Yield and Quality of Silage Corn as Affected by Hybrid Maturity, Planting Date and Harvest Stage

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ABSTRACT : Silage corn (*Zea mays* L) is grown extensively in livestock operations, and many managements focus on forage yield. This experiment was conducted at Seoul National University (SNU) Experimental Livestock Farm, Suwon in 1998. We determined the effect of planting date and harvest stage on forage yield and quality responses of corn hybrids (five relative maturity groups). The five maturity groups (100 d, 106 d, 111 d, 119 d and 125 d) were planted on 15 April and 15 May, and harvested at maturity stages (1/3, 1/2 and 2/3 kernel milkline). Whole plant dry matter (DM) and ear percentages had significant differences among corn hybrids. Ear percentages of early maturing corns (100 d and 106 d) were higher than for other hybrids. Ear percentage at the early planting date was higher than that at the late planting date for all corn hybrids. The DM and total digestible nutrients (TDN) yields of the 106 d and 111 d corn hybrids were higher than other hybrids, and the DM and TDN yields at the early planting date were higher than that at the late planting date. The acid detergent fiber (ADF) and neutral detergent fiber (NDF) percentages were greater for the late maturity corn hybrids. For plants of the early planting date, the ADF and NDF percentages were lower than for those of late planting date for hybrids. From the comparison among harvest stages, ADF and NDF percentages were decreased as harvest stage progressed. The TDN, net energy for lactation (NEL), and cellulase digestible organic matter of dry matter (CDOMD) were decreased as maturity of corn hybrid delayed. The TDN, NEL, and CDOMD values at the early planting date were higher than those at the late planting date among for corn hybrids. From the comparison among harvest dates, TDN, NEL, and CDOMD values were increased as harvest stage progressed. The correlation coefficient for DM percentage of grain at harvest with DM and TDN yields were 0.68*** and 0.76***, respectively. And the correlation coefficient for ear percentage with ADF, NDF, and CDOMD were -0.81***, -0.82*** and 0.73***, respectively. Our study showed differences of silage corn in forage production and quality resulting from hybrid maturity, planting date, and harvest stage. We believe that for the best silage corn, selection of the hybrid and best management practices are very important. ***(Asian-Aust. J. Anim. Sci. 2001. Vol 14, No. 12 : 1705-1711)***

Key Words : Forage Yield and Quality, Maturity Stage, Kernel Milkline

INTRODUCTION

Silage corn (*Zea mays* L.) is one of the most important forages in the world today, primarily because it is an excellent energy source in dairy rations. Increased nutritional demands for optimal animal performance challenge corn producers to select hybrids and management practices for high forage yield and favorable quality characteristics (Aldrich et al., 1986; Graybill et al., 1991).

Corn forage production and quality is a function of numerous interacting factors, namely, environment, management practice, and genetics. Management practices such as hybrid selection, planting dates, and harvest dates strongly influence yield and quality (Holland et al., 1990; Graybill et al., 1991).

A hybrid of later relative maturity can increase dry matter (DM) yield because corn is response to the higher heat units of a long growing seasons (Stoskopf, 1981). A hybrid of later relative maturity, however, must be planted by mid-April and harvested by late August in Korea for silage to avoid the rainy season and typhoon of autumn. To match this time, most of adapted hybrids range from 115 to 125 d maturity. In a double-cropping silage system, however, the corn planting date is delayed until after mid-May. Corns planted in mid-May were 100 to 115 d maturity hybrids (Kim et al., 1997a; 1997b; Kim et al., 1999a).

Several researchers have evaluated corn DM accumulation and nutritive value at various stages of crop maturity or DM percentage (Caldwell and Perry, 1971; Daynard and Hunter, 1975; Weaver et al., 1978; Hunt et al., 1989; Wiersma et al., 1993; Kim et al., 1999b). Maximum whole plant yield is generally reported to occur at whole plant DM percentage between 30 and 35%.

