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Yield and quality of three corn hybrids as affected by broiler litter fertilization and crop maturity

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Abstract

Specific hybrids, fertilization and maturity impact yields and nutrient quality of corn silage. To address these effects, three corn hybrids (*Zea mays* L.) (Pioneer 3136, 3140, 3154) with five N fertilization (F) treatments were planted for 2 years and harvested at approximately 1/3, 2/3 or 100% milk line in a split–split plot design. Main treatments were No-F, 4.5, 9.0, 13.5 (Year 1) or 18.0 (Year 2) Mg ha^{-1} of broiler litter (BrL) or 202 kg ha^{-1} of NH_4NO_3. At harvest, milk lines and whole plant, stover and grain yields were determined. Whole plant and stover portions were chopped and subsampled for subsequent nutrient component and in vitro dry matter disappearance (IVDMD). Milk line advanced rapidly, especially during Year 1 that was a dry year. Whole plant yields were greatest for the 13.5/18.0 BrL treatments with no difference between 9.0 BrL and NH_4NO_3 treatments. Nutrient content varied with fertilizer treatment and year; during Year 1, NH_4NO_3 treatments had greater CP and lower ADF values, but the 13.5/18.0 BrL had the greatest CP content in Year 2, a wetter year. Whole plant IVDMD values were greater for NH_4NO_3 than the 13.5/18.0 BrL treatments during both years, but this occurred only during Year 1 for stover. Corn hybrid did not consistently affect yield, but during both years stover ADF was lower and IVDMD was higher for Hybrid 3136. These advantages existed in the whole plant only during Year 1. Increased maturity enhanced grain and whole plant yield, but effects on nutrient quality were variable. Appropriate application rates of BrL provide comparable yields to commercial fertilizer without an adverse effect on nutrient composition, although digestibility may be reduced.

Keywords: Corn silage; Nutrient analyses; Fertilization; Broiler litter

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1. Introduction

Corn (*Zea mays* L.) silage is a popular forage source for ruminants due to its palatability, energy content, yield and ease in feeding. Silage digestibility varies among hybrids (Hunt et al., 1992; Roth et al., 1970; Roth, 1994; Vattikonda and Hunter, 1983) and should be given more consideration because of its effect on feed value and animal performance. The non-grain (stover) portion of the corn plant accounts for about one-half of silage yield and has a large impact on the nutrient supply. Greater variation may occur in stover digestibility than in the whole plant (Roth, 1994; Vattikonda and Hunter, 1983). The relationship between stover and whole plant quality may be high (Vattikonda and Hunter, 1983; Deinum and Bakker, 1981), but this does not necessarily occur (Roth, 1994).

Proper ensiling procedures, including the maturity at ensiling, can drastically influence the nutritive value of silage. Maximum silage yield normally occurs at 30–35% DM (Wiersma et al., 1993). Ensiling at this maturity has improved nutrient availability in some cases (Cummins, 1970), but not in others (Daynard and Hunter, 1975).

In an attempt to optimize nutrient value, ensiling at specific kernel maturity as measured by the milk line (ML) is often recommended. Ensiling corn at 1/2 to 3/4 ML is often considered optimum for yield, DM content and quality traits (Hunt et al., 1989; Wiersma et al., 1993). Ganoe and Roth (1992) reported harvesting at 1/2 ML corn might be too dry for optimum quality. This could be critical with the fast dry-down of corn in hot climates.

Nitrogen fertilization increases yield and protein content and decreases fiber content (Cherney and Cox, 1992; Keeney et al., 1967). Feed digestibility may (Cherney and Cox, 1992; Robinson and Murphy, 1972) or may not (Keeney et al., 1967) be enhanced. Livestock waste, especially broiler litter (BrL), can serve as an economical fertilizer source (Ketcheson and Beauchamp, 1978; Oyer, 1990; Kingery et al., 1993). However, the effect of livestock waste on plant digestibility as related to yield is not known.

The objective of this study was to determine effects of poultry litter fertilization and corn hybrid upon yields, nutrient composition and digestibility when harvesting at different maturities.

