

## Effect of Corn Silage Hybrid on Dry Matter Yield, Nutrient Composition, In Vitro Digestion, Intake by Dairy Heifers, and Milk Production by Dairy Cows

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### ABSTRACT

Three corn hybrids, Mycogen TMF94, Cargill F337 (which contains a brown midrib trait), and Pioneer 3861 were compared in a plot trial, an intake trial, and a lactation trial. In the plot trial, the three corn hybrids were planted in replicated 15.2 × 385-m plots. Mycogen TMF94 and Cargill F337 had lower yields of dry matter (DM), higher concentrations of neutral detergent fiber, and higher in vitro true DM disappearance compared with Pioneer 3861. Mycogen TMF94 had a higher yield of DM than Cargill F337 despite having a lower plant population. However, Cargill F337 had a higher in vitro true DM disappearance than Mycogen TMF94. In the intake trial, six individually penned Holstein heifers were blocked and assigned randomly to one of three total mixed rations containing 79% (DM basis) Mycogen TMF94, Cargill F337, or Pioneer 3861 corn silages in replicated 3 × 3 Latin squares. Heifers fed the Pioneer 3861-based TMR had lower DMI than heifers fed Mycogen TMF94 and Cargill F337-based TMR. In the lactation trial, 75 midlactation Holstein cows were blocked and assigned randomly to one of three total mixed rations containing 31% (DM basis) Mycogen TMF94, Cargill F337, or Pioneer 3861 corn silages used in the intake trial. Milk production was highest for cows fed Cargill F337-based total mixed rations. It is concluded from this study that Mycogen TMF94 was higher yielding, but less digestible, and resulted in lower milk production by lactating cows than Cargill F337. In addition, Mycogen TMF94 had higher in vitro true DM disappearance, and similar DM yield and milk production by lactating cows when compared with Pioneer 3861.

(**Key words:** corn, hybrid, yield, nutrient composition, milk production)

**Abbreviation key:** BMR = brown midrib, Cargill = Cargill F337, IVTDMD = in vitro true DM disappearance, IVNDFD = in vitro NDF disappearance, Mycogen = Mycogen TMF94, Pioneer = Pioneer 3861.

### INTRODUCTION

In recent years there has been increasing interest by different seed companies to develop corn hybrids specifically intended for silage production (Johnson et al., 1997; Kuehn et al., 1999). Some of these corn hybrids have been evaluated under field conditions and for in vitro digestibility (Allen et al., 1997; Cherney et al., 1991; Johnson et al., 1997), and for intake and milk production responses using lactating dairy cows (Block et al., 1981; Frenchick et al., 1976; Keith et al., 1979; Oba and Allen, 1999, 2000; Rook et al., 1977; Sommerfeldt et al., 1979; Stallings et al., 1982). Important determinants of the adaptability of a hybrid to silage production include grain:stalk ratio, whole plant yields of DM and digestible DM per hectare, and milk production per hectare or per tonne of forage. The TMF corn silage hybrids (Mycogen Seeds, Eagan, MN) feature tall, leafy plants and stalks with thinner rinds. The grain has softer starch, which could potentially result in better digestibility. Because of the robust plant morphology, the recommended seeding rates for TMF hybrids are relatively lower than those recommended for other corn hybrids. Cargill Hybrid Seeds (Minneapolis, MN) has been conducting intensive silage adaptability testing of their corn hybrids for several years, which has led to the release of the brown midrib (BMR) corn hybrids. The BMR mutations decrease the forage lignin concentration and increase NDF digestibility (Allen et al., 1997; Cherney et al., 1991; Oba and Allen, 1999). Enhanced digestibility of DM and NDF promotes higher DMI and yields of milk and milk compo-

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nents by cows fed BMR corn when compared with cows fed non-BMR corn silage (Oba and Allen, 1999, 2000). Several older studies have also reported improved milk yield by dairy cows fed BMR corn silage (Block et al., 1981; Frenchick et al., 1976; Keith et al., 1979; Oba and Allen, 1997). However, BMR corn has been shown to have substantially lower DM yield (Allen et al., 1997; Frenchick et al., 1976; Cherney et al., 1991), increased susceptibility to lodging (Cherney et al., 1991), and the price of seed for BMR corn hybrids is about three times that of most corn hybrids. Pioneer Hi-Bred International (Des Moines, IA) also has evaluated several corn hybrids for silage adaptability, but has not released any corn hybrids solely for silage production.

The objective of this study was to use three corn hybrids (94- to 95-d relative maturity), Mycogen TMF94 (**Mycogen**), a leafy hybrid developed for corn silage, Cargill F337 (**Cargill**), which is a BMR hybrid, and Pioneer 3861 (**Pioneer**), which was bred for dual purpose with grain yield as the main criterion, to determine hybrid effects on 1) agronomic characteristics, yield of DM and digestible DM, 30-h in vitro true DM disappearance (**IVTDMD**), 30-h in vitro NDF disappearance (**IVNDFD**), and nutrient composition, 2) ensiling characteristics and end products of fermentation of whole-plant corn silages, 3) DMI by Holstein heifers fed diets consisting primarily of whole-plant corn silage, and 4) milk production and composition by mid-lactation, multiparous Holstein cows fed TMR containing whole-plant corn silage. In this study, the dual-purpose hybrid from Pioneer with good silage quality (Pioneer Hi-Bred International seed catalog, Eastern Area, 1998) was used as a comparison for Mycogen and Cargill hybrids, which were bred specifically for silage production.