Commercial corn hybrids have been selected primarily for forage yield and disease resistance. Selection of hybrids for silage has ignored potential hybrid differences in the quality of silage corn. Several studies have identified variations in quality of stover (Hunt et al., 1989; Hunt et al., 1992; Kim et al., 1999a,b). Limited research has focused on laboratory analyses, which are associated with differences in whole-plant corn quality. Percentages of crude fiber and fiber constituents (ADF, NDF, and ADL) of silage corn were associated with digestibility (Marten et al., 1975; Hunt et al., 1992; Kim et al., 1999a,b). Other research by Coors (1996) indicated that silage corn has relatively high fiber

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Received April 27, 2001; Accepted July 12, 2001

concentrations, as measured by NDF and ADF, but low lignin concentrations.

Management studies and selection of hybrid on corn for silage in Korea during the last 25 years have focused primarily on agronomic characteristics (DM percentage, lodging, and disease resistance) and forage production (DM and total digestible nutrients (TDN) yields).

The objective of this experiment was to evaluate forage yield and quality responses of corn hybrids (five relative maturity groups) to planting date and harvest stage. Correlation between DM percentage and forage yield, and quality constituents also were determined.

MATERIALS AND METHODS

This study was conducted at the Experimental Livestock Farm, Seoul National University (SNU), Suwon in 1998. Soil type at the site is a well-drained silt loam. Soil tests indicated a pH of 6.5 and medium value of P and K. A rotation of fall oats (*Avena sativa* L.) and corn had been grown at the experimental site for the past 10 yr.

The experimental design was a randomized complete block in a split-split arrangement with three replications. Main plots consisted of corn hybrids, subplots consisted of planting dates (15 April and 15 May), and sub-subplots consisted of the harvest stages 1/3 kernel milkline (ML) (GDD, 1,300°C); 1/2 ML (GDD, 1,380°C); and 2/3 ML (GDD, 1,460°C). The hybrids of five different maturity groups were 100 d (Dekalb 501); 106 d (Pioneer 3514); 111 d (Pioneer 3352); 119 d (Pioneer 3163); and 125 d (Norvatis G4743) (table 2).

Seed was hand-planted in 75 cm rows, and thinned after emergence to a uniform stand of 70,000 plants ha^{-1}. A basal fertilizer application was broadcast at 90, 200, and 150 kg ha^{-1} of N, P, and K, respectively. When corn was 0.3 to 0.4 m in height, all plots were side-dressed with 90 kg N ha^{-1}.

At harvest, four representative plants were selected to estimate DM percentage and provide samples for forage quality analysis. The four-plant samples are divided into stover and ear fractions, then weighed and dried for 168 h by forced-air drying oven at 65°C. Both ears and shelled corn weighed. The samples were reassembled and ground through a 1 mm screen in a Wiley Mill.

The ground samples were analyzed for DM (AOAC, 1990) and the fiber constituents NDF, ADF, ADL (Goering and Van Soest, 1970). However, NDF was treated with 50 ul of α-amylase (Sigma Chemical Co., St. Louis, MO. no. A3306; Van Soest et al., 1991).

The two energy indices chosen were net energy for lactation (NEL), which measures the amount of energy in a feed available for milk production; and TDN, which is a measure of the digestibility of nutrients contained within a feed that may be used as energy by the animal. Values for NEL and TDN were calculated from the following equations modified from Jurgens (1988) for corn forage samples; $NEL=2.3924 - (0.033\times ADF)$, and $TDN=(NEL\times 40.862)+2.898$.

Cellulase digestible organic matter of dry matter (CDOMD) was determined by the method described by De Boever et al. (1986).

Data were analyzed with analysis of variance (ANOVA) procedures using the SAS Statistical Software Package (1988). The mean separation among treatment means for hybrid, planting date, and harvest stage was obtained by using the Least Significant Difference (LSD) test (Steel and Torrie, 1980). Effects were considered in all statistical calculations for $P\text{-value} < 0.05$.

RESULTS AND DISCUSSION

Precipitation, evaporation, and growing degree days (GDD) values during the growing season are presented in table 1. Although precipitation in 1998 was 332 mm above the 30-yr mean, dry conditions existed from April to May. Evaporation in 1998 was 18 mm below a normal year (table 1). Consequently, during the early growing season (April to May), the low precipitation stressed early growth of corn when planted at mid-April.

In general, the higher the yield potential a corn hybrid, the greater is the number of GDD required to reach that potential in a given season. Therefore, in order to help

Table 1. Monthly and growing season precipitation, evaporation, and growing degree days accumulations at Suwon, Korea, in 1998

Month	Precipitation (mm)		Evaporation (mm)		GDD (°C)*	
	1998	30 yr Avg	1998	30 yr Avg	1998	30 yr Avg
April**	12	41	63	65	125	73
May	86	95	144	142	268	222
June	214	133	129	143	354	359
July	306	303	143	129	476	473
August	592	306	113	131	487	485
Sum	1,210	878	592	610	1,710	1,612

* Growing degree days. ** 15 April to 30 April.

maximize potential yields, a grower must choose a hybrid to match the GDD in a given season for the location (Dysinger et al., 1996). The silk GDD of late maturing hybrids (119 d and 125 d) was greater than that of early maturing hybrids (table 2). The silk GDD difference of optimum planting date was higher than that of late planting date. This result was due to environmental stress. The corn of optimum planting date had long growing season and high temperatures, and affected growth of corn. Therefore, the forage yield and nutritive value of optimum planting date was higher than that of the late planting date with short growing season.

Significant main effects (hybrid, planting date, and harvest stage) and their interactions were observed for most measured parameters (table 3). There were significant effect for hybrid × management practices (planting date and harvest stage) for most traits. Hybrid × planting date interactions were more often significant than hybrid × harvest stage interactions.

Differences in whole plant DM were significant among hybrid, planting date, and harvest stage ($p<0.05$; table 3 and 4). Early maturing corn (100 d) ranked highest in DM percentage, and DM percentage was decreased as hybrid maturity was delayed. Ear percentage of all corn hybrids was increased as harvest stage progressed. The range in DM percentage among hybrids was greater than the range between harvest stages, with a range of up to 15 percentage-points. Crookston and Kurle (1988) also reported only hybrid differences in whole plant DM percentage. Although variation existed among hybrids, harvest stage (kernel milkline), excepting for the 100 d and 106 d hybrids, indicated when the whole plant DM percentage at both the 1/3 ML and 2/3 ML stages was within the acceptable 25 to 35% range (Daynard and Hunter, 1975; Wiersma et al., 1993; Kim et al., 1999b).

Ear percentage differences also were shown among hybrid, planting date, and harvest stage ($p<0.05$; table 3 and 4). Ear percentages in terms of total DM of the early maturing hybrids (100 d and 106 d) were higher than the other hybrids. Ear percentages of corn planted at the optimum planting date were higher than that of late planting date for all hybrids. Ear percentages of all hybrids were increased as harvest stage progressed, showing conclusively that hybrid maturity strongly affected ear percentage. Because the grain content strongly influences quality of silage corn (Graybill et al., 1991), Our results further confirm that ear percentage of the hybrid selection can influence forage quality.

The DM yield of the medium maturing hybrid (111 d) was the highest among hybrids. The DM yield at optimum

Table 2. Characteristics of corn hybrids of five maturity groups for silage

Item	Relative maturity of hybrid				
	100 d	106 d	111 d	119 d	125 d
Company hybrids	DK501	P3525	P3352	P3163	G4743
Planting to silking*	63 / 75	63 / 76	67 / 79	71 / 83	72 / 85
Silking GDD**	715 / 765	726 / 765	750 / 784	773 / 803	788 / 804

* Optimum / late planting date, ** Growing degree days from planting to silking, P = Pioneer Hi-Bred International, Inc., DK = Dekalb Genetics Corporation, G = Novartis Seed Company.