2. Materials and methods

2.1. Location

Three corn hybrids (H), each receiving five fertilization (F) treatments, were planted for 2 years and each harvested at three maturities (M) from plots (15.2 m × 6.1 m) with Compass sandy loam soil sited at 32°22′N, 85°52′W with an altitude of 64 m and 1300 mm mean annual precipitation. US National Weather Service Station measurements showed that more precipitation occurred during March of Year 1 than Year 2 (Table 1). Precipitation was much less during the growing period (June and July) of Year 1 (93 mm) compared to Year 2 (238 mm) with similar precipitation to the 30-year average (244 mm) for these months. Plots were irrigated 11 times (154 mm) in Year 1 and twice (24 mm) in Year 2. Growing degree units (GDU, °C) were calculated as [(daily maximum + daily

Table 1
Mean air temperature, precipitation and irrigation during the growing seasons of the corn study

Month	Year 1		Year 2	
	Temperature[a] (°C)			
	Maximum	Minimum	Maximum	Minimum
March	(24.1)	(7.6)	21.3	5.9
April	(24.3)	(9.2)	23.4	13.2
May	28.1	14.7	28.4	18.1
June	32.8	18.8	30.3	19.4
July	33.6	20.6	32.6	21.9
August	35.0	20.6	(31.5)	(20.9)
Mean	32.4	18.7	27.2	15.7
	Precipitation[a] (mm)			
March	(277)		93	
April	(74)		86	
May	116		123	
June	42		161	
July	51		69	
August	60		(96)	
Total	269		532	
	Irrigation[b] (mm)			
March	–		–	
April	–		–	
May	–		–	
June	70 (5)		24 (2)	
July	42 (3)		–	
August	42 (3)		–	
Total	154 (11)		24 (2)	

[a] Values in parentheses indicate months before planting or after harvest.
[b] Values in parentheses indicate the number of irrigations.

minimum temperatures)/2) − 10] with upper/lower limits of 30 and 10 °C for daily maximum and minimum temperatures, respectively.

2.2. *Cultivation*

Rains delayed planting (2 May) about 3–4 weeks beyond normal during Year 1. Soil pH was 5.7 and plots received 1.7 Mg ha^{-1} of dolomitic lime 1 week before planting. Seed were planted at 83,950 seed ha^{-1} and 22 days later all plots were thinned to 69,000 plants ha^{-1}. The mix of all fertilizer sources supplied (kg ha^{-1}) K, 25; Mg, 15; S, 32; P, 10; Zn, 5.8 and B, 3. In Year 2, the same plots were planted on 27 March with 93,800 seeds ha^{-1} and cultivated and thinned to 69,000 plants ha^{-1} at 28-day post-planting. Soil pH was 6.5; the fertilizer mix was applied as in Year 1. Insect control was with 14.9 kg ha^{-1} of Carbofuradan (2-3-dihydro-2,2-dimethyl-4-benzofuranyl methylcarbamate) in the furrow. Weed control was with yearly applications at planting of 1.2 kg ha^{-1} of metolachlor [2-chloro-2′,6′-diethyl-*N*(anthoxymethyl) acetanilide] plus 1.2 kg ha^{-1} of Atrazine (2-chloro-4-ethylamino-6-isopropylamino-*S*-triazine).

3. Experimental design

The experimental design was a split–split plot arrangement. Main plots were F treatments, subplots were hybrids and sub-subplots were maturities (M1, M2 and M3). Plots (4 replications) were eight 76.2 cm wide × 15.2 m rows. In Year 1 main plot were treatments of (1) No-F, (2) low (L)-BrL: 4.5 Mg ha^{-1}, (3) medium (M)-BrL: 9.0 Mg ha^{-1}, (4) high (H)-BrL: 13.5 Mg ha^{-1}, and (5) ammonium nitrate (NH_4NO_3) commercial fertilizer (202 kg ha^{-1}). Treatments were the same in Year 2 except H-BrL plots received 18.0 Mg ha^{-1}. The BrL was obtained from a commercial broiler operation just prior to planting. Broiler litter was analyzed for DM at 105 °C for 24 h. Ash content was analyzed according to AOAC (1990) Official Method 942.05 and organic matter calculated as the difference between ash content and initial weight of the sample. Total N was determined by dry combustion with a LECO CHN-600 analyzer (LECO Corp., St. Joseph, MI). Nitrate-N was measured by colorimetric procedures (Keeney and Nelson, 1982) on a Lachat autoanalyzer (Lachat QuickChem Systems, Milwaukee, WI). Mineral analyses were by inductively coupled plasma (ICP) spectrophotometer. The BrL used in the 2 years had a considerable difference in composition (Table 2) but were within reported ranges

Table 2
Composition of broiler litter and dry matter (DM), total nitrogen (TN) and NH_4 application from broiler litter

Composition	Year 1	Year 2
DM (g kg^{-1})	708.00	841.00
OM (g kg^{-1})	597.00	691.00
Total N (g kg^{-1})	39.7	42.6
Inorganic N (mg kg^{-1} in DM)	3212.00	5440.00
P (g kg^{-1} of DM)	10.2	18.1
K (g kg^{-1} of DM)	29.4	24.0
Ca (g kg^{-1} of DM)	12.1	23.8
Mg (g kg^{-1} of DM)	5.7	5.4
S (g kg^{-1} of DM)	8.6	6.1
Cu (mg kg^{-1} in DM)	25.8	332
Fe (mg kg^{-1} in DM)	42.8	599
Mn (mg kg^{-1} in DM)	119	369
Zn (mg kg^{-1} in DM)	50.8	337
Al (mg kg^{-1} in DM)	–[a]	1682
B (mg kg^{-1} in DM)	55.2	–[a]

Application rate	Year 1			Year 2		
	DM	TN	NH_4	DM	TN	NH_4
Fertilization[b] (kg ha^{-1})						
0	0	0	0	0	0	0
L-BrL	3172	125	10.0	3768	160	18.3
M-BrL	6344	250	19.9	7536	320	36.6
H-BrL	9516	375	29.9	15072	640	73.2

[a] Not analyzed.
[b] L-BrL = 4.5 Mg BrL ha^{-1}; M-BrL = 9.0 Mg BrL ha^{-1}; H-BrL = 13.5 Mg BrL ha^{-1} in Year 1 = 18.0 Mg BrL ha^{-1} in Year 2.

(Stephenson et al., 1990). Higher DM and N in the BrL for Year 2 than Year 1 resulted in greater N application on plots receiving BrL in the second year (Table 2). The BrL was applied and rotavated into the soil the day prior to planting each year. Subplots were Pioneer brand hybrids (3136, 3140 and 3154) with relative maturities of 120, 118 and 119 days and estimated GDU to physiological maturity of 2931, 2860 and 2860, respectively (Pioneer Hi-Bred, International Inc., 1995). Kernel maturity at harvest (sub-subplots) were intended for a ML of 1/3 and 2/3 down from the top of the kernel for M1 and M2, respectively, and at kernel black layer (BL) formation for M3.

3.1. Harvesting and sampling

At harvest 6–8 ears per plot were broken in the middle and the total and ML length determined on the endosperm side of 24 kernels. The ML was determined by probing the boundary between the liquid and solid endosperm with a sharp awl, measuring the line from the top of the kernel and expressing this distance as a fraction of the total length of the kernel.

Two 0.0004 ha samples were harvested from the inner rows of each plot to determine yield (35% DM basis for whole plant and stover) and forage quality. One sample was weighed intact (whole plant) and approximately one-half chopped through a shredder/chipper (Tomahawk Model #11385). The chopped sample was mixed, a subsample (0.75–1.50 kg) placed in a pre-weighed cotton sack (30.5 cm × 40.6 cm) and wet weight determined. Samples were dried to a constant weight at 54–60 °C for 24–48 h.

Ear and stover portions were separated on a second sample. A portion of ears was placed intact in cotton sacks for subsequent weighing and drying to determine grain yield (85% DM basis). The stover was chopped and handled as described for the whole plant.

After drying, stover and whole plant samples were stored at 4 °C and subsequently ground (3 mm) through a Comminuting Machine (Model D, W.J. Fitzpatrick Company, Chicago) and a Wiley mill (1 mm). A commercial laboratory (Livestock Nutrition Laboratory Services, Columbia, MO) analyzed whole plant and stover samples according to AOAC (1990) methods for DM (935.29) and CP (988.05). Non-sequential acid detergent fiber (ADF) and neutral detergent fiber (NDF) analyses were according to Van Soest et al. (1991). Heat-stable amylase was used with the NDF assay, but sodium sulfite was not. Values include residual ash. Whole plant and stover in vitro dry matter digestibilities (IVDMD) were determined (Tilley and Terry, 1963) on the H-BrL and NH_4NO_3 fertilization treatments.

3.2. Statistical analysis

Statistical analysis of the data was with the general linear models procedure (SAS, 1989). Yield and nutrient content data were analyzed statistically as a split–split-plot design with five fertilization (F) treatments (main plots), three hybrids (H; sub-plots), three maturities (M; sub-subplots) and four replications (R). Yield and nutrient content data were run with year in the model resulting in a number of significant year interactions for several variables. Therefore, data are presented by year. Within each year, two-way interactions existed, but most of these were omitted as they were due to minor shifts in ranking that had little practical or biological significance.

Means were separated by Fisher's Protected LSD; unless otherwise noted, all statistical tests were performed at the $\alpha = 0.05$ level of significance. Stepwise regression also was used to quantify the effect of milk line on the yield and nutrient content of whole plant and stover.

4. Results and discussion

4.1. Growth

Neither fertilization nor hybrid had a consistent effect on ML during both years (Table 3). The ML for BrL treatments was more advanced than either the No-F or the NH_4NO_3 treatments. During Year 2, the cooler–wetter season, the ML was less for the H-BrL than the L-BrL and M-BrL treatments. Thus, commercial fertilizer and consecutive large applications of BrL slowed maturity. The ML of H3140 was least advanced with H3136 most advanced in Year 1, but no hybrid difference existed in Year 2. The effect of H on maturity may be more prevalent during periods of drought stress than when moisture is ample.

Corn was harvested very close to the desired milk line values of 0.33 for M1 whereas the harvesting for M2 was slightly less mature than the targeted milk line (0.66). The M3 sampling was near the intended black line so ML were essentially 100% for all fertilizations and hybrids. Progression from M1 through M3 was very rapid during both years, but was more rapid in Year 1. Days to harvest were 92–96, 98–100 and 107 for M1, M2 and M3, respectively, in Year 1. Corresponding values were 104–105, 110 and 118–120 in

Table 3
Effect of fertilization, hybrid and maturity on kernel milk line[a]

Treatments	Milk line	
	Year 1	Year 2
Fertilization (F)	(mm solid endosperm)	(mm total kernel length)$^{-1}$
No-F	0.57 a	0.55 c
L-BrL	0.65 b	0.66 a
M-BrL	0.66 b	0.64 a
H-BrL	0.66 b	0.60 b
NH_4NO_3	0.62 c	0.56 c
LSD at $P < 0.05$	0.026	0.026
Hybrid (H)	(mm solid endosperm)	(mm total kernel length)$^{-1}$
3136	0.69 a	0.60
3140	0.58 c	0.60
3154	0.62 b	0.60
LSD at $P < 0.05$	0.020 c	ns
Maturity (M)	(mm solid endosperm)	(mm total kernel length)$^{-1}$
M1	0.33 c	0.31 c
M2	0.56 b	0.51 b
M3	0.99 a	0.98 a
LSD at $P < 0.05$	0.020	0.020

[a] Means with different letters within the same column differ.

Year 2. The hot dry weather in Year 1 provided little leeway in harvest time. Based upon regression equation calculations, movement from the dent stage (no ML) to the black line required 15.6 and 24.1 days in Years 1 and 2, respectively. The latter value is similar to the time reported for other geographic regions (Crookston and Kurle, 1988). Under practical conditions, the rapid movement of the ML would give little time for harvesting in hot weather if ensiling was postponed until the desired ML was attained. In addition, maturity would be attained early. Corn was planted 37 days later in Year 1 than Year 2, but plants reached desired maturity dates 7–13 days earlier in Year 1, most likely due to higher maximum temperatures. The cumulative GDU from planting through black layer harvest was slightly greater in Year 2 (1558 GDU) than Year 1 (1498 GDU), but the GDU accumulation proceeded more rapidly in Year 1. The cumulative GDU were similar to that considered normal for these hybrids.

4.2. *Yields*

Fertilization had a significant effect on grain, whole plant and stover yields (Table 4). Except for the No-F treatment, yields were greater in Year 1 than in Year 2. The combination of more rainfall, a high application (Table 2) and uptake of N (Table 5) would have influenced yields in Year 2. Carryover effect of F treatments, especially the BL applications, would affect yields. A significant pool of residual N for subsequent crops is associated with BL

Table 4
Effect of fertilization, hybrid and maturity of corn on grain, whole plant and stover yield and grain:stover ratio[a]

Treatments	Year 1				Year 2			
	Grain (MT ha^{-1})[b]	Whole plant (MT ha^{-1})[c]	Stover (MT ha^{-1})[c]	G:S[d]	Grain (MT ha^{-1})[b]	Whole plant (MT ha^{-1})[c]	Stover (MT ha^{-1})[c]	G:S[d]
Fertilization (F)								
No-F	1.1 d	18.1 d	13.4 d	0.25 c	1.3 e	13.2 d	9.9 e	0.33 d
L-BrL	3.3 c	29.6 c	19.5 c	0.51 b	5.0 d	34.7 c	20.8 d	0.60 c
M-BrL	6.2 b	39.4 b	22.8 b	0.67 ab	8.8 c	53.1 b	28.0 b	0.78 b
H-BrL	6.6 a	43.0 a	25.5 a	0.64 ab	11.2 a	61.8 a	29.8 a	0.91 a
NH_4NO_3	6.4 a	38.8 b	21.7 b	0.73 a	9.3 b	54.0 b	25.3 c	0.91 a
LSD at $P < 0.05$	0.59	2.36	1.54	0.18	0.36	2.27	1.07	0.04
Hybrid (H)								
3136	4.4 c	31.8 b	20.8 b	0.54 ab	6.7 b	41.9 b	22.6 b	0.66 b
3140	4.7 b	35.8 a	22.4 a	0.48 b	7.2 a	43.9 a	24.0 a	0.68 b
3154	5.1 a	33.4 b	18.4 c	0.67 a	7.5 a	44.1 a	21.5 c	0.78 a
LSD at $P < 0.05$	0.45	1.83	1.19	0.14	0.28	1.76	0.83	0.03
Maturity (M)								
M1	4.2 c	32.3 b	21.1	0.47 b	6.3 c	42.3 b	23.5 a	0.61 c
M2	4.7 b	32.9 b	20.4	0.53 b	7.2 b	43.2 a b	22.2 b	0.74 b
M3	5.3 a	36.1 a	20.4	0.69 a	7.8 a	44.4 a	22.4 b	0.78 a
LSD at $P < 0.05$	0.45	1.83	1.19	0.14	0.28	1.76	0.83	0.03

[a] Means with different letters within the same column differ.
[b] Grain yield reported is metric tons per hectare at 85% DM.
[c] Whole plant and stover yields are metric tons per hectare at 35% DM.
[d] G:S ratio is grain:stover weight ratio on a DM basis.

Table 5
Nitrogen uptake[a] of corn stover and whole plant as affected by hybrid, harvest period, and fertilization

	Whole plant		Stover	
	Year 1	Year 2	Year 1	Year 2
Hybrid ($kg\ ha^{-1}$)				
3136	90.3	117.7	43.3	46.6
3140	102.6	123.9	50.1	55.4
3154	96.2	123.3	39.1	53.0
Maturity ($kg\ ha^{-1}$)[b]				
M1	93.2	120.4	48.2	57.6
M2	93.1	118.4	42.7	48.4
M3	103.6	126.2	41.9	49.4
Fertilization ($kg\ ha^{-1}$)[b]				
No-F	36.1 e	25.8 e	20.8 e	17.3 e
L-BrL	64.9 d	77.1 d	29.4 d	37.4 d
M-BrL	118.5 c	143.3 c	48.4 c	57.1 c
H-BrL	137.0 b	233.5 a	61.3 b	89.0 a
NH_4NO_3	156.3 a	182.9 b	69.5 a	72.0 b
LSD at $P < 0.05$	13.3	11.5	5.5	7.2
Fertilization ($g\ kg^{-1}$ of total N applied)[c]				
No-F	0	0	0	0
L-BrL	524	484	238	234
M-BrL	475	446	190	180
H-BrL	362	366	162	138
NH_4NO_3	773	904	346	355

[a] Nitrogen uptake = $g\ kg^{-1}$ N in whole plant (Table 6 or 7) × DM yield of whole plant (Table 4).
[b] Maturity: M1 = 1/3 milk line from top; M2 = 2/3 milk line from top; M3 = black layer.
[c] See Table 2.

applications (Huneycutt et al., 1988; Kingery et al., 1993). During the second year, N uptake ($kg\ ha^{-1}$) by the whole plant was 29% less and whole plant yield was about 27% less on the No-F treatment. This contrasted with the L-BrL, M-BrL and NH_4NO_3 treatments that had 17–21 and 17–39% greater N uptake and whole plant yields, respectively (Tables 4 and 5).

Use of low amounts of BrL was beneficial as this treatment yielded more than the No-F treatments. Grain yields were slightly greater for the NH_4NO_3 than the M-BrL treatment, but the whole plant and stover yields did not differ during Year 1 for those two treatments. During Year 2, stover yield was greater for the M-BrL treatment than for the NH_4NO_3 treatment, but greater grain yield for the NH_4NO_3 treatment resulted in similar whole plant yields. Stover and whole plant yields were greater during both years for the H-BrL treatment than for other treatments. Grain yield did not differ between the NH_4NO_3 and H-BrL treatments in Year 1, but the latter treatment produced a greater yield in Year 2. This difference could be attributed to more total N application (640 $kg\ ha^{-1}$) and N uptake (Table 5) from BrL in Year 2 than Year 1 (375 $kg\ ha^{-1}$), whereas the NH_4NO_3 application was the same during both years. Thus, under these irrigated conditions, corn yields were best with applications of 13.5 and 18 Mg litter ha^{-1} (H-BrL), or more appropriately, a minimum of 375 kg N ha^{-1}.

More N was applied with the L-BrL treatment in this study than was used (49–63 kg N ha^{-1}) by Oyer (1990) in a 3-year study to determine the effects of poultry manure applications on maize yields and nutrient uptake and on soil fertility. In that study, maize grain yields were consistently higher with poultry manure in both optimal and inadequate rainfall years, even when rates of inorganic N were higher than those recommended. In the current study, L-BrL did not produce yields equivalent to 202 kg N ha^{-1} supplied as NH_4NO_3. Based upon yield, M-BrL (4.5 Mg ha^{-1} containing 250–320 kg N ha^{-1}) was apparently equivalent to the NH_4NO_3 rates used.

There were no consistent yield advantages for any one hybrid. Hybrid 3154 had higher grain yields but not total forage during the first year, but this did not occur in the second year. Hybrid 3140 had greater stover yields during both years than did the other two hybrids, but neither whole plant nor grain yields were consistently greater for this hybrid.

As expected, grain yield increased with maturity. Whole plant yields increased at the third maturity over M1 and M2 due to the increase in grain content as stover yields increased minimally with maturity from M1 to M3. The inconsistent increase in yield of whole plant differs from that of Xu et al. (1995) who reported increased yields from milk stage to 1/2 ML and black layer.

The grain to stover ratios (G:S) did not differ for the M-BrL, H-BrL and NH_4NO_3 treatments in Year 1 nor were there any differences between H-BrL and NH_4NO_3 treatments in Year 2. The G:S were greatest for H3154 during Year 2 and greater than H3140 in Year 1. This was due to a combination of less stover and a high grain yield for H3154. The G:S increased with maturity during both years.

4.3. Nutrient content

4.3.1. Dry matter

Plants were drier in Year 1 than Year 2 regardless of F-treatment, hybrid or maturity (Tables 6 and 7). In Year 1, whole plant DM content increased with fertilization but this trend was not consistent in Year 2. The increase in whole plant DM would relate to greater grain maturity and DM as there was not a consistent increase in stover DM during either year.

During Year 1, H3154 whole plant samples were driest followed by H3136 and H3140. In Year 1, the stover DM followed the same pattern as that of the whole plant for the different hybrids. This did not occur in Year 2 as stover DM for the different hybrids did not differ. The difference in whole plant DM was due to differences in DM of the grain.

Whole plant and stover DM increased with advancing maturity with considerable differences between the two years. The DM content at M2 and M3 in Year 2 was similar to other reported values (Xu et al., 1995) for this maturity. However, using ML as a basis for timing ensiling could result in improper silage moisture because DM content at different ML maturities varied widely between years. Year 1 corn, cut at M2, was dry compared to the range normally recommended (30–40% DM) for ensiling whereas corn cut at a similar maturity in Year 2 was within the normal range. Correlations between whole plant DM and yields (whole plant and grain) were significant (Table 8) but not between stover DM and yields (Table 9).

Table 6
Effect of fertilization, hybrid and maturity of corn on nutrient content (g kg^{-1} of DM) of whole plant[a]

Treatments	Year 1					Year 2				
	DM[b] (g kg^{-1})	CP	ADF	NDF	IVDMD[c]	DM (g kg^{-1})	CP	ADF	NDF	IVDMD[c]
Fertilization (F)										
No-F	394.1 e	35.4 c	344 a	664 a		345.4 d	34.9 d	332 a	645 a	
L-BrL	447.3 d	39.6 c	346 a	646 b		381.3 b	39.8 d	338 a	612 b	
M-BrL	470.5 c	53.8 b	322 b	605 c		389.6 ab	48.0 c	322 b	574 c	
H-BrL	489.2 b	56.3 b	314 b	595 c	676 b	360.8 c	67.6 a	297 c	537 d	654 b
NH_4NO_3	514.1 a	72.0 a	306 c	592 c	701 a	401.8 a	60.4 b	285 d	536 d	725 a
LSD at $P < 0.05$	17.7	4.00	13.6	23.0		14.4	3.2	12.4	22.3	
Hybrid (H)										
3136	454.8 b	50.7	326 b	620	732 a	375.4 b	50.2	320 a	584 a	690
3140	423.7 c	51.1	343 a	628	659 b	364.8 b	50.4	327 a	592 a	689
3154	510.6 a	51.5	312 b	615	675 b	387.2 a	49.9	298 b	567 b	689
LSD at $P < 0.05$	13.7	3.1	10.5	17.8		11.2	2.5	9.6	17.3	
Maturity (M)										
M1	387.0 c	51.6	336 a	638 a	651 b	322.9 c	50.8	316 a	576	717 a
M2	460.8 b	50.4	322 b	609 b	757 a	369.4 b	48.9	305 b	574	685 b
M3	541.2 a	51.3	322 b	615 b	658 b	435.1 a	50.8	323 a	592	667 c
LSD at $P < 0.05$	13.7	3.1	10.5	17.8		11.2	2.5	9.6	17.3	

[a] Means with different letters within the same column differ.
[b] DM content at harvest.
[c] Values determined only for H-BrL and NH_4NO_3 treatments.

Table 7
Effect of fertilization, hybrid and maturity of corn on nutrient content (g kg^{-1} of DM) of stover[a]

Treatments	Year 1					Year 2				
	DM[b] (g kg^{-1})	CP	ADF	NDF	IVDMD[c]	DM[b] (g kg^{-1})	CP	ADF	NDF	IVDMD[c]
Fertilization (F)										
No-F	365.8 d	28.0 d	390 c	714 c		327.9 a	31.1 c	391 c	727 c	
L-BrL	394.3 c	27.2 d	427 b	754 b		326.7 a	32.1 c	437 a	761 a	
M-BrL	406.1 bc	37.1 c	442 a	769 ab		306.2 b	36.8 b	442 a	744 b	
H-BrL	418.1 b	42.5 b	436 b	771 a	554 b	260.4 c	53.0 a	428 b	724 c	556
NH_4NO_3	474.1 a	57.4 a	434 b	773 a	595 a	302.3 b	50.6 a	419 b	720 c	564
LSD at $P < 0.05$	15.0	3.1	12.2	19.5		13.4	5.0	10.6	16.7	
Hybrid (H)										
3136	404.4 b	37.2	413 c	742 b	655 a	308.5	36.8 c	427 b	737	570 a
3140	377.5 c	39.9	438 a	753 b	556 b	304.9	41.3 b	433 a	735	551 b
3154	453.1 a	38.0	426 b	774 a	557 b	300.7	44.0 a	411 c	734	557 b
LSD at $P < 0.05$	11.6	2.4	9.4	15.1		10.4	3.8	8.2	12.9	
Maturity (M)										
M1	343.5 c	40.8 a	414 c	731 c	557 b	268.0 c	43.7 a	412 b	721 b	585 a
M2	415.2 b	37.4 b	424 b	765 b	627 a	290.4 b	39.0 b	414 b	713 b	566 b
M3	477.4 a	36.7 b	439 a	773 a	545 b	355.8 a	39.4 b	443 a	772 a	530 c
LSD at $P < 0.05$	11.6	2.4	9.4	15.1		10.4	3.8	8.2	12.9	

[a] Means with different letters within the same column differ.
[b] DM content at harvest.
[c] Values determined only for H-BrL and NH_4NO_3 treatments.

Table 8
Correlation coefficients between various chemical constituents, yields, milk line, date of harvest and IVDMD of whole plant by year

	ADF	NDF	CP	WPY	GY	DM	ML	DH	IVDMD
Year 1									
ADF		0.85*	−0.55*	−0.44*	−0.47*	−0.45*	−0.15	−0.24*	−0.69*
NDF			−0.57*	−0.55*	−0.49*	−0.39*	−0.16*	−0.19*	−0.67*
CP				0.62*	0.63*	0.39*	0.001	0.005	0.54*
WPY (whole plant yield)					0.81*	0.47*	0.19*	0.12	−0.20
GY (grain yield)						0.50*	0.22*	0.18*	−0.21
DM (DM at harvest)							0.69*	0.74*	0.44
ML (milk line)								0.93*	−0.03
DH (date harvest)									0.08
IVDMD									
Year 2									
ADF		0.77*	−0.51*	−0.39*	−0.38*	−0.05	0.14	0.06	−0.57*
NDF			−0.63*	−0.62*	−0.61*	−0.03	0.12	0.08	−0.51*
CP				0.72*	0.74*	0.12	0.009	0.008	−0.003
WPY (whole plant yield)					0.96*	0.25*	0.07	0.05	−0.46
GY (grain yield)						0.27*	0.17*	0.16*	−0.74*
DM (DM at Harvest)							0.72*	0.72*	−0.01
ML (milk line)								0.95*	−0.47*
DH (date harvest)									−0.42
IVDMD									

Table 9
Correlation coefficients between various chemical constituents, yields, milk line, date of harvest and IVDMD of corn stover by year

	ADF	NDF	CP	SY	DM	ML	DH	IVDMD
Year 1								
ADF		0.84*	0.08	0.28*	0.36*	0.30*	0.25*	−0.22
NDF			0.04	0.12	0.50*	0.32*	0.35*	0.25
CP				0.37*	0.22*	−0.10	−0.13	−0.01
SY (stover yield)					0.12	0.03	−0.09	−0.002
DM (DM% at harvest)						0.66*	0.72*	0.23
ML (milk line)							0.93*	−0.10
DH (date harvest)								−0.13
IVDMD								
Year 2								
ADF		0.67*	−0.07	0.31*	0.32*	0.43*	0.31*	−0.61*
NDF			0.28*	−0.08	0.54*	0.50*	0.41*	−0.60*
CP				0.42*	−0.33*	−0.13	−0.11	−0.46
SY (stover yield)					−0.29	0.01	−0.06	−0.16
DM (DM% at harvest)						0.63*	0.60*	−0.41
ML (milk line)							0.95*	−0.72*
DH (date harvest)								−0.68*
IVDMD								

4.3.2. Crude protein

All CP values (Tables 6 and 7) were low compared to NRC (1989). In general, the CP content followed the N uptake values (Table 5) although there were some differences. As with N uptake values, whole plant CP was affected by F level but not maturity or hybrid. The lack of a maturity effect on whole plant CP differs from other observations (Xu et al., 1995; Wiersma et al., 1993) of decreased protein with increasing maturity but this did occur in our study for stover.

Whole plants from the NH_4NO_3 treatment contained a higher CP content than did plants from other treatments in Year 1. In Year 2, the CP content of the H-BrL treatments was higher than CP content of the NH_4NO_3 treatments indicating that the value of BrL increased with subsequent applications. The increased CP content emphasizes the value of appropriate fertilization in growing silage regardless of the fertilizer source. The positive correlation between whole plant and grain yield and CP content also emphasizes the value of fertilization. The effect of fertilizer on stover CP was similar to that for the whole plant.

4.3.3. ADF and NDF

Whole plant ADF content (Table 6) decreased with increased fertilization whereas the effect on stover ADF values (Table 7) was not consistent. This is also indirectly shown through the negative correlations between both ADF and NDF and whole plant and grain yields (Table 8). Lower whole plant ADF values for the NH_4NO_3 treatment probably occurred due to a combination of small differences in stover ADF content and the greater G:S ratio (Table 6) as grain ADF content is low (NRC, 1989).

Whole plant ADF was higher for H3140 than the other hybrids during the dry year, but the trend was not consistent when more rainfall was available.

The effects of maturity on whole plant ADF and NDF content were inconsistent. Fiber content decreased between M1 and M2, but not between M2 and M3 during Year 1. Fiber fractions of whole corn plant generally decrease with maturity (Wiersma et al., 1993; Xu et al., 1995), but others (Ganoe and Roth, 1992; Hunt et al., 1989) have reported a decline to mid stage maturity with no decline thereafter.

Stover ADF and NDF increased with maturity, but at different rates during the two seasons. An increase in stover fiber with increasing maturity often occurs (Hunt et al., 1989; Russell, 1986; Xu et al., 1995) but fiber may decrease with maturity during unusual seasons (Russell, 1986).

4.3.4. Digestibility

The IVDMD values were greater for whole plants from the NH_4NO_3 than from the H-BrL treatment during both years, but differed only in Year 1 for stover (Tables 6 and 7). Whole plant IVDMD values were negatively correlated with ADF and NDF content (Table 8) but the corresponding correlation for stover occurred only in Year 2 (Table 9). Several researchers have reported a strong relationship between plant fiber content and digestibility (Deinum et al., 1984; Russell et al., 1992; Zimmer et al., 1980), but that may be obscured by lignin content and the rate of fiber digestion (Allen, 1995).

Digestibility of H3136 stover was greater than the other hybrids during both years, but there was an advantage in whole plant IVDMD for this hybrid only during Year 1. This is consistent with the findings of Hunt et al. (1992) who observed that digestibility differences were more pronounced in stover than whole plant. Grain content alone did not affect the whole plant IVDMD difference as the G:S ratio for H3136 was lower during both years than for H3154. Furthermore, the correlation between grain yield and IVDMD during the dry year (Year 1; Table 8) was not significant. This supports the common view that the corn hybrid difference in chemical composition, and therefore potential nutritive value, is due to the stover portion of the plant.

An increase in IVDMD of whole plant generally occurs with maturity, at least until the three-fourth milk line (Cummins, 1970; Wiersma et al., 1993; Xu et al., 1995). This pattern occurred during Year 2 when both whole plant and stover IVDMD decreased with increasing maturity. Lower IVDMD values for M3 than M2 (Year 1) could be attributed to a later physiological harvest as later harvest decreases stover IVDMD (Russell, 1986).

5. Conclusions

Broiler litter can provide corn silage or grain yields comparable to commercial fertilizer if appropriate amounts are applied. If litter application supplies sufficient N to corn, compared to NH_4NO_3, then the nutrient content of corn harvested for silage (whole plant) will be similar. The CP content may be less the first year of litter use, but greater than with commercial fertilizer with consecutive applications of litter. Acid detergent fiber content may be higher, and IVDMD lower, on corn plants fertilized with litter. Thus, the energy content may be slightly lower for silage made from corn fertilized with litter versus commercial fertilizer.

There were no consistent advantages among the hybrids studied, although each had benefits. The H3140 had slightly greater yields although H3154 had the highest grain to stover ratio. The H3136 had the greatest whole plant IVDMD during a dry year and the greatest stover IVDMD regardless of weather conditions.

Maturity did not have a consistent effect on nutrient quality, but grain yields were lower at 1/3 versus 2/3 milk line or black layer. The milk line changed very rapidly for corn grown under these hot environmental conditions, especially in dry weather.

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