## MATERIALS AND METHODS

### Plot Trial

**Planting and establishment.** Three corn hybrids (94- to 95-d relative maturity), Mycogen, Cargill, and Pioneer were planted on a tile-drained (76 cm spacing) Hogsburg loam soil at the Miner Institute farm on May 13, 1997, and harvested on September 22, 1997, after 131 growing days. Relative maturities provided by the seed companies for Mycogen, Cargill, and Pioneer, respectively, were 94, 95 and 95 d. The seeding rates recommended by the company were 66,690 kernels/ha for Mycogen and 81,510 kernels/ha for Cargill and Pioneer. The field was divided into three blocks, and each block was subdivided into three 15.2 × 385-m plots, which were then assigned randomly to one of the three corn hybrids, resulting in three replications per treatment. Within each plot, corn was planted in

20 385-m long rows with row spacing of 76 cm. The field received 54-54-109 kg/ha (N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O) as dairy manure in October 1996, and 145 kg/ha of potassium (K<sub>2</sub>O) was applied in November 1996. Starter fertilizer was applied at a rate of 40-36-50 kg/ha (N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O) during planting.

**Harvesting, sampling, and ensiling.** Forage yields were determined by harvesting the four center rows, each 385 m in length, from each plot. At harvest, the final plant population was determined by counting plants in one 4 × 4-m quadrant per plot, and expressing smut-infected ears, barren ears, and lodged plants as a percentage of counts made on 200 plants. Forages from each plot were harvested using a self-propelled Fox Brady forage harvester (without a kernel processor) (model 6650; Koehring, Appleton, WI) with a theoretical chop length of 0.95 cm and collected into a wagon. The chopped forages were emptied from the wagon at a bunk silo, and samples were collected into a 10-L container halfway through the unloading process for each plot and ensiled in a total of nine minisilos for 15 d for silage characterization. The minisilos were made out of polyvinyl chloride and were 0.102 m in diameter and 0.457 m long. The remaining samples of chopped forages for each plot were subsampled for chemical analyses. The DM was determined by drying forage samples in a forced-air oven at 60°C to a constant weight. The particle sizes of the chopped forages were characterized at ensiling using the Penn State forage particle separator (Nasco, Fort Atkinson, WI) as small (<0.79 cm), medium (0.79 to 1.9 cm), and large (>1.9 cm) forage particles. Percentages of particles that were retained on the large screen, medium screen, and in the bottom pan were reported. The mesh sizes of the medium and large screens, respectively, were 0.79 and 1.9 cm.

### Intake Trial

**Forages and diets.** Mycogen and Cargill hybrids grown on a commercial dairy farm in Chazy, New York, located 10 km from Miner Institute, and Pioneer hybrid grown at Miner Institute were tested in this trial. Hybrids were planted on May 13, 1997, on a tile-drained (76-cm spacing) Hogsburg loam soil on both locations. The seeding rates and fertilization practices were the same as in the plot trial. Forages were harvested beginning October 1, 1997, using the self-propelled forage harvester (without a kernel processor) used to harvest forages in the plot trial and collected into a wagon. Pioneer was trucked to the commercial dairy farm, where it was ensiled into a silage bag for 5 mo. Mycogen and Cargill also were ensiled in silage bags for 5 mo at the farm. The silage bags were made

**Table 1.** Composition of Mycogen TMF94 (Mycogen), Cargill F337 (Cargill), and Pioneer 3861 (Pioneer) corn silage-based diets fed to Holstein heifers (intake trial).

Ingredient	Mycogen	(DM basis)	
		Cargill	Pioneer
Composition, %			
Mycogen corn silage	79.33	0.00	0.00
Cargill corn silage	0.00	79.33	0.00
Pioneer corn silage	0.00	0.00	79.33
Soybean meal	10.55	10.55	10.55
Heifer Focus pellet <sup>1</sup>	9.00	9.00	9.00
Magox mineral mix <sup>2</sup>	0.16	0.16	0.16
Cal-29 mineral mix <sup>3</sup>	0.79	0.79	0.79
Sel-Plus mineral mix <sup>4</sup>	0.16	0.16	0.16
Chemical			
CP, %	14.6	15.9	14.4
NDF, %	40.2	36.4	41.3
NE <sub>M</sub> , Mcal/kg	1.46	1.68	1.48
NE <sub>G</sub> , Mcal/kg	0.88	1.06	0.88

<sup>1</sup>Heifer Focus pellet (% of DM) contained 49.13% wheat middlings, 5.78% brewers grains, 1.55% urea, 2.06% salt, 2.78% blood meal, 22.98% canola meal, 1.34% corn gluten meal, 8.54% rendered animal products, 4.64% Cal-29 mineral mix, 1.32% sodium monophosphate, and 0.88% Beacon trace mineral mix. The Beacon trace mineral mix contained (DM basis) 15% calcium, 0.18% magnesium, 2.5% sulfur, and (per kg) 11,000 mg of iron, 210,000 mg of zinc, 40,600 mg of copper, 70,000 mg of manganese, 825 mg of selenium, 2400 mg of cobalt and 2000 mg of iodine.

<sup>2</sup>Magox mineral mix contained 56% magnesium.

<sup>3</sup>Cal-29 mineral mix contained 29% calcium, 5% magnesium, 3% potassium, 3% sulfur and (per kg) 2020 mg of iron, 3030 mg of zinc, 404 mg of copper, 1515 mg of manganese, 20 mg of selenium, 51 mg of cobalt, and 51 mg of iodine.

<sup>4</sup>Sel-Plus mineral mix contained 202 mg/kg of selenium, 14,222 IU of vitamin E, and 37% calcium.

of 9-mm thick plastic material. Three TMR containing 79% (DM basis) corn silage from Mycogen, Cargill, or Pioneer corn hybrids (Table 1), were formulated using the CPM Dairy nutrition model (version 1.0; Cornell-Penn-Miner, Cornell University, Ithaca, NY). The TMR were formulated to be approximately isocaloric and support a 0.68-kg average daily gain by Holstein heifers. The corn silages were trucked from the commercial dairy farm to Miner Institute daily for mixing and feeding to the Holstein heifers.

**Animals, feeding, and sampling.** Six Holstein heifers averaging  $172 \pm 35$  d pregnant,  $18 \pm 1.8$  mo old, and weighing  $549 \pm 39$  kg at the beginning of the trial were blocked and assigned randomly to one of three diets in a  $3 \times 3$  Latin square with three 21-d periods with two replications conducted simultaneously. The BW, age, and estimated calving date were used as the criteria for blocking. The heifers were housed individually in box stalls at Miner Institute. During each period, the heifers were offered their test diets ad libitum for a 2-wk adjustment period, followed by a 1-wk data collection period. During the data collection period, feed offered and refused by the animals was recorded daily for determination of DMI. Silage samples were collected at the beginning of the study, dried, and stored for later chemical analyses. Animals were weighed at the beginning of the study and at the end of each Latin square period thereafter. Animals also

were scored for body condition using the five-point scale where 1 = thin to 5 = fat (Wildman et al., 1982) at the end of each Latin square period. To minimize variation, all heifers were body condition scored by the same investigator throughout the study.

## Lactation Trial

**Forages and diets.** Three TMR were formulated using the CPM Dairy nutrition model with Mycogen, Cargill, and Pioneer corn silages used in the intake trial as the treatment variables (Tables 2 and 3). Diets were isocaloric and contained the same amount of ADF and NDF. Forages were analyzed at the beginning of the study. Apart from differences in corn hybrid for the corn silages, the ingredients used to formulate the TMR were similar. Chemical analyses revealed that diets contained similar concentrations of CP, ADF, NDF, calcium, and potassium (Table 2). Mycogen silage-based TMR tended to have a slightly higher hemicellulose concentration, whereas Pioneer silage-based TMR tended to have lower concentrations of DM, phosphorus, sodium, iron, zinc, copper, manganese, and molybdenum.

**Animals, feeding, and sampling.** Seventy-five midlactation ( $240 \pm 104$  DIM), multiparous Holstein cows at the commercial dairy farm where the corn silages used in the intake trial were stored were used

**Table 2.** Composition of Mycogen TMF94 (Mycogen), Cargill F337 (Cargill), and Pioneer 3861 (Pioneer) corn silage-based TMR fed to lactating Holstein cows (lactation trial).

Composition	TMR		
	Mycogen	Cargill	Pioneer
	(DM basis)		
Ingredient, %			
Mycogen corn silage	31.14	0.00	0.00
Brown midrib corn silage	0.00	31.14	0.00
Pioneer corn silage	0.00	0.00	31.14
Alfalfa-grass silage	17.30	17.30	17.30
Grass hay <sup>1</sup>	1.73	1.73	1.73
High-moisture corn	20.24	20.24	20.24
Sugar beet pulp	7.79	7.79	7.79
Energy booster <sup>2</sup>	0.61	0.61	0.61
Whole cotton seed	2.25	2.25	2.25
Roasted soybeans <sup>3</sup>	6.06	6.06	6.06
Concentrate mix <sup>4</sup>	12.46	12.46	12.46
Sodium bicarbonate	0.43	0.43	0.43
Chemical			
DM, %	46.9	46.2	45.0
NE <sub>L</sub> , Mcal/kg	1.6	1.6	1.6
CP, %	17.0	17.3	17.7
Soluble protein, % of CP	36.0	38.0	37.0
ADF-CP, %	1.3	1.3	1.1
ADF, %	22.7	23.4	23.9
NDF, %	35.3	34.7	35.1
Hemicellulose, %	12.6	11.3	11.2
Calcium, %	0.97	0.85	0.82
Phosphorus, %	0.42	0.41	0.34
Sulfur, %	0.19	0.18	0.17
Magnesium, %	0.29	0.30	0.25
Potassium, %	1.19	1.21	1.21
Sodium, %	0.88	0.76	0.52
Iron, mg/kg	265.0	296.0	210.0
Zinc, mg/kg	94.0	89.0	76.0
Copper, mg/kg	22.0	21.0	17.0
Manganese, mg/kg	49.0	49.0	41.0
Molybdenum, mg/kg	1.7	1.8	1.5

<sup>1</sup>Predominantly timothy hay containing 7% CP and 72% NDF on DM basis.

<sup>2</sup>Energy booster contains hydrolyzed animal fat (preserved with butylated hydroxytoluene) and sodium silico-aluminate.

<sup>3</sup>Roasted in a microwave oven.

<sup>4</sup>Composition of concentrate mix is shown in Table 3.

in the lactation trial. The cows, which yielded  $34 \pm 4.1$  kg/d of milk at the beginning of the study, were blocked by parity, DIM, current milk production, and 305-d mature equivalent and assigned randomly to one of the three dietary treatments. Cows were penned by treatment, fed ad libitum as a group, and had free access to clean water. Before the cows were fed their test diets they were fed the farm's medium group TMR, which did not contain any corn silage from the three test corn hybrids during a 1-wk adjustment period. The medium group TMR contained (DM basis): 3% grass hay, 22% grass-alfalfa silage, 27% corn silage, 25% high-moisture corn, 3% whole cottonseed, and 20% of a concentrate mix. The same concentrate mix (Table 3) also was used in the test diets. High-moisture corn

was composed of coarsely ground corn kernels. During the adjustment period, milk yield was measured daily, and a weekly average was calculated for use as a covariate in statistical analysis of milk yield data collected during the test period. The test period, during which the experimental TMR were fed, lasted for 4 wk. Samples of silages were collected at the beginning of the test period, and samples of feed offered to the animals were collected every week during the test period to determine DM content and chemical analysis. The TMR samples were composited by treatment for chemical analysis. Milk yield by each cow was recorded daily and then averaged by week. Milk samples were collected from each cow during the last two consecutive milkings of the adjustment period and in wk 4 of the test period and sent to the Northeast DHI Dairy Lab (Ithaca, NY) for analysis of CP, fat, and lactose by infrared procedure (Foss 4000; Foss Technology, Eden Prairie, MN) (AOAC, 1995), and analysis of SCC by infrared procedure (Foss 5000; Foss Technology, Eden Prairie, MN) (AOAC, 1995). Milk samples collected from some commercial dairy farms were used as internal standards in the analysis of milk components.

**Table 3.** Composition of concentrate mix.

Ingredient	% of DM
Soybean hulls	8.53
Roasted soybeans	11.17
Canola meal	6.53
Corn gluten meal (67% CP)	5.02
Rendered animal products	9.34
Tallow	2.24
Urea	2.85
Soybean meal (53% CP)	23.22
Soy Plus <sup>1</sup>	5.13
Fish meal	1.03
Blood meal	6.05
Salt	2.80
Sodium bicarbonate	4.86
Calcium carbonate	5.87
Calcium sulfate	0.92
Magnesium oxide	0.75
Biophosphate	0.70
Monoammonium phosphate	1.13
Phosphorus-20	1.24
Beacon trace mineral mix <sup>2</sup>	0.23
854 Dairy 5X <sup>3</sup>	0.09
Vitamin E	0.18
Niacin	0.11

<sup>1</sup>Soy Plus (48% CP) contains soybeans that have been cracked and heated to extract soy oil.

<sup>2</sup>Beacon trace mineral mix on DM basis contained 15.0% calcium, 0.2% magnesium, 2.5% sulfur, 70,000 mg/kg of manganese, and (mg/kg) 210,000, zinc; 40,600, copper; 2,400, cobalt; 11,000, iron; 825, selenium; and 2,000, iodine.

<sup>3</sup>Dairy 5X contained on DM basis 2.7% CP, 49.9% NDF, 35.1% ADF, 7% fat, 9.8% calcium, 0.06% phosphorus, 1.05% magnesium, 1.33% potassium, 0.04% sulfur, 0.53% sodium, 0.13% salt, 35,946 IU/g vitamin A, 12,247 IU/g vitamin D, and 44,535 kg/IU vitamin E.

These standards were stored under refrigeration at 0 to 4°C for a maximum of 14 d.

### Chemical Analyses

Fresh corn forage and silage samples collected during the plot trial were sent to Cumberland Valley Analytical Services (Hagerstown, MD) where they were dried at 60°C and ground to pass through a 1-mm screen using a cyclone mill (Udy Co., Fort Collins, CO) for chemical analysis. Feed and silage samples collected during the intake and lactation trials were sent to the Northeast DHI Forage Laboratory (Ithaca, NY) where they were dried at 60°C and ground to pass through a 1-mm screen using a Wiley mill (model 3; Arthur H. Thomas Co., Philadelphia, PA) for chemical analysis. At both forage laboratories, the ground samples were analyzed for DM (100°C), ash (500°C), CP, soluble protein, fat (AOAC, 1995), NDF (without sodium sulfite), ADF, and ADL (Van Soest et al., 1991). Hemicellulose was determined as the difference between NDF and ADF, and cellulose as the difference between ADF and ADL. The NDF and ADF residues, respectively, were analyzed for their CP content (AOAC, 1995) to determine NDF-CP and ADF-CP. Sulfur was analyzed with a Leco model SC-432 (Leco, St. Joseph, MI). At the Cumberland Valley Analytical Services, analysis of calcium, magnesium, potassium, sodium, iron, zinc, copper, manganese, and molybdenum were performed using atomic absorption spectrophotometry (AOAC, 1995). Phosphorus was analyzed by colorimetry (AOAC, 1995), and chloride ion was determined using a Brinkman Metrohm 716 Titrino titration unit with a silver electrode (model 716; Brinkman Instruments, Inc., Westbury, NY). At the Northeast DHI Forage Laboratory, analysis of calcium, phosphorus, magnesium, potassium, sodium, iron, zinc, copper, manganese, and molybdenum were performed with a Thermo Jarrell Ash IRIS Advantage Inductively Coupled Plasma Radial Spectrometer (model ICAP 61; Thermo Jarrell Ash, Ithaca, NY). Chloride ion was analyzed with a Brinkman Metrohm 716 Titrino titration unit with a silver electrode (model 716; Brinkman Instruments, Inc., Westbury, NY). In addition, fresh corn forage and silage samples also were analyzed for sugars and starch at West Virginia University (Morgantown, WV) by the enzymatic digestion procedure of Smith (1969). In vitro true DM disappearance and IVNDFD were determined with the DAISY<sup>II</sup> incubator (ANKOM Technology Corp., Fairport, NY) using the method outlined by Goering and Van Soest (1970). Approximately 0.5 g of sample DM was weighed into 4.5 × 5.0-cm Ankom Dacron bags that were heat sealed and exposed to in vitro digestion for 30 h in medium

containing buffer and mineral solution (Goering and Van Soest, 1970) and ruminal fluid, respectively, mixed in ratio of 4:1. Ruminal fluid was collected from a non-pregnant, dry cow fed a corn and grass silage-based TMR ad libitum and strained through four layers of cheesecloth before mixing with buffer. Bags were made from nitrogen-free, white polyester monofilament fabric with 57- $\mu$  pore size. At the end of incubation, bags were placed in an ANKOM<sup>200/220</sup> Fiber Analyzer and digesta samples exposed to NDF extraction. The NDF residue was either expressed as a fraction of initial sample DM to determine IVTDM, or as a fraction of initial sample NDF to determine IVNDFD on DM basis.

Corn silage samples were analyzed for free ammonia nitrogen with a Wescan Ammonia Analyzer, pH was determined with a digital pH meter, and the silage samples were processed according to Fenner (1984) to determine concentrations of VFA and lactic acid by gas chromatography (Supelco, Inc., 1975). The pieces of equipment used were a Varian 3700 gas chromatograph (Varian, Inc., Walnut Creek, CA), a 4% carbowax 20M/80/120 carbopack B-DA column (Supelco, Bellefonte, PA) at the temperature setting of 175°C, and a Perkin Elmer LC-100 intergrator (Perkin-Elmer Corp., Norwalk, CT). The flow rates for the nitrogen, hydrogen, and air, respectively, were 24, 30, and 300 ml/min.

### Statistical Analysis

Data collected from the plot trial were analyzed as a randomized block design using the GLM procedures of the SAS (1993) using the following model

$$Y_{ijl} = \mu + \tau_i + \gamma_j + \tau\gamma_{ij} + e_{ijl}$$

where,

- $\mu$  = overall mean,
- $\tau_i$  = the effect of the *i*th treatment,
- $\gamma_j$  = the effect of the *j*th plot or block,
- $\tau\gamma_{ij}$  = the treatment by plot interaction, and
- $e_{ijl}$  = residual error.

Least squares means and SE were reported. If treatment differences were significant, orthogonal contrasts were performed for the corn hybrid developed for dual purpose with grain production as the main criteria (Pioneer) versus the two corn hybrids specifically developed for silage production (Mycogen and Cargill) (contrast 1), or between Mycogen and Cargill (contrast 2). If interaction and (or) plot were not significant, they

were removed from the full model and the reduced model was reanalyzed.

Data collected from the intake trial were analyzed as a replicated simultaneous  $3 \times 3$  Latin Square using the GLM procedures of the SAS (1993) and hybrid differences were determined by orthogonal contrasts when treatment effects were significant. The following model was used

$$Y_{ijkl} = \mu + S_i + C_{j(I)} + P_k + T_l + ST_{il} + e_{ijkl}$$

where,

- $\mu$  = overall mean,
- $S_i$  = the random effect of square ( $i = 1$  to  $2$ ),
- $C_{j(I)}$  = the random effect of cow within square ( $j = 1$  to  $3$ ),
- $P_k$  = the random effect of period ( $k = 1$  to  $3$ ),
- $T_l$  = the fixed effect of treatment ( $l = 1$  to  $3$ ),
- $ST_{il}$  = the interaction of square and treatment, and
- $e_{ijkl}$  = residual error, assumed to be normally distributed.

Square  $\times$  treatment interaction was dropped from the full model because it was not significant ( $P > 0.10$ ), and the reduced model ran again.

Data collected from the lactation trial were examined for normality, tested for homogeneity of variance, and analyzed as a randomized block design using the GLM procedures of SAS (1993) using the following model

$$Y_{ijk} = \mu + \tau_i + \gamma_j + \beta(x_{ijk} - \bar{x}_{..}) + e_{ijk}$$

where,

- $\mu$  = overall mean,
- $\tau_i$  = the effect of the  $i$ th treatment,
- $\gamma_j$  = the effect of the  $j$ th block,
- $\beta$  = a linear regression coefficient indicating the dependency of  $Y_{ijk}$  and  $x_{ijk}$ ,
- $x_{ijk}$  = the  $ijk$ th observation on the covariate, and
- $e_{ijk}$  = residual error.

Data collected during the adjustment period were used as a covariate in the statistical analysis of the data collected during the test period for milk yield and milk composition. If treatment differences were significant, hybrid effects were determined using orthogonal contrasts as described for intake trial data. Because animals were group fed, with no replications of pens

within treatment, the investigators assumed 1) no pen effect, and 2) that errors within pens were independent (St-Pierre and Jones, 1999), allowing for cow to serve as the experimental unit. Because cows were group fed, no statistical analysis was conducted on DMI data.

## RESULTS AND DISCUSSION

### Plot Trials

**DM yield, in vitro digestion, plant population, and nutrient composition.** There were no differences in plant population, infected ears, barren ears, or lodged plants when Pioneer was compared with Mycogen and Cargill (Table 4). Cargill did not lodge as has been reported by Cherney et al. (1991) to occasionally be a problem with BMR corn. However, it should be noted that conditions such as excessive rain and heavy winds late in the season, which would have allowed lodging to be evaluated intensively, did not occur. During the growing season a total of 571 mm of precipitation (122% of 37-yr mean) was received, and the growing degree days or heat units were 2475 (108% of 37-yr mean). Most of the rain was received in late June. Mycogen had fewer plants ( $P = 0.0068$ ) than Cargill. Pioneer had larger ears relative to the non-grain part of the plant when compared with Mycogen and Cargill, and Mycogen had large leafy plants. Mycogen and Cargill corn forages had lower DM content at harvest ( $P = 0.0004$ ), a higher IVTDMD ( $P = 0.0714$ ), and a lower DM yield ( $P = 0.0012$ ) than Pioneer (Table 4). Although not significant, IVNDFD followed a similar trend to that shown by IVTDMD, and in vitro digestible DM yield followed a similar trend to that shown by DM yield. Mycogen had lower IVTDMD ( $P = 0.0671$ ) and higher DM yield ( $P = 0.0053$ ) than Cargill.

When compared with Pioneer, Mycogen and Cargill had higher concentration of ash ( $P = 0.0319$ ), ADF ( $P = 0.0560$ ), NDF ( $P = 0.0338$ ), magnesium ( $P = 0.0255$ ), and copper ( $P = 0.0111$ ), and a lower concentration of fat ( $P = 0.0018$ ) (Table 5). Mycogen had higher concentrations of ADL ( $P = 0.0057$ ) and fat ( $P = 0.0132$ ) than Cargill. The three hybrids had similar concentrations of CP, soluble protein, sugars, starch, NSC, cellulose, calcium, phosphorus, potassium, iron, and zinc (Table 5). The CP levels for the fresh corn forages were slightly lower than reported values (NRC, 1988), which might be explained by leaching of N from the rainfall that was received in late June when it was too late to apply supplemental N fertilizer. There were no differences among hybrids for particle size distribution at ensiling (Table 6).

It was expected that Mycogen would have the lowest plant population because of the lower seeding rate used compared with the other hybrids. Because Mycogen

**Table 4.** Plant population, DM content at harvest, in vitro disappearance of true DM (IVTDMD) and NDF (IVNDFD) at 30 h of incubation, and yields of DM and in vitro digestible DM (IVDDM) of fresh Mycogen TMF94 (Mycogen), Cargill F337 (Cargill), and Pioneer 3861 (Pioneer) corn hybrid forages (plot trial).

Item	Treatment means				Contrasts		
	Mycogen (M)	Cargill (C)	Pioneer (P)	SE	<i>P</i>	P vs. (M+C)	M vs. C
Plant population							
Plants/ha	66,278	82,333	76,570	2812	0.0184	0.5353	0.0068
Smut-infected, %	0.17	2.17	0.00	0.70	0.1274		
Barren ears, %	1.00	0.33	0.83	0.40	0.5060		
Lodged, %	0.17	0.17	0.00	0.14	0.6297		
DM, %	27.8	27.3	33.7	0.4	0.0009	0.0004	0.4721
IVDMD <sup>1</sup> , %	75.1	79.2	73.7	1.6	0.0612	0.0714	0.0671
IVNDFD <sup>2</sup> , %	44.7	48.9	43.5	3.3	0.1263		
DM yield, t/ha	15.1	13.9	15.8	0.2	0.0035	0.0012	0.0053
IVDDM yield, t/ha	11.3	11.0	11.7	0.3	0.4421		

<sup>1</sup>In vitro true DM disappearance is determined by expressing NDF residue after in vitro digestion as a fraction of initial sample DM.

<sup>2</sup>DM basis.

**Table 5.** Nutrient composition of fresh Mycogen TMF94 (Mycogen), Cargill F337 (Cargill), and Pioneer 3861 (Pioneer) corn hybrid forages (plot trial).

Item	Treatment means				Contrasts		
	Mycogen (M)	Cargill (C)	Pioneer (P)	SE	<i>P</i>	P vs. (M+C)	M vs. C
	(DM basis)						
Ash, %	5.2	5.2	4.7	0.1	0.0763	0.0319	0.8655
CP, %	6.6	6.7	6.8	0.1	0.8264		
Soluble protein, %	1.5	1.7	1.0	0.2	0.2829		
ADF, %	26.0	24.3	23.2	0.5	0.0688	0.0560	0.1115
NDF, %	45.6	44.9	40.8	1.2	0.0786	0.0338	0.6753
Hemicellulose, %	19.6	20.6	17.6	1.1	0.3281		
Cellulose, %	23.0	22.0	20.7	0.5	0.1447		
ADL <sup>1</sup> , %	3.0	2.3	2.5	0.1	0.0130	0.2302	0.0057
NSC <sup>2</sup> , %	41.4	41.7	39.9	1.6	0.7696		
Sugars, %	8.6	8.2	8.4	1.1	0.9662		
Starch, %	32.7	33.5	31.5	2.5	0.8868		
Fat, %	2.4	2.2	2.6	0.03	0.0028	0.0018	0.0132
Calcium, %	0.20	0.22	0.14	0.01	0.3160		
Phosphorus, %	0.19	0.22	0.20	0.02	0.7157		
Potassium, %	1.33	1.15	1.10	0.03	0.4000		
Magnesium, %	0.13	0.14	0.10	0.01	0.0166	0.0255	0.9180
Iron, mg/kg	66.3	50.3	61.3	8.7	0.5251		
Manganese, mg/kg	17.0	19.0	13.7	1.3	0.1292		
Zinc, mg/kg	20.7	25.0	18.3	2.6	0.3665		
Copper, mg/kg	5.3	5.3	3.7	0.3	0.0278	0.0111	1.0000

<sup>1</sup>Acid detergent lignin (Van Soest et al., 1991).

<sup>2</sup>Analyses for sugars and starch were by the enzymatic digestion procedure of Smith (1969).

**Table 6.** Particle size distribution at ensiling of fresh Mycogen TMF94 (Mycogen), Cargill F337 (Cargill), and Pioneer 3861 (Pioneer) corn hybrid forages (plot trial).

Particle size	Treatment means <sup>1</sup>			SE	<i>P</i>
	Mycogen	Cargill	Pioneer		
	(% of DM)				
Small (< 0.79 cm)	7.3	7.1	6.6	2.1	0.9593
Medium (0.79 to 1.90 cm)	65.5	64.0	64.8	1.6	0.8387
Large (> 1.90 cm)	27.2	28.8	28.6	1.3	0.4496

**Table 7.** Dry matter content, in vitro disappearance of true DM (IVTDMD), in vitro disappearance of NDF (IVNDFD), and nutrient composition of Mycogen TMF94 (Mycogen), Cargill F337 (Cargill), and Pioneer 3861 (Pioneer) silages fermented in mini-silos (plot trial).

Item <sup>1</sup>	Treatment means			SE	P	Contrasts	
	Mycogen (M)	Cargill (C)	Pioneer (P)			P vs. (M+C)	M vs. C
	(% , DM basis)						
DM	26.4	25.9	32.7	0.4	0.0015	0.0006	0.5860
IVDMD	73.8	77.5	73.9	1.7	0.3297		
IVNDFD	44.3	51.7	40.8	3.5	0.2644		
NDF	48.3	46.7	44.2	1.3	0.0672	0.0360	0.2532
NSC <sup>2</sup>	29.5	30.5	31.3	1.8	0.8424		
Sugars	1.0	1.2	1.3	0.1	0.3783		
Starch	28.5	29.3	30.0	1.9	0.8947		
VFA							
Acetate	0.95	1.06	0.88	0.15	0.7173		
Propionate	ND <sup>3</sup>	ND	0.35	0.35	0.4444		
Lactate	5.0	5.8	4.2	0.5	0.2136		

<sup>1</sup>Valerate was not detected.

<sup>2</sup>Analyses for sugars and starch were by the enzymatic digestion procedure of Smith (1969).

<sup>3</sup>Not detected.

has a robust plant morphology, produces large ears, and has two to four extra leaves above the ear compared with nonleafy corn hybrids, it had higher yield of DM than Cargill despite having a lower plant population. Frenchick et al. (1976) and Allen et al. (1997) also reported that BMR corn hybrids were low yielding when compared with normal corn hybrids. The lower DM content of Mycogen and Cargill at harvest when compared with Pioneer and the fact that the forages were grown for 131 d, suggest that the relative maturities for these two corn hybrids are more than the 94 to 95 d stated by the seed suppliers before the initiation of the trial. The nutrient composition and digestibilities of DM and NDF of Mycogen were similar to those reported by Kuehn et al. (1999) for this corn hybrid. The higher DM and NDF digestibilities of the Cargill hybrid may be explained in part by its low ADL concentration, which is consistent for BMR hybrids. This is supported by other workers who also reported that BMR corn hybrids had lower lignin concentration (Cherney et al., 1991; Keith et al., 1979; Oba and Allen, 1997, 1999), higher IVTDMD (Allen et al., 1997), and higher IVNDFD (Allen et al., 1997; Cherney et al., 1991; Keith et al., 1979; Oba and Allen, 1997, 1999) than isogenic normal corn hybrids. Lignin has long been recognized as a significant impediment to forage digestibility (Jung and Allen, 1995). The higher concentration of minerals in Mycogen and Cargill explains their higher ash content compared with Pioneer.

**Nutrient composition of corn silages fermented in mini-silos.** Compared with Pioneer, Mycogen and Cargill had lower DM content ( $P = 0.0006$ ) and numerically higher IVNDFD and concentration of NDF (Table 7). Although not significant, Cargill had numerically

higher IVTDMD and IVNDFD, and lower NDF concentration than Mycogen. The higher digestibility of the Cargill hybrid is attributed in part to its lower ADL concentration (Cherney et al., 1991; Keith et al., 1979; Oba and Allen, 1997, 1999, 2000). Concentrations of sugars, starch, NSC, VFA, and lactate were similar among the silages of the three corn hybrids. Increased NDF concentration postensiling was a result of partial fermentation of NSC and hemicellulose.

### Intake Trial

The nutrient composition of corn silages fed to animals in the intake and lactation trials is shown in Table 8. Cargill had the highest IVTDMD and IVNDFD, which are attributed in part to the lower lignin content of this BMR hybrid compared with Mycogen and Pioneer. Mycogen and Pioneer had similar IVTDMD, IVNDFD, and lignin concentration. Mycogen silage had the highest concentration of total VFA, acetate, and lactate.

The Pioneer silage diet resulted in lower DMI ( $P = 0.0046$ ) by Holstein heifers compared with Mycogen and Cargill silage diets (Table 9). No differences were observed in DMI between the Mycogen and Cargill silage diets (Table 9), even though the Cargill hybrid was more digestible in vitro. Even though other workers have reported increased DMI by dairy cows fed BMR corn silage compared with cows fed non-BMR corn silage (Oba and Allen, 1997, 1999; Stallings et al., 1982), failure to observe differences in intake is not unusual (Keith et al., 1979; Sommerfeldt et al., 1979).

**Table 8.** Nutrient characteristics of Mycogen TMF94 (Mycogen), Cargill F337 (Cargill), and Pioneer 3861 (Pioneer) corn silages, used in diets fed to Holstein heifers or lactating Holstein cows (intake and lactation trials).

Composition	Mycogen corn silage	Cargill corn silage	Pioneer corn silage
	(DM basis)		
DM, %	26.6	25.7	29.0
IVTDMD, %	69.1	74.8	68.7
IVNDFD, %	28.2	45.7	32.1
Ash, %	3.7	4.3	3.4
CP, %	7.4	8.7	7.1
ADF-CP, %	0.5	0.4	0.6
NDF-CP, %	0.9	1.0	0.9
Soluble protein, % of CP	45.5	48.0	40.5
ADF, %	25.8	25.3	26.0
NDF, %	42.2	41.7	41.5
Hemicellulose, %	16.4	16.4	15.5
Cellulose, %	23.2	23.3	22.9
Acid detergent lignin, %	2.6	2.0	3.1
NSC <sup>1</sup> , %	30.1	30.9	32.1
Sugars, %	2.1	2.1	2.1
Starch, %	28.0	28.8	30.0
Fat, %	3.4	2.8	3.2
Calcium, %	0.22	0.29	0.21
Phosphorus, %	0.24	0.23	0.22
Sulfur, %	0.08	0.11	0.06
Magnesium, %	0.16	0.20	0.12
Potassium, %	1.04	0.93	1.06
Sodium, %	0.018	0.017	0.003
Iron, mg/kg	130.0	147.0	63.0
Zinc, mg/kg	22.0	23.0	17.0
Copper, mg/kg	5.0	7.0	4.0
Manganese, mg/kg	19.0	23.0	15.0
Molybdenum, mg/kg	1.0	0.8	0.8
End products of fermentation <sup>2</sup>			
pH	3.75	3.78	3.76
Acetate, %	1.03	0.81	0.53
Lactic acid, %	7.5	5.2	2.8

<sup>1</sup>Analyses for sugars and starch for corn silages were by the enzymatic digestion procedure of Smith (1969).

<sup>2</sup>Propionate, butyrate, isovalerate, and valerate concentrations were < 0.04 (% DM) or not detected.

## Lactation Trial

Milk yield was lower for cows fed Pioneer silage-based TMR compared with cows fed Mycogen and Cargill silage-based TMR ( $P = 0.06$ ) (Table 10). Improved milk yield ( $P = 0.001$ ) and 3.5% FCM ( $P = 0.0397$ ) by

cows fed Cargill silage-based TMR compared with cows fed Mycogen silage-based TMR may be attributed to the higher in vitro digestibility of Cargill silage. Cows fed the Cargill silage-based TMR had higher milk yield ( $P = 0.0049$ ) and 3.5% FCM ( $P = 0.0260$ ) than cows fed the Pioneer-based TMR. There were no differences in

**Table 9.** Body weight, BCS, and DMI by Holstein heifers individually fed diets consisting of 79% (DM basis) Mycogen TMF94 (Mycogen), Cargill F337 (Cargill), or Pioneer 3861 (Pioneer) silage (intake trial).

Item	Treatment means			SE	<i>P</i>	Contrasts	
	Mycogen (M)	Cargill (C)	Pioneer (P)			P vs. (M+C)	M vs. C
BW, kg	561	572	569	25	0.9518		
BCS <sup>1</sup>	3.67	3.67	3.79	0.11	0.6592		
DMI							
kg/d	12.0	12.0	11.5	0.1	0.0141	0.0046	0.8506
% of BW	2.14	2.11	2.02	0.02	0.0093	0.0033	0.4042

<sup>1</sup>Scored using a five-point scale where 1 = thin to 5 = fat (Wildman et al., 1982).

**Table 10.** Milk yield and milk composition of lactating Holstein cows group-fed TMR based on Mycogen TMF94 (Mycogen), Cargill F337 (Cargill), and Pioneer 3861 (Pioneer) silages.

Item	Treatment means			SE	P	Contrasts	
	Mycogen (M)	Cargill (C)	Pioneer (P)			P vs. (M+C)	M vs. C
Milk <sup>1</sup> , kg/d	31.1	33.4	31.2	0.5	0.0020	0.0600	0.0010
3.5% FCM <sup>2</sup> , kg/d	33.5	35.8	33.3	0.8	0.0465	0.1609	0.0397
Milk fat, %	4.27	4.13	4.20	0.08	0.5153		
Milk CP, %	3.26	3.2	3.21	0.02	0.1417		
Milk lactose, %	4.82	4.81	4.78	0.02	0.3341		
Linear SCC	4.83	4.62	4.79	0.16	0.6054		

<sup>1</sup>P vs. M ( $P = 0.7472$ ) and P vs. C ( $P = 0.0049$ ).

<sup>2</sup>P vs. M ( $P = 0.8613$ ) and P vs. C ( $P = 0.0260$ ).

milk yield ( $P = 0.7472$ ) and 3.5% FCM yield ( $P = 0.8613$ ) between cows fed the Mycogen and Pioneer-based TMR. Kuehn et al. (1999) also failed to observe any corn hybrid effect on milk yield, 3.5% FCM, and milk composition by lactating Holstein cows fed diets containing Mycogen, a grain hybrid, or a generic hybrid. Cows fed Pioneer silage-based TMR had similar milk fat, milk CP, milk lactose, and linear SCC as cows fed Mycogen and Cargill silage-based TMR (Table 10). Enhanced IVNDFD of Cargill was associated with increased milk production by lactating dairy cows. The greater digestion of the Cargill silage would suggest that more energy might be available to the animal from the structural carbohydrates of the Cargill silage than from the Mycogen or Pioneer silage. These results agree with the observations of other researchers (Block et al., 1981; Frenchick et al., 1976; Keith et al., 1979; Oba and Allen, 1997, 1999, 2000), who reported higher DMI and improved milk yield by lactating dairy cows from feeding BMR corn silage.

## CONCLUSIONS

Although Mycogen and Cargill had lower yields of DM and higher concentrations of NDF and cellulose when compared with Pioneer, they had higher IVTDMD. Mycogen had higher DM yield despite having a lower plant population, lower IVTDMD, and resulted in lower milk production by lactating cows when compared with Cargill. There were no differences in DMI between Cargill and Mycogen silages fed as 79% (DM basis) of the heifer's diet. Mycogen hybrid had higher IVTDMD and DMI by heifers, but had similar yields of DM, and promoted similar milk production by lactating cows when compared with Pioneer.

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