Table 3. Significance of main effects and their interactions in analysis of variance for dry matter percentage, ear percentage, forage yield, fiber composition, total digestible nutrients, net energy for lactation, and cellulase digestible organic matter of dry matter

Source	df	DM	% Ear	Yield		Fiber composition			TDN	NEL	CD OMD
				DM	TDN	ADF	NDF	ADL			
Hybrid (H)	4	***	***	***	***	***	***	**	***	***	***
Planting (P)	1	***	***	***	***	***	***	NS	***	***	NS
Harvest (S)	2	***	***	*	**	***	***	NS	***	***	***
H × P	4	***	**	*	*	NS	NS	***	NS	NS	***
H × S	8	*	***	NS	NS	NS	NS	NS	NS	NS	**
P × S	2	***	**	NS	NS	NS	NS	***	NS	NS	**
H × P × S	8	*	*	NS	NS	NS	NS	NS	NS	NS	NS
Error	60										
Total	89										

DM = dry matter percentage, % Ear = Ear percentage of total DM, TDN = total digestible nutrients, NEL = net energy for lactation, CDOMD = cellulase digestible organic matter of dry matter.

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

NS = not significant.

Table 4. Whole plant dry matter (DM) and ear percentages for corn hybrids of five maturity groups at two planting dates and three harvest stages

Planting date	Harvest stage*	Hybrid maturity				
		100 d	106 d	111 d	119 d	125 d
DM %						
	1/3 ML	29.0	28.9	26.8	24.4	23.2
Optimum	1/2 ML	34.3	32.5	28.4	27.3	25.9
	2/3 ML	42.4	36.7	35.1	32.1	33.9
	1/3 ML	36.3	32.7	28.7	25.6	23.5
Late	1/2 ML	41.7	35.9	32.2	27.7	27.1
	2/3 ML	44.0	38.7	36.1	31.7	29.8
Ear %						
	1/3 ML	52.8	51.5	45.4	45.5	40.0
Optimum	1/2 ML	58.4	58.2	52.3	51.3	45.0
	2/3 ML	59.9	57.3	53.1	52.5	50.8
	1/3 ML	42.7	46.8	40.6	36.8	35.2
Late	1/2 ML	52.7	49.6	40.2	40.1	37.4
	2/3 ML	48.6	50.8	44.7	40.5	43.8
LSD (0.05)		DM %			Ear %	
Hybrid maturity		0.7			1.3	
Planting date		0.4			0.8	
Harvest stage		0.5			1.0	

* ML = milkline.

Table 5. Dry matter (DM) and total digestible nutrients (TDN) yields for corn hybrids of five maturity groups at two planting dates and three harvest stages

Planting date	Harvest stage*	Hybrid maturity				
		100 d	106 d	111 d	119 d	125 d
DM yield (Mg ha^{-1})						
	1/3 ML	16.8	21.9	21.7	20.7	19.5
Optimum	1/2 ML	17.5	20.7	21.1	20.7	18.7
	2/3 ML	19.2	20.6	21.7	21.4	20.0
	1/3 ML	13.8	16.0	17.1	16.2	15.5
Late	1/2 ML	12.8	15.3	16.2	15.7	16.4
	2/3 ML	13.7	16.8	15.5	16.4	16.8
TDN yield (Mg ha^{-1})						
	1/3 ML	12.2	15.8	15.3	14.5	13.5
Optimum	1/2 ML	13.0	15.2	15.2	14.9	13.1
	2/3 ML	14.3	15.1	15.7	15.5	14.4
	1/3 ML	9.6	11.3	11.8	11.5	10.5
Late	1/2 ML	9.3	10.9	11.1	10.7	11.2
	2/3 ML	9.8	12.1	10.9	11.3	11.7
LSD (0.05)		DM yield			TDN yield	
Hybrid maturity		0.8			0.5	
Planting date		0.5			0.3	
Harvest stage		0.6			0.4	

* ML = milkline.

planting date was higher than that at the late planting date in all hybrids ($p<0.05$). The TDN yields of the 106 d and 111 d hybrids were highest. Among all corn hybrids, the TDN yields at the early planting date were higher than that at late dates, From the comparison among harvest date, TDN yield at late harvest (2/3 ML) was the highest in all hybrids except for the 106 d entry. But, treatments which were higher in DM yield for hybrid, planting date, and harvest stage were not always higher in TDN yield. Interestingly, treatments which were numerically high in ear percentage were high in TDN yield also. These data suggest that selection for TDN yield can be found on ear percentage.

While significant differences were detected for percentage of ADF and NDF in hybrid, planting date, and harvest stage treatments, significant differences were not observed for ADL (table 6). Percentages of ADF and NDF were increased as maturity of the hybrid was delayed ($p<0.05$). At early planting date, ADF and NDF percentages were lower than those at the late planting dates. From the comparison among harvest dates, percentages of ADF and NDF were decreased as harvest stage progressed. Hybrids that were high in ear percentage were numerically low in fiber percentage (table 6). This trend suggests that quality improvement via lower fiber percentage is an important in screening the hybrids for silage. This premise was reflected in the calculated values for TDN and NEL (table 7). We concluded that any prospective differences in chemical composition of corn for silage, and the relationships to forage quality, probably would be best determined from the whole plant. This conclusion is consistent with the finding of Hunt et al. (1992), who studied corn hybrid composition and digestibility.

Treatment differences in TDN and NEL values (table 7) were observed for hybrid maturity, planting date, and harvest stage ($p<0.001$). As hybrid maturity was delayed, TDN and NEL decreased. The TDN and NEL at the early planting date were higher than those at late planting dates among all hybrids. From the comparison among harvest dates, TDN and NEL were increased as harvest stage progressed. Because TDN and NEL values were calculated

Table 6. Fiber composition for corn hybrids of five maturity groups at two planting dates and three harvest stages

Planting Date	Harvest stage*	Hybrid maturity 100 d	106 d	111 d	119 d	125 d
ADF (%)						
	1/3 ML	25.0	28.0	28.0	29.3	30.3
Optimum	1/2 ML	24.6	26.2	26.4	27.0	27.5
	2/3 ML	22.8	25.7	25.6	25.4	26.1
	1/3 ML	26.6	28.6	31.2	30.0	32.6
Late	1/2 ML	26.6	27.1	29.4	30.9	32.1
	2/3 ML	24.3	26.8	27.3	28.3	28.6
NDF (%)						
	1/3 ML	59.0	59.0	61.0	63.9	64.3
Optimum	1/2 ML	54.4	57.4	56.6	57.6	61.7
	2/3 ML	52.6	53.1	54.8	54.6	61.0
	1/3 ML	57.6	59.8	65.4	65.0	68.4
Late	1/2 ML	58.5	58.9	63.0	63.4	64.5
	2/3 ML	54.7	56.8	59.5	59.0	61.7
ADL (%)						
	1/3 ML	4.9	7.6	6.4	6.4	6.9
Optimum	1/2 ML	6.0	7.0	7.3	5.7	6.1
	2/3 ML	7.8	6.0	6.6	6.0	5.7
	1/3 ML	7.6	5.6	6.7	7.1	5.7
Late	1/2 ML	5.7	5.0	7.1	5.6	7.5
	2/3 ML	5.7	5.8	6.6	6.2	7.4

LSD (0.05)	ADF	NDF	ADL
Hybrid maturity	0.9	1.4	0.4
Planting date	0.6	0.9	NS
Harvest stage	0.7	1.1	NS

* ML = milkline.

Table 7. Total digestible nutrients (TDN), net energy for lactation (NEL), and cellulase digestible organic matter of dry matter (CDOMD) for corn hybrids of five maturity groups at two planting dates and three harvest stages

Planting Date	Harvest stage*	Hybrid maturity				
		100 d	106 d	111 d	119 d	125 d
TDN (%)						
	1/3 ML	66.9	62.9	62.8	61.1	59.7
Optimum	1/2 ML	67.4	65.2	65.0	63.7	63.4
	2/3 ML	69.8	65.9	66.0	66.3	65.4
	1/3 ML	64.8	62.0	58.5	60.2	56.5
Late	1/2 ML	65.5	64.7	60.9	58.9	57.2
	2/3 ML	67.8	64.5	63.8	62.4	62.0
NEL (Mcal kg^{-1})						
	1/3 ML	1.57	1.47	1.47	1.42	1.39
Optimum	1/2 ML	1.58	1.53	1.52	1.49	1.48
	2/3 ML	1.64	1.54	1.54	1.55	1.53
	1/3 ML	1.51	1.45	1.36	1.40	1.31
Late	1/2 ML	1.53	1.51	1.42	1.37	1.33
	2/3 ML	1.59	1.51	1.49	1.46	1.45
CDOMD (%)						
	1/3 ML	67.4	64.8	63.4	64.1	62.1
Optimum	1/2 ML	70.7	66.8	66.0	65.2	62.7
	2/3 ML	72.2	67.3	68.1	69.3	64.7
	1/3 ML	71.4	66.3	64.1	63.3	61.5
Late	1/2 ML	70.6	66.5	67.2	63.5	62.1
	2/3 ML	71.3	66.9	68.8	65.0	63.1

LSD (0.05)	TDN	NEL	CDOMD
Hybrid maturity	1.2	0.03	0.7
Planting date	0.8	0.02	NS
Harvest stage	0.9	0.02	0.6

* ML = milkline.

from ADF, the observed differences were reflective of the previously described ADF difference.

The cellulase digestible organic matter of dry matter (CDOMD) followed trends similar to TDN and NEL ($p<0.01$), indicating that ADF percentage, which was used to calculate these values, accurately predicted hybrid difference in digestibility. Differences among silage corn in TDN, NEL, and CDOMD observed in this study appear to be similar to those of other studies (Hunt et al., 1989; Hunt et al., 1992; Kim et al., 1999a; 1999b). We concluded that the increase in ADF percentages of corn reflect the decreased ear or grain percentage of silage corn. Likewise, Danley and Vetter (1973) observed that lignin was negatively correlated with IVDMD of whole plant corn. The CDOMD of this experiment was similar to ADL (table 3 and table 8).

DM and TDN yields were positively correlated with DM percentage of grain ($p<0.001$), while ADF, NDF, and CDOMD were correlated with DM percentage of the ear ($p<0.001$). The correlation coefficient for DM and TDN yields with DM percentage of grain were 0.68*** and 0.76***, respectively (table 8). And, the correlation

Table 8. Correlation coefficients between dry matter percentage and forage yield, and nutritive value of corn hybrids

	DM yield	TDN yield	ADF	NDF	ADL	CDOMD
DM percentage						
Grain	0.68***	0.76***	-0.50***	-0.48***	0.04	0.15
Ear	0.18	0.41***	-0.81***	-0.82***	-0.08	0.73***
Stover	-0.59***	-0.44***	0.32**	0.35***	-0.07	0.63***
Whole plant	-0.31**	-0.08	-0.63***	-0.65***	-0.10	0.81***

, * Significant at the 0.01 and 0.001 probability levels, respectively.

coefficient for ear DM percentage with percentages of ADF, NDF, and CDOMD were -0.81***, -0.82***, and 0.73***, respectively (table 8). These data support our theory that corn silage yield is closely correlated with on DM percentage of grain, while nutritive value would depend on DM percentage of the ear.

In this study, large differences among several silage corn hybrids were shown in hybrid maturity, planting date, and harvest stage. Differences found were primarily in the fiber composition and ear percentage, which probably resulted in the differences in the digestibility energy that would be available to the ruminant animal. While conventional thought is that a superior silage corn must have superior forage production, data from this study suggest that corn hybrids for silages with equal forage production do indeed have differences in nutritive value. On the basic of the findings in our study, the selection of hybrid and management practice such as planting date and harvest stage may even be more important than high production so that the effects of low fiber composition could improve animal productivity. Utilization of silage corn in the field, therefore, should consider both selection of the hybrid as well as management practices.

ACKNOWLEGMENTS

The authors are deeply grateful to the Adjunct Professor Walter F. Wedin, University of Minnesota, for helpful review of this manuscript and greatly improving the grammar of a late draft of the manuscript.

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