybrid with 52% NDF requires 30% less land for corn silage production than a hybrid with 36% NDF if both provide the same yield assuming that the balance of corn grain required in the ration will be purchased separately. If land is limiting, growing a high-grain hybrid results in a deficiency of forage fiber for the whole herd and the need to buy highly digestible forage fiber, which is expensive. Choosing a low-grain hybrid with high NDF (and equal DM yield) allows the required amount of forage to be grown on a smaller amount of land; typically less expensively than purchasing forage of equal quality on the open market.

Cost of corn silage. The cost of producing corn silage is calculated as the total costs for seed, land, and other production costs, as well as the costs and DM losses for harvesting, storing, and feeding the corn silage. These factors vary greatly among farms.

1) Annual seed cost is calculated from the cost per bag of seed, the number of kernels per bag, planting rate (population density), and number of acres planted.

2) Land availability must be taken into account because the acreage required for corn silage varies with the yield and NDF concentration of corn hybrids. CornPicker accounts for the opportunity cost of land (cost to use land for corn silage when it could be used for another purpose) based on the number of acres required for corn silage production and the rental value equivalent per acre per year. The rental value is highly variable across farms, ranging from less than $60 to more than $150 per acre per year, largely based on expected yield and alternative uses.

3) Production costs associated with growing the corn silage crop include pre-harvest machinery, fertilizer, lime, herbicide, insecticide, insurance, and interest. This should be calculated for specific farms but is in the range of $180 to $220 per acre (see Dartt and Schwab 2001 for estimates).

4) Harvest costs per ton are assumed to be equal across hybrids and include costs of equipment, labor, and fuel to chop, process, haul, apply inoculants or preservatives, pack, and cover the corn silage. They likely range from $6 to $9 per ton of wet corn silage, but should be calculated for individual farms.

5) Storage cost. The NDF concentration of corn silage also directly affects the silo capacity required on the farm; feed-out rate is lower for higher-NDF hybrids because less corn silage (and more corn grain) is included in diets. Costs include initial cost of silo structure and interest amortized over its useful lifespan, insurance, taxes, and repairs.

Storage costs for corn silage are highly variable depending upon the silo type. In general, storage costs are greater for vertical silos compared to horizontal silos and small silos compared to large silos (Rotz et al., 2003). A spreadsheet named STOCOST, developed at the University of Wisconsin, is useful to calculate the cost of corn silage storage on individual farms (Holmes and Frank, 1997). Using STOCOST, silage storage costs ranged from $29 to $54 per ton of DM (1997 prices) before accounting for storages losses.

The Adjustments

Once the total costs of producing corn silage for the "Defender" and "Challenger" hybrids are calculated, cost adjustments must be made for differences in supplemental feed and milk yield. Differences in concentrations of NDF and CP between hybrids affect the amount of corn grain and soybean meal fed per year. Difference in IVNDFD affects milk yield and feed intake of lactating cows. CornPicker accounts for these differences by adjusting (credit or debit) the cost per year of the "Challenger" hybrid relative to the "Defender" hybrid.

***Concentrates*.** Annual amounts of CP supplied from each hybrid are calculated, converted to soybean meal equivalents, and multiplied by the price of soybean meal (44% crude protein as fed which is a 'user input') to get the value of the protein adjustment for the "Challenger" hybrid. This might be a positive or negative amount, depending upon the differences in yield and CP concentrations of the two hybrids.

Difference in the amount of corn grain fed per year in rations with the two hybrids is calculated as the difference in corn silage DM fed per year minus the difference in soybean meal required (because soybean meal replaces some corn grain). Corn grain has higher CP concentration than corn silage and reduces the soybean meal required in the ration. The financial value of this difference is then calculated by multiplying by the price of dry ground corn delivered to the farm. Because both NDF and CP must be adjusted simultaneously, CornPicker requires an add-in called "Solver", which is part of the Excel software package. Look for it in the *Tools* menu to see if it is already installed. If not, you will have to check (√) the Solver add-in (*Tools* menu under Add-ins) to install it.

The current version of CornPicker for Silage (1.4) assumes that the difference in corn grain supplemented in rations with the two different hybrids is purchased as dry ground corn. Future versions of this spreadsheet may allow calculation of the cost of high moisture or dry corn grain produced on the farm. Storage cost for corn grain is included because existing storage might not be available. However, this cost is much lower when corn grain is purchased because a relatively small quantity needs to be stored on-farm at one time. Storage cost for soybean meal is not included because existing storage is assumed to be available and increased inclusion rates would only require more frequent delivery.

Milk yield. CornPicker adjusts the cost of the "Challenger" hybrid for changes in expected milk yield and feed intake of lactating cows based on differences in IVNDFD between the two hybrids. Greater milk yield results with enhanced IVNDFD is because of greater feed intake, so CornPicker also accounts for increased feed costs and for the land required to grow the corn silage fraction of the additional feed consumed. The marginal increase in feed intake per pound of 4% fat-corrected milk is about 0.4 lb of DM. This is multiplied by the cost of the ration (user input) to adjust for the difference in feed intake to support the milk yield difference. The cost of the corn silage fraction of the increased feed required is subtracted from this because it is accounted for by increasing the harvested corn silage required.

CornPicker uses a default value of 0.55 lb increase in 4% fat-corrected milk per unit difference in IVNDFD as reported in Oba and Allen (1999) for all lactating cows if corn silage is the only forage. This relationship reported by Oba and Allen (1999) was from experiments comparing forages that were the only forage in diets being compared. Therefore, this value is linearly adjusted by the fraction of forage NDF in the ration from corn silage (i.e. if the fraction of forage NDF from corn silage is 67%, the value used is 0.37 lb 4% FCM/ unit difference in IVNDFD which is 67% of 0.55).

It should be noted that increased IVNDFD does not always result in the same response for feed intake and milk yield for all cows. Response to forages with increased IVNDFD is dependent upon both animal and dietary factors. Response is greatest for animals with high energy requirements and for diets higher in forage NDF concentration (Allen et al., 2003). Enhanced IVNDFD has greater importance for herds with high milk yield compared with lower milk yield, for high production group cows compared with low production group cows, and for cows fed low grain diets compared with high grain diets. CornPicker allows adjustment of milk yield and feed intake responses to differing IVNDFD depending on milk yield which might be used as more research results become available. IVNDFD has less relative impact for dry cows and growing heifers.

"Challenger" vs. "Defender"

CornPicker compares the adjusted annual estimated cost of corn silage from the "Challenger" hybrid compared to the "Defender" hybrid. These partial budget costs include those pertaining to production including seed and the opportunity cost of land, and costs of harvesting, storing, and feeding of each hybrid. Adjustments (credits or debits) for feed costs and milk yield are made to the cost of the "Challenger" hybrid.

Summary

The partial budget approach employed by CornPicker accounts for economically important factors related to hybrid selection for corn silage that varies from farm to farm and over time. Selection indices that rank corn hybrids fail to consider many important biological and cost differences related to nutritional quality of corn hybrids that vary among farms and should not be used because they may provide the wrong ranking for <u>specific</u> farms. The initial time it takes to calculate accurate inputs for CornPicker will pay off by identifying the best hybrids to select for corn silage on specific farms.

CornPicker 1.4 can be downloaded from the Michigan Dairy Review web site at http://www.msu.edu/user/mdr/

References

Allen, M. July 2005. Milk per acre: right for few, wrong for many. Michigan Dairy Review 10(3):1-4.

Allen, M. S. et al. 2003. Corn silage. **In:** Silage Science and Technology, D. Buxton, R. Muck, and J. Harrison, eds. Am. Soc. Agr., Crop Sci. Soc. Am., and Soil Sci.Soc. Am., Madison, WI.

Dartt, B. and G. D. Schwab. 2001. 2001 Crops and Livestock Budgets Estimates for Michigan. Agricultural Economics Report No. 609. Dept. Ag. Econonomics, Michigan State Univeristy, East Lansing, MI 48824-1039. http://www.aec.msu.edu/agecon/aecreports/aec609.pdf

Holmes, B. J. and G. G. Frank. 1997. Capital and annual costs of forage storage. Excel spreadsheet (stocost.xls). Center for Dairy Profirability, University of Wisconsin, Madison, WI. http://cdp.wisc.edu/Decision%20Making%20Tools.htm

Michigan Corn Hybrids Compared. Michigan State University Extension Bulletin E-431. www.css.msu.edu:varietytrials:corn:Corntrials.htm

NRC. 2001. Nutrient Requirements of Dairy Cattle. 7th revised edition. National Research Council. National Academy Press, Washington, D.C.

Oba, M. and M. S. Allen. 1999. Effects of brown midrib 3 mutation in corn silage on dry matter intake and productivity of high yielding dairy cows. J. Dairy Sci. 82:135-142.

Oba, M. and M. S. Allen. 1999. Evaluation of the importance of the digestibility of neutral detergent fiber from forage: effects on dry matter intake and milk yield of dairy cows. J. Dairy Sci. 82:589-596.

Rotz, C.A., S. A. Ford, and D. R. Buckmaster. 2003. Silages in farming systems. In: Silage Science and Technology, Agronomy Monograph no. 42, D. Buxton, R. Muck, and J. Harrison, eds. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison, WI.

Example

This is an example of the CornPicker for Silage (1.0) spreadsheet for a 100-cow herd (lactating and dry) using default values for farm-specific inputs and example inputs for “Defender” and “Challenger” yield and quality. Farm inputs and cow group inputs are entered on separate worksheets and hybrid inputs are entered on the results worksheet. Default farm inputs can be seen in the Farm inputs worksheet below.

Farm specific inputs[1]	
Plant population, seeds/acre	30,000
Harvest dry matter (DM), %	32%
Shrinkage/spoilage, % of DM	12%
Feed refusals, %	5%
Corn silage production cost, $/acre	$175.00
Corn silage harvest cost, $/ wet ton	$7.50
Corn silage storage cost, $/ ton DM	$33.00
Corn grain storage cost, $/ ton DM	$2.00
Land rent equiv., $/ acre per year	$90.00
Milk price, $/ 100 lb	$14.00
Corn grain, dry ground, $/ ton as fed	$90.00
Soybean meal 48%, $/ ton as fed	$200.00

[1]assumed to be the same for all hybrids

Default values for corn silage fed are 67% of the forage NDF for all animals on the farm including 8 fresh cows, 60 high production group cows, 16 low production group cows, 10 far-off dry cows, 6 close-up dry cows, 50 heifers less than 12 months old and 50 heifers over 12 months old (cow group inputs worksheet not shown).

The Hybrid Inputs – Results worksheet can be seen below. Data for “Defender” and “Challenger” hybrids are input at the top of the worksheet and the land required and partial budget costs are output at the bottom of the worksheet.

CornPicker® for Silage

v. 1.0 1/15/06
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	Defender	Challenger
Company	Trailblazer Seeds	MaxGrow Hybrids
Hybrid	4593	Z28
	Click solve button below each time you change NDF or CP concentrations	
Hybrid inputs		
Seed cost, $/ bag	$110.00	$125.00
Number of kernels per bag	80,000	80,000
Yield of corn forage, tons of DM per acre (before ensiling)	9.1	8.6
In vitro neutral detergent fiber digestibility, % of NDF	48.1%	52.9%
Neutral detergent fiber, % of DM	36.1%	45.9%
Crude protein, % of DM	6.6%	6.3%
	Defender	Challenger
Corn seed required, number of bags per year	24.6	20.7
Amount of corn silage stored, tons per year	596.4	474.8
Differences from the Defender		
Soybean meal, tons of DM per year		-4.7
Corn grain, tons of DM per year		116.7
Milk yield, lb per year		53,964
DMI to support milk yield, lb per year		-23,432
	Defender	Challenger
Seed corn cost, $/year	$2,703.45	$2,588.07
Land cost, $/year	$5,898.44	$4,969.10
Production cost, $/year	$11,469.19	$9,662.14
Harvesting cost, $/year	$13,978.08	$11,128.72
Corn silage storage cost, $/year	$19,681.13	$15,669.23
Differences from the Defender		
Corn grain storage cost, $/year		$233.49
Soybean meal, $/year		($1,042.10)
Corn grain, $/year		$11,674.47
Milk yield difference, $/year		($7,555.00)
Feed costs (not incl. corn silage) for milk yield difference, $/year		$1,055.06
	Defender	Challenger
Land required for corn silage production, acres per year	**65.5**	**55.2**
Partial budget cost for corn silage production, $/year	**$53,730**	**$48,383**
Profit advantage for Challenger compared to Defender, $ /year		**$5,347**

Solve

Start Here | Farm Inputs | Cow Group Inputs | Hybrid Inputs-Results

Results in the example. "Defender" has greater DM yield than the "Challenger" (9.1 vs. 8.6 ton DM/acre) but it requires more land to grow (65.5 vs. 55.2 acres/year) because it has lower NDF concentration. Annual seed cost is higher for "Defender" despite lower cost per bag because more acres must be planted compared to "Challenger". "Challenger" corn silage contains less grain and requires more corn grain supplementation (116.7 tons/year) but less soybean meal (4.7 tons/year) despite lower CP concentration because supplemental corn grain has higher CP concentration than the corn silage. Annual herd 4% fat-corrected milk yield is approximately 54,000 lb /year greater with "Challenger" because of greater IVNDFD, but cows consume over 23,000 lb of DM to support the increased milk yield. The partial budget cost is lower for "Challenger" compared with "Defender" ($48,383 vs. 53,730) giving a profit advantage of $5,347 per year to "Challenger" for this 100-cow herd with replacement heifers. This profit advantage is primarily because of greater milk yield from higher IVNDFD for "Challenger" and is despite its lower DM yield and CP concentration and higher seed price compared to "Defender". It should be noted that higher NDF (and lower grain) concentration added to the profit advantage for "Challenger" compared to "Defender" because corn silage is more expensive to produce, harvest, store, and feed than it costs to purchase, store, and feed corn grain in this example