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Abstract

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Keywords

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Effect of Maturity at Harvest on Yield, Composition, and Feeding Value of Hybrid Forage Sorghum Silages

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Summary

Results from three trials showed the diversity among forage sorghum hybrids for both agronomic and nutritive characteristics. Later maturing and nonheading hybrids produced silages with low dry matter (DM) contents, low pH values, high levels of fermentation acids, and low voluntary intakes. Earlier maturing and moderate grain-producing hybrids had whole-crop DM yields similar to the later hybrids, but their silages had higher DM contents and higher voluntary intakes. Stage of maturity at harvest had surprisingly little influence on silage chemical composition, intake, or digestibility.

Introduction

In 1984, Kansas produced nearly 200,000 acres of forage sorghum, yielding almost 2 millon tons of silage. Little information is available concerning how stage of maturity at harvest affects composition and digestibility of forage sorghum hybrids. Several researchers have reported decreased digestibility of dry matter, crude protein, and fiber components with advancing maturity. However, others suggest that the effects of maturity might vary among hybrids.

The objective of these three experiments was to measure how stage of maturity at harvest influences yield, composition, and nutritive value of silage from several forage sorghum hybrids.

Experimental Procedures

Trial 1. Two forage sorghums, DeKalb FS-25A+ (a late maturing, moderate grain producing hybrid) and Funk's G-1990 (a late maturing, nonheading hybrid), were seeded on June 9, 1983 and grown under dryland conditions near Manhattan. Harvests were made at six stages of maturity for the FS-25A: boot (stage 1), anthesis (stage 2), early-milk (stage 3), late-milk to early-dough (stage 4), late-dough (stage 5), and post-freeze, hard-grain (stage 6). Since G-1990 does not head, it was harvested on the same days as FS-25A. Days post-emergence (DPE) for the six harvests were: 81, 93, 100, 110, 114, and 160 for stages 1 through 6, respectively. Whole-crop yield was determined by harvesting two rows, each 450 ft long.

At each harvest six, 55-gallon, metal drum, pilot silos lined with 4 ml plastic were filled with approximately 225 lb of fresh material from each hybrid. Silos were stored at ambient temperature (60 to 75 F) for at least 100 days prior to opening. Silage samples were taken at three levels from the geometric center as the pilot silos were emptied.

Chemical analyses of the silages included DM, crude protein (CP), ash, fiber constituents, pH, lactic acid, volatile fatty acids, and hot water insoluble nitrogen.

Twenty-four crossbred wether lambs (average wt., 80 lb) were allotted by weight to the 12 silages (two lambs per silage) for three digestion trial periods. All rations were 90% of the appropriate silage and 10% supplement (DM basis). Rations were formulated to 11.5% CP and supplied equal amounts of minerals and vitamins (Table 41.1). Between periods, all lambs were weighed and randomly re-assigned to the 12 silage rations.

Each 24-day period was divided into a 10-day preliminary phase, a 5-day voluntary intake, a 2-day ration intake adjustment, and 7-day fecal collection phases. During the intake adjustment and collection phases, all lambs received 85% of their previously established ad libitum intake.

Trial 2. Three forage sorghum hybrids were seeded on June 14, 1984 and grown under dryland conditions near Manhattan. Hybrids were: Acco Paymaster 351 (a middle maturing, high grain producing hybrid), DeKalb FS-25E (a late maturing, low to moderate grain producing hybrid similar to FS-25A in Trial 1), and Funk's G-1990, also described in Trial 1. Harvests were made at three stages of maturity for the Acco 351 and FS-25E: late-milk to early-dough (stage 4, described in Trial 1), late-dough (stage 5), and post-freeze, hard-grain (stage 6). The G-1990 was harvested on the same day as FS-25E, which was at 102, 116, and 127 DPE for stages 4, 5, and 6, respectively. Whole-crop yield was determined by harvesting three rows, each 400 ft long.

At each harvest for each hybrid, fresh material was ensiled, stored, weighed, and sampled as described in Trial 1. Silos were opened at about 75 day post-filling. Preparation and analyses of samples were identical to Trial 1.

Twenty-seven crossbred wether lambs (avgerage wt., 73 lb) were allotted by weight to the nine silages (three lambs per silage) for two digestion trial periods. All rations were 90% of the appropriate silage and 10% supplement (DM basis). Rations were formulated to 11.5% CP and supplied equal amounts of vitamins and minerals (Table 41.1). Period and phase length, re-assignment between periods, preparation of samples, and chemical analyses were similar to Trial 1.

Trial 3. Three forage sorghum hybrids, Pioneer 947, Acco Paymaster 351, and DeKalb FS-25E, were selected to represent a range of maturities, plant heights, and forage and grain yields. Harvests were made at four stages of crop maturity: late-milk to early-dough (stage 4), late-dough (stage 5), post-frost, hard-grain (stage 6), and 2 to 4 weeks after hard-grain (stage 7).

Field plots were seeded on June 8, 1985 under dryland conditions near Manhattan. About 100 lb per acre of anhydrous ammonia was applied 1 month before planting. Furadan 15 G insecticide was placed in the furrows at planting and the following day, pre-emergence herbicide (Ramrod) was broadcast. On July 24, the plots were sprayed with Cygon 400 for greenbug control.

The hybrids were assigned in a randomized complete block design to three replicate plots each. Single plots had 18 rows, 30 inches apart and 200 ft long. Whole-crop yield for each plot at each stage of maturity was determined by harvesting three rows with a Field Queen forage harvester. One row was left as a border from which the heads were clipped from a random 40 ft to determine grain yield. The heads were dried and threshed in a stationary thresher.

Results and Discussion

Trial 1. Harvest dates, dry matters, and whole-crop yields for the two hybrids are shown in Table 41.2. The increase in DM content with advancing maturity was similar for the two hybrids. FS-25A reached maximum DM yