Kernel Milkline Stage and Corn Forage Yield, Quality, and Dry Matter Content

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Research Question

In the North Central states, a high proportion of corn (*Zea mays* L.) harvested for silage is planted in the extreme northern part of the region, where adapted hybrids range from 70 to 90 d relative maturity (RM). When growing corn intended for silage use, critical factors which influence optimum harvest timing include whole plant dry matter (DM) content, total yield, and nutritional quality. Determining the proper maturity to harvest corn for whole plant silage is difficult for growers.

The objective of this study was to determine the relationship between kernel milkline position and whole plant yield, quality, and dry matter content. Our goal was to develop a means to predict the optimum stage for harvesting corn silage.

Literature Summary

Estimates of whole plant DM content in corn frequently are based on grain maturity. Researchers in Minnesota demonstrated that kernel milkline position was a reliable and useful visual indicator of grain maturity and whole plant DM content. Several investigations have evaluated corn whole plant DM accumulation and nutritive value at various stages of crop maturity. Maximum whole plant yield is generally reported to occur at whole plant DM contents between 30 and 35%. Previous studies did not evaluate relationships between kernel maturity stage and all three critical factors: corn forage yield, nutritive value, and DM content.

Study Description

Four early maturity hybrids (85d RM) were evaluated for yield, forage quality, and DM content at five stages of kernel maturity over 3 yr (1988–1990) in north central Wisconsin.

Kernel maturity stages

- Soft dough — dents first visible
- Early dent — dents visible on 95% of kernels
- 1/2 Milkline (ML) — milkline positioned halfway between the tip and base of the kernel
- 3/4 ML — milkline positioned 3/4 of the way between the tip and base of the kernel
- No ML — milkline no longer present in the kernel; physiological maturity.

Applied Questions

Can the kernel milkline method reliably predict whole plant DM content?

We have verified that the kernel milkline method is a valid indicator of kernel and whole plant DM content for corn grown in a short season region. Although DM contents vary by up to 7 percentage units at particular stages across years and among hybrids, this is not large enough to discourage use of the kernel milkline method in northern corn silage production regions. The method offers farmers a simple, field-based tool to assist in judging corn maturity and DM content of whole plant and grain.

Full scientific article from which this summary was written begins on page 94 of this issue.

When is the optimum stage to harvest corn for silage?

The optimum stage to harvest corn for silage depends primarily on whole plant DM content, yield, and forage quality (Table 1). Our results indicate that whole plant DM content is within the acceptable ensiling range (30 to 40% DM content) beginning at 1/2 ML. Whole plant yield appears to reach a peak at 1/2 ML. Concentrations of crude protein decline with increasing maturity, indicating that harvest delays to No ML stage result in lower forage quality. Whole plant acid detergent fiber, neutral detergent fiber, and in vitro dry matter disappearance appear to be at an optimum between the early dent and 3/4 ML stages of maturity. Based on these criteria, corn silage harvest should begin at 1/2 ML and should conclude by 3/4 ML.

Table 1. Three year average of whole plant DM, yield, CP, ADF, NDF, and digestibility at five stages of kernel maturity.

	Whole plant					
Maturity stage†	DM† %	Yield ton/acre	CP‡ %	ADF‡ %	NDF‡ %	Digestibility§ units, %
Soft dough	24	5.4	10.3	27.2	52.7	77.1
Early dent	27	5.6	9.9	24.3	48.0	79.0
1/2 milkline	34	6.3	9.2	22.8	45.1	80.0
3/4 milkline	37	6.4	8.9	23.8	47.3	79.6
No milkline	40	6.3	8.4	24.0	47.3	78.6

† Means across four 85d RM corn hybrids and 3 yr (1988–1990).
‡ DM = dry matter, CP = crude protein, ADF = acid detergent fiber, NDF = neutral detergent fiber.
§ Digestibility = in vitro dry matter disappearance.

Kernel Milkline Stage and Corn Forage Yield, Quality, and Dry Matter Content

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Determining the proper time to harvest corn (*Zea mays* L.) for whole plant silage is difficult for growers. The objective of this study was to determine the relationship between kernel milkline position and whole plant yield, quality, and dry matter (DM) content. Our goal was to develop a means to predict the optimum stage for harvesting corn for silage. Four early maturity (85 d) hybrids were evaluated for yield, forage quality, and DM content at five stages of kernel maturity, including: soft dough (SD) (dents first visible); early dent (ED) (dents visible on 95% of kernels); 1/2 milkline (1/2 ML) (milkline positioned halfway between the tip and base of the kernel); 3/4 milkline (3/4 ML) (milkline positioned 3/4 of the way from tip to base); and no milkline (No ML) (milkline no longer present in kernel) over 3 yr (1988–1990) in north central Wisconsin. Whole plants, stover, and ears were harvested before killing frosts, except in 1989 when plants were frozen shortly after 1/2 ML. Whole plant DM content was within the optimum range for silage harvest (30 to 40%) when corn plants were between the 1/2 and 3/4 ML stages. Maximum whole plant yield was reached by 1/2 ML, while grain yield reached maximum levels by 3/4 ML. Whole plant neutral detergent fiber (NDF) and acid detergent fiber (ADF) decreased an average of 7.6 and 4.4 percentage units from SD to 1/2 ML and then increased at the No ML stage. Whole plant in vitro dry matter disappearance (IVDMD) was greatest between ED and 3/4 ML. Whole plant and stover crude protein (CP) concentration declined at each successive harvest stage from SD to No ML. Early season hybrids can be harvested for silage between 1/2 and 3/4 ML for maximum whole plant yield and optimum quality and DM content. Kernel milkline position was a good indicator of optimum harvest stage for this range of kernel maturities.

A HIGH PROPORTION of corn harvested for silage is planted in the extreme northern part of the North Central states, where adapted hybrids range from 70 to 90 d relative maturity (RM) (Carter et al., 1992). When growing corn for silage use, critical factors which influence optimum harvest timing include whole plant DM content, total DM yield, and nutritional quality.

Harvesting silage at the correct DM content is important since ensiling forages that are too wet (<30% DM content) results in losses due to poor fermentation patterns and excessive seepage, while ensiling forages that are too dry (>50% DM) increases the potential for heat damage and mold problems (Vetter and VonGlan, 1978). Silage preserved between 30 and 40% DM content provides acceptable fermentation, preservation, and animal performance (Lusk, 1978).

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Published in J. Prod. Agric. 6:94–99 (1993).

Estimates of whole plant DM content in corn are frequently based on grain maturity. Work by Daynard and Hunter (1975) showed that grain DM content varied with whole plant DM content in a predictable manner, therefore, grain DM content was suggested as an indicator of the proper stages of ensiling. Daynard and Duncan (1969) and Rench and Shaw (1971) found that black layer development in the placental region of the kernel indicated that grain had reached maximum DM accumulation. Since the early 1970s, a common recommendation was to harvest corn for silage when the black layer appears. Daynard (1972) reported, however, that grain DM content varied from 58 to 70% at black layer appearance and that premature appearance of the black layer might occur due to cool weather. This large variation of whole plant DM content often means harvesting silage with a DM content that is not optimal for proper ensiling. Afuakwa and Crookston (1984) and Crookston and Kurle (1988) demonstrated that kernel ML position was a more reliable and useful visual indicator of grain maturity and proper DM content for ensiling.

Several investigations have evaluated corn whole plant DM accumulation and nutritive value at various stages of crop maturity or DM content (Caldwell and Perry, 1971; Daynard and Hunter, 1975; Weaver et al., 1978). Maximum whole plant yield is generally reported to occur at whole plant DM contents between 30 and 35%. Cummins (1970) reported that whole plant digestibility increased with advancing plant maturity until DM content levels reached 35 to 40%, but Daynard and Hunter (1975) found whole plant digestibility to be constant from 24 to 44% DM content.

Previous studies did not evaluate relationships between kernel maturity stage and all three critical factors: corn forage yield, nutritive value, and DM content. Nevertheless, based on Minnesota work by Crookston and Kurle (1988), many dairy producers in the northern USA now harvest corn for silage when the kernel ML is between 1/2 ML and No ML stages. Hunt et al. (1989), in Idaho and California, recommended harvesting between 1/2 ML and 2/3 ML to optimize yield and quality. In Pennsylvania, however, Ganoe and Roth (1993) found that corn plants were often drier than optimum for silage fermentation when corn reached the 1/2 ML stage. They also stated that the ML method was inconsistent.

Therefore, this study was conducted to determine relationships among kernel ML position, yield, nutritional

Abbreviations: ADF, acid detergent fiber; CP, crude protein; DM, dry matter; ED, early dent stage; IVDMD, in vitro dry matter disappearance; KMS, kernel maturity stage or stages; ML, milkline; NDF, neutral detergent fiber; No ML, milkline no longer present in kernel; RM, relative maturity; SD, soft dough stage; 1/2 ML, milkline halfway between tip and base of kernel; 3/4 ML, milkline 3/4 of way between tip and base of kernel.

Table 1. Dry matter (DM) content of four hybrids averaged across kernel maturity stages from 1988 to 1990.

	Whole plant			Stover		
Hybrid	1988	1989†	1990	1988	1989†	1990
	DM content (%)					
CM105 x W182BN	31.6	34.1	29.0	24.9	25.8	21.3
A554 x CM105	32.0	35.4	30.2	24.9	27.0	22.0
LH82 x LH145	32.2	36.4	31.6	26.5	27.1	23.5
Pioneer 3790	33.3	37.0	31.6	25.9	28.5	24.5
LSD (0.10)	NS	1.5	1.0	NS	1.3	0.9

† 1989 averages include plots harvested post-frost.

quality, and whole plant DM content for short-season corn hybrids.

MATERIALS AND METHODS

Plots were established at the University of Wisconsin Agricultural Research Station in Marshfield (44°39′N, 90°8′W; 1240 ft elevation), on a somewhat poorly drained Withee silt loam (fine-loamy, mixed Aquic Glossoboralf) from 1988 to 1990. Previous crops were alfalfa (*Medicago sativa* L.) (1988) and corn (1989, 1990). Soil P and K levels were maintained at optimum levels based on University of Wisconsin recommendations. Plots received an annual application of 50 ton/acre of liquid dairy manure before planting and 14-35-45 lb/acre of N-P-K as row applied starter fertilizer at planting. Preemergence applications of metolachlor at 2.5 lb/acre and cyanazine at 2 lb/acre were applied in 1988 for annual weed control and EPTC was preplant incorporated in 1989 and 1990. Terbufos (Phosphorodithioic acid S-[[(1,1-dimethylethyl)thio]methyl]0,0-diethyl ester)) was applied at planting at a rate of 7 lb/acre for corn rootworm (*Diabrotica* spp.) control. Plots were cultivated each year to aid in annual weed control. Planting dates were 6 May 1988, 11 May 1989, and 5 May 1990. Corn was seeded at a rate of 35 000 kernels/acre and then hand thinned to 24 000 plants/acre at the V6 stage of growth (Ritchie et al., 1986).

The experimental design was a randomized complete block in a split-plot arrangement with three replicates. Main plots were four genetically diverse 85 d RM hybrids including CM105 x W182BN, A554 x CM105, LH82 x LH145, and Pioneer brand 3790. Main plots were eight 2.5-ft wide by 25-ft long rows with three outside rows serving as sample areas to determine kernel maturity.

Sub plots were five harvest times based on stage of kernel maturity (ML progression). Kernel ML was determined by periodic sampling of four to six ears per hybrid from the border rows. Ears were broken in the middle and kernel ML was visually assessed by looking at the endosperm side of exposed kernels. The five harvest times were: SD (dents first visible on kernels); ED (dents visible on 95% of kernels); 1/2 ML (ML positioned halfway between the tip and base of the kernel); 3/4 ML (ML positioned 3/4 of the way from tip to base); and No ML (ML no longer present in kernel). Sub plots were single rows 2.5-ft wide by 25-ft long.

In 1988, all hybrids were harvested at each stage of maturity before frost. In 1989, all hybrids reached the 1/2 ML stage of maturity before a killing frost. Remaining plots were harvested post-frost and will be designated post-frost 1d (PF 1d), harvested 1 d after a killing frost, and post-frost 10d (PF 10d), harvested 10 d after the frost. In 1990, plants of two hybrids were frozen before the last harvest stage (No ML) and were not harvested.

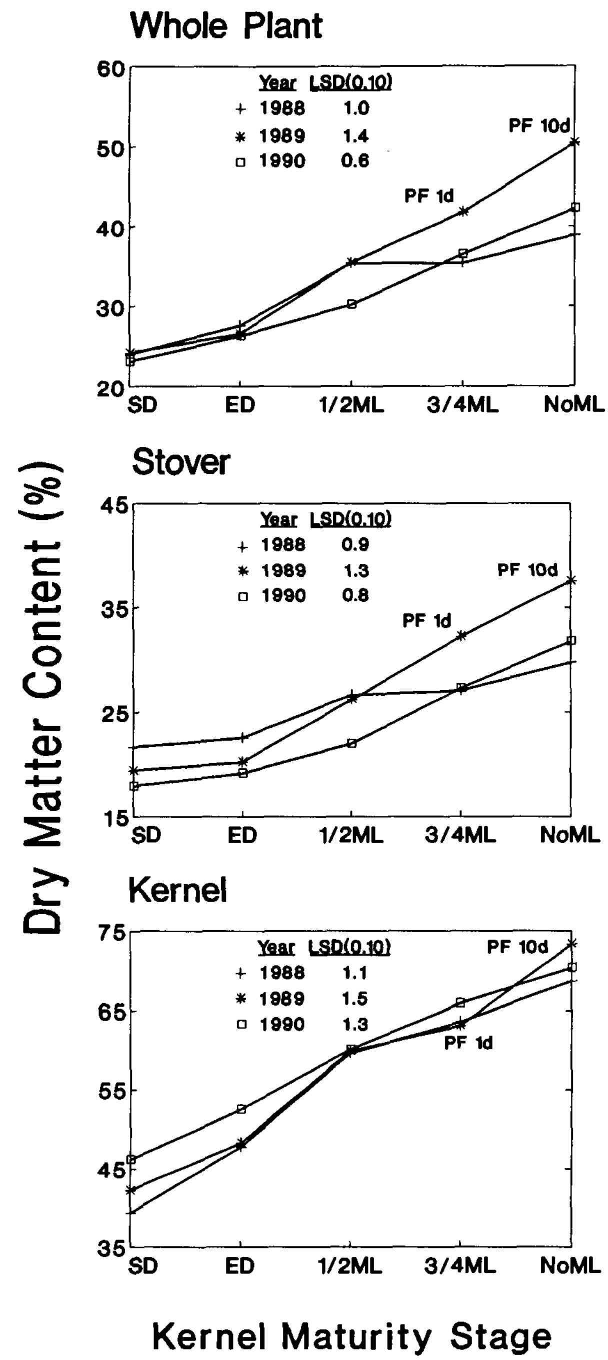

Fig. 1. Dry matter content of whole plant, stover, and kernels at soft dough (SD); early dent (ED); and 1/2, 3/4, and no milkline (ML) kernel stages. Values are averaged across four hybrids from 1988 to 1990. Post-frost harvests in 1989 are indicated by PF 1 d (harvested 1 d after the frost) and PF 10 d (harvested 10 d after the frost). LSD values are for comparisons of kernel maturity stages within years.

At harvest time, two subsamples of five uniform plants were hand harvested from each plot. The first subsample was chopped with a stationary brush chipper to < 1-in. particles, and weighed. After mixing, a 2 lb subsample was retained for DM determination and quality analysis. The second subsample was separated into ear and stover portions before weighing, chopping, and subsampling. A 0.5 lb sample of kernels was taken from the central portions of each ear for grain DM determination. Subsamples were dried in a forced air dryer at 140°F and ground to pass a 0.034-in. screen. The remaining plants were harvested from the plot and weighed. All subsample weights were combined to determine whole plant yield.

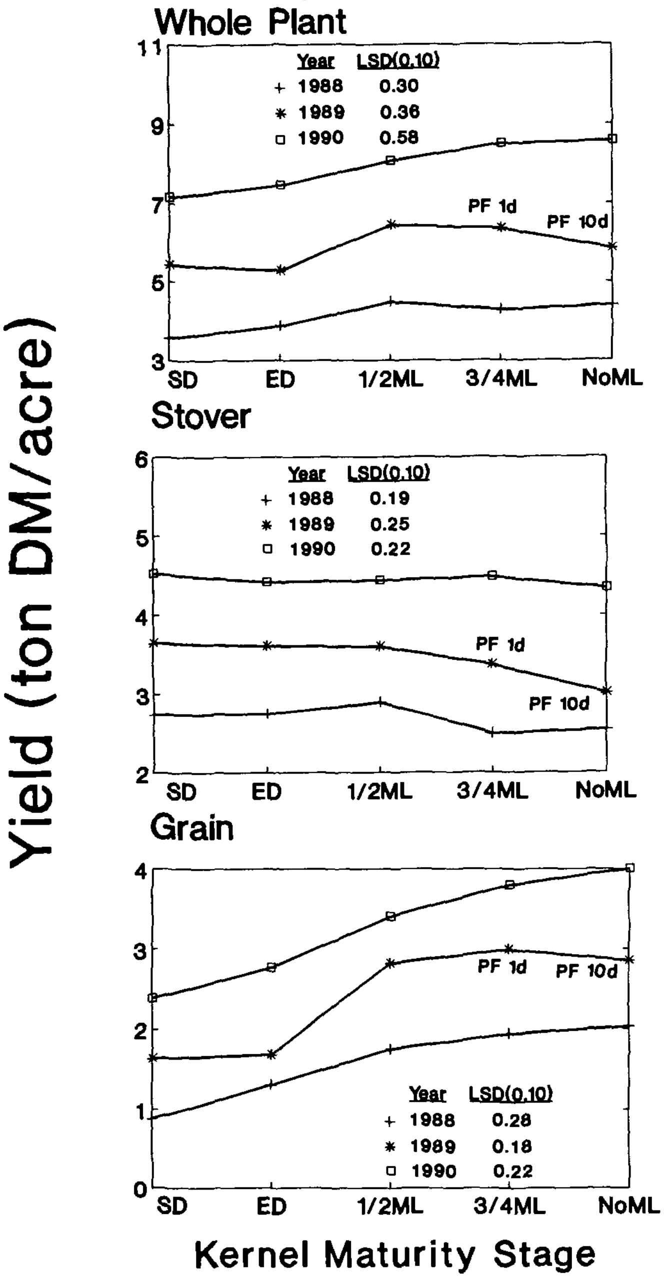

Fig. 2. Dry matter (DM) yield of whole plant, stover, and grain at soft dough (SD); early dent (ED); and 1/2, 3/4, and no milkline (ML) kernel stages. Values are averaged across four hybrids from 1988 to 1990. Post-frost harvests in 1989 are indicated by PF 1 d (harvested 1 d after the frost) and PF 10 d (harvested 10 d after the frost). LSD values are for comparisons of kernel maturity stages within years.

Neutral detergent fiber and ADF concentrations were determined on whole plant and separated stover samples by the sequential analysis procedure of Robertson and Van Soest (1981), with modifications. The modifications were a reduction in sample size to 0.018 oz and treating samples with 0.0034 oz of α-amylase (Sigma Chemical Co., St. Louis, MO, no. A-5426) during refluxing in neutral detergent solution and again during sample filtration.

In vitro dry matter disappearance was determined by a modification of the method described by Goering and Van Soest (1970). The 48 hr fermentation was performed in centrifuge tubes according to Marten and Barnes (1980) except that buffer and mineral solutions described by Goering and Van Soest were used. Undigested residue was refluxed in neutral detergent solution with the α-amylase step as described above. Rumen fluid was collected from a rumen canulated Jersey cow (*Bos taurus*) fed an alfalfa hay diet.

Total N concentrations of forage samples were deter-

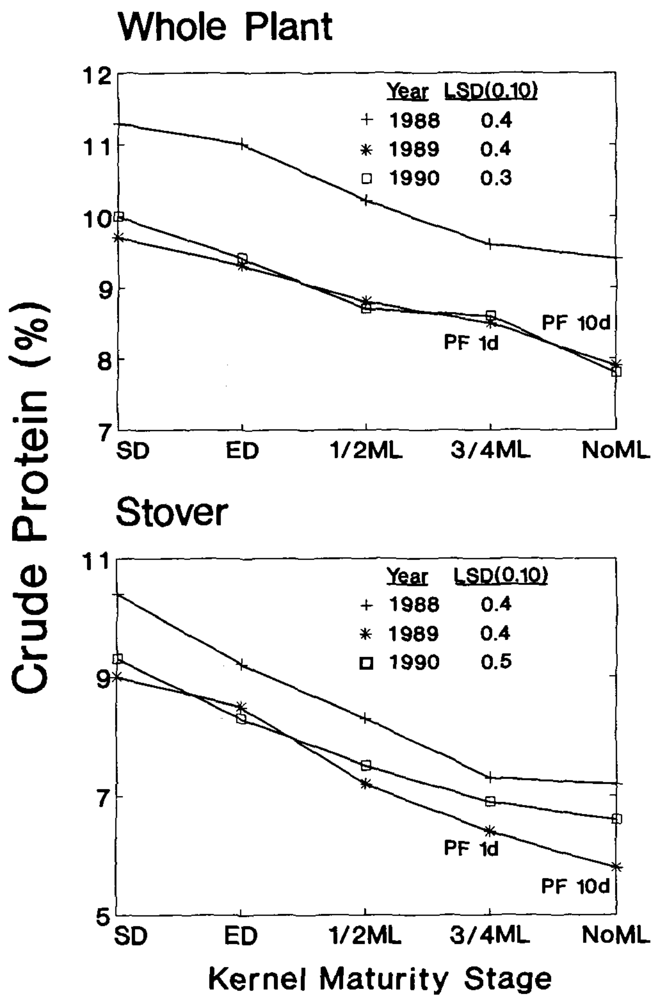

Fig. 3. Crude protein concentration of whole plant and stover at soft dough (SD); early dent (ED); and 1/2, 3/4, and no milkline (ML) kernel stages. Values are averaged across four hybrids from 1988 to 1990. Post-frost harvests in 1989 are indicated by PF 1 d (harvested 1 d after the frost) and PF 10 d (harvested 10 d after the frost). LSD values are for comparisons of kernel maturity stages within years.

mined by the micro-Kjeldahl procedure of Bremner and Breitenbeck (1983), with the salicylic acid modification described by Bremner (1965) for recovery of nitrate. Crude protein concentration was estimated by multiplying total N by 6.25.

Analysis of variance was computed for data separately for each year because of variable environmental conditions among years. Treatment mean comparisons were made using the least significant difference (LSD) test (Steel and Torrie, 1980) at the $P = 0.10$ level.

RESULTS AND DISCUSSION

Seasonal precipitation varied dramatically from 1988 to 1990, resulting in large differences in corn performance among years. Total seasonal (May to September) precipitation was 13.7, 14.9, and 21.8 in. for 1988, 1989, and 1990 respectively, compared with a 30-yr average of 20.4 in. Average air temperature for May through September was 5.1, 1.4, and 9.4°F above normal for 1988, 1989, and 1990, respectively. In 1989 and 1990, frost occurred before the No ML kernel maturity stage (KMS) was reached. Because of this year-to-year variability, combined analysis across years was not performed and individual year data are presented. In this study, the four hybrids were selected based on diversity of genetics. Although some hybrid × KMS interactions were detected statistically, they are limited, inconsistent among years, and would not change the overall conclusions of this study.

Dry Matter Content

Whole plant and stover DM content differences were found among hybrids in 1989 and 1990 (Table 1), but kernel DM content differences were not found among hybrids in any year of the study. In each year, LH82 × LH145 and Pioneer brand 3790 reached each kernel maturity stage several days later than CM105 × W182BN and A554 × CM105 and had average whole plant and stover DM contents about 2 percentage units higher than the other two hybrids. Although there were main effect

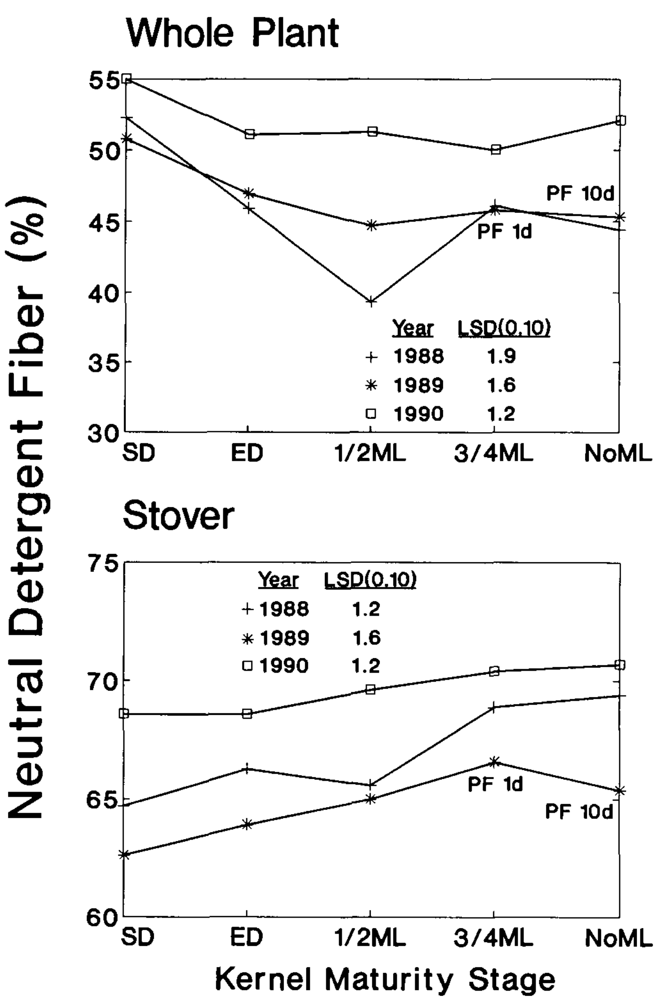

Fig. 4. Neutral detergent fiber concentration of whole plant and stover at soft dough (SD); early dent (ED); and 1/2, 3/4, and no milkline (ML) kernel stages. Values are averaged across four hybrids from 1988 to 1990. Post-frost harvests in 1989 are indicated by PF 1 d (harvested 1 d after the frost) and PF 10 d (harvested 10 d after the frost). LSD values are for comparisons of kernel maturity stages within years.

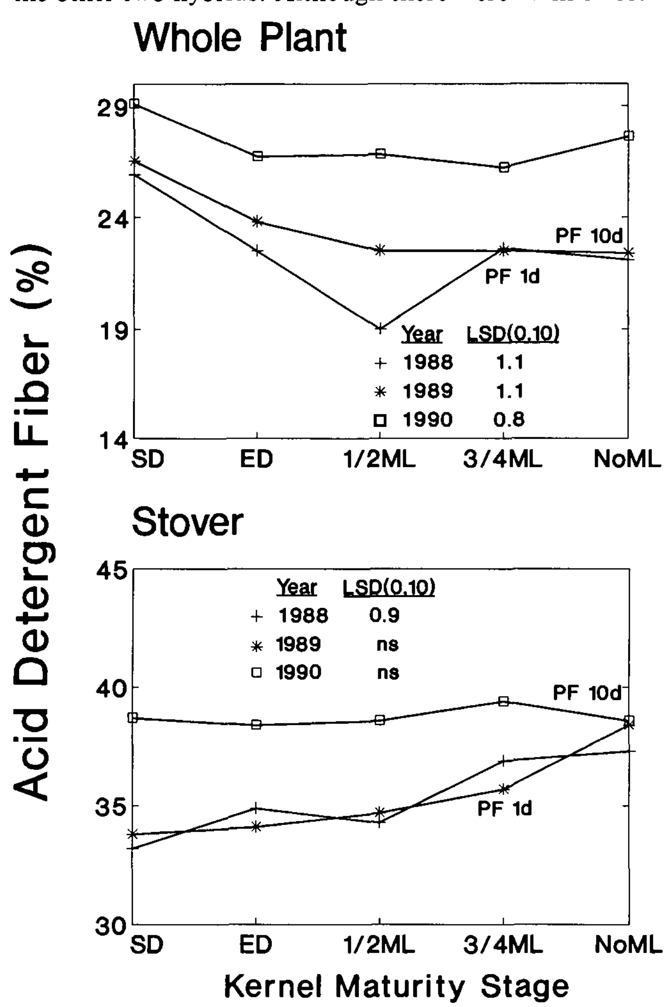

Fig. 5. Acid detergent fiber concentration of whole plant and stover at soft dough (SD); early dent (ED); and 1/2, 3/4, and no milkline (ML) kernel stages. Values are averaged across four hybrids from 1988 to 1990. Post-frost harvests in 1989 are indicated by PF 1 d (harvested 1 d after the frost) and PF 10 d (harvested 10 d after the frost). LSD values are for comparisons of kernel maturity stages within years.

hybrid differences and hybrid × KMS differences for whole plant and stover DM content, the magnitudes of these differences were small, varying at most by 3 percentage units within a kernel stage and year. Crookston and Kurle (1988) also found only small hybrid differences in plant DM content at kernel ML stages.

The range in DM content among years for whole plant and stover was greater than the range between hybrids, with a range of up to 7 percentage units within some KMS (Fig. 1). This yearly variation probably was related to large seasonal precipitation differences and to frost after the 1/2 ML stage in 1989. At the 1/2 ML stage, stover and whole plant DM contents were about 5 percentage units higher in the low rainfall years (1988 and 1989) than in 1990. Although variation existed among years and hybrids, the kernel ML indicated when the whole plant was at an ensilable DM content, since whole plant water content at both the 1/2 ML and 3/4 ML stages was within the acceptable 30 to 40% range (Lusk, 1978) in all years of the study.

Dry matter content of whole plant, stover, and ker-

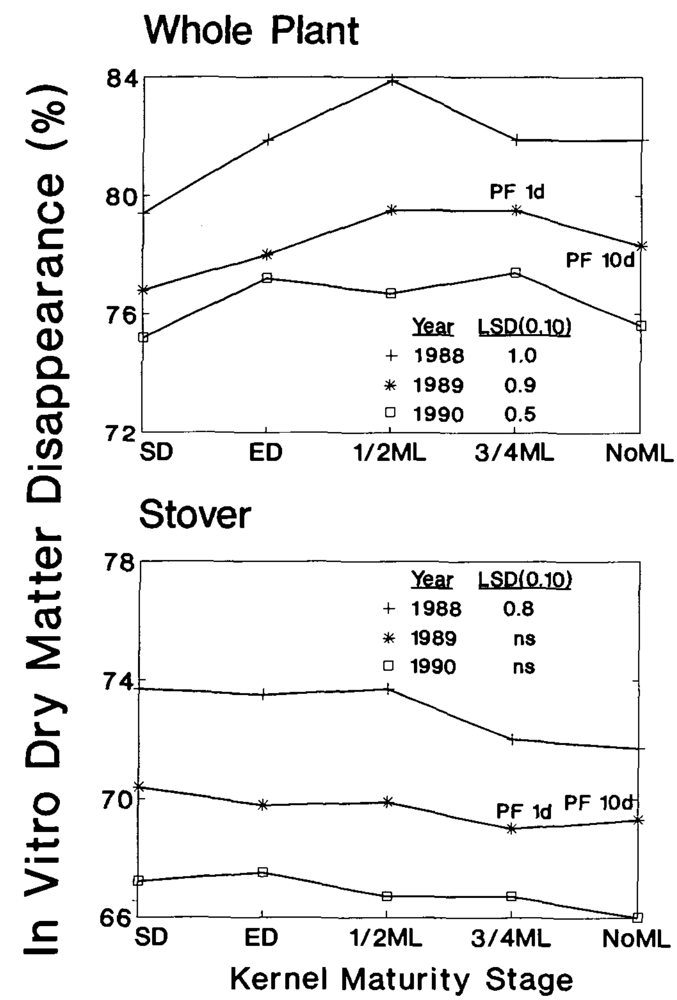

Fig. 6. In vitro dry matter disappearance of whole plant and stover at soft dough (SD); early dent (ED); and 1/2, 3/4, and no milkline (ML) kernel stages. Values are averaged across four hybrids form 1988 to 1990. Post-frost harvests in 1989 are indicated by PF 1 d (harvested 1 d after the frost) and PF 10 d (harvested 10 d after ther frost). LSD values are for comparisons of kernel maturity stages within years.

nels increased with each successive KMS (Fig. 1). Kernel DM content increased at the highest rate, gaining nearly 1 percentage unit per day, while whole plant and stover had slower rates of about 1/2 percentage unit per day over the 30 d time period.

In 1989, corn plants were frozen shortly after the 1/2 ML stage. Harvest delay of 10 d after the frost resulted in a high whole plant DM content. Whole plant DM content increases averaged 0.58 percentage units per day from 1/2 ML to No ML for unfrosted corn (1988, 1990), and 1.07 percentage units per day from 1/2 ML to PF 10 d for frosted corn (Fig. 1). This is in contrast to Major and Schaaje (1985), who found that frost did not accelerate corn whole plant drydown rates. Rates of kernel DM content gain averaged 0.77 percentage units per day from 1/2 ML to No ML for unfrosted corn (1988, 1990), and 0.79 percentage units per day from 1/2 ML to PF 10 d for frosted corn (Fig. 1). Hicks et al. (1976) found no differences in grain drydown rates among various simulated frost treatments and normally maturing corn grain.

Kernels at 1/2 ML consistently contained 60% DM, which agrees with Afuakwa and Crookston (1984) and Hunter et al. (1991). In addition to indicating optimum DM content for whole plant silage harvest, the kernel ML position is related to kernel DM content across the optimum range of DM contents for ensiling shelled corn. At 3/4 ML, grain contained an average of 65% DM, which would be adequate for properly ensiling shelled corn (Faber et al., 1989).

The time span between KMS averaged 5 d between SD and ED, 12 d between ED and 1/2 ML, 6 d between 1/2 ML and 3/4 ML, and 7 d between 3/4 ML and No ML. Crookston and Kurle (1988) in Minnesota also reported a span of 13 d between 1/2 ML and No ML, while Hunter et al. (1991) in Kentucky found 16 d between these stages.

Yield

Yields of whole plants and plant parts were largely influenced by season, with average whole plant yield ranging from 4.1 ton DM/acre in the 1988 drought to 7.9 ton DM/acre in 1990. Grain yields at No ML ranged from 75 to 95 bu/acre among hybrids in 1988 and from 150 to 175 bu/acre in 1990.

In each year, whole plant yield (Fig. 2) reached a maximum at approximately 1/2 ML. No further significant changes were measured after 1/2 ML except at the PF 10 d sample date in 1989, when whole plant yield decreased. Stover yield was greatest at the SD stage of maturity and only showed a significant decline between 1/2 ML and 3/4 ML in 1988 and between the PF 1 d and PF 10 d sample dates in 1989. Grain yield reached a maximum at about 3/4 ML. These findings are similar to Cummins (1970), Caldwell and Perry (1971), Weaver et al. (1978), and Daynard and Hunter (1975), which corresponds to 1/2 ML in this study. Hunter et al. (1991) concluded that 3/4 ML represents a useful and reliable indicator of physiological maturity as measured by ^{14}C seed uptake, which concurs with the results of this study. Our data suggest that whole plant harvest can begin at

1/2 ML, and grain harvest for high moisture ear corn can begin at 3/4 ML without a reduced yield potential.

Forage Quality

Corn grown under the low-yield drought conditions in 1988 generally had higher whole plant and stover forage quality than that in 1989 and 1990 (Fig. 3 to 6). Average CP concentration (Fig. 3) was highest in 1988 at 10.3% for whole plants and 8.5% for stover, and was at more typical levels in 1989 and 1990, averaging 9.0% for whole plants and 7.7% for stover. Both ADF and NDF were generally lower for 1988 and 1989, when whole plant and stover yields were lowest (Fig. 4 and 5). There was also considerable variation for IVDMD among years, with a tendency for increased digestibility of whole plant and stover in years with lower yields (Fig. 6). Hybrid differences for forage quality were limited and no consistent trends were detected among years.

Crude protein concentration declined rapidly with increasing maturity, averaging a drop of 2 percentage units from SD to No ML for whole corn plants and 3 percentage units for stover (Fig. 3). Decreasing CP concentration appears to be the result of continued carbon assimilation (as indicated by increasing yield), even though N uptake probably was completed, thereby diluting plant N concentration. Stover fiber concentration increased an average of 3.2 NDF and 2.9 ADF percentage units during the period from SD to No ML (Fig. 4 and 5). Whole plant fiber concentration generally declined from SD to 1/2 ML and then plateaued after 1/2 ML (Fig. 4 and 5). Decreases in whole plant fiber levels from SD to 1/2 ML averaged 7.6 NDF and 4.4 ADF percentage units. In each year of the study, the highest level of whole plant digestibility occurred during the period from ED to 3/4 ML, with a tendency for lower digestibility at SD and No ML (Fig. 6). The average magnitude of whole plant digestibility differences across maturity stages ranged about 3 percentage units from minimum to maximum. Stover digestibility differences among kernel maturity stages occurred only in 1988 (Fig. 6).

These data agree with findings of Cummins (1970), in which digestibility of corn whole plants increased until 35 to 40% DM content and then plateaued. Data published by Hunt et al. (1989) indicate a larger change in digestibility, especially of stover, as the ML progresses. This difference may be attributable to the length of digestion time since their measurement was based on a 24 h fermentation compared with the 48 h fermentation period for this study. The longer digestion time may have narrowed differences in degradability, although the 3 percentage unit change in degradability is quite important given the extensive time of incubation.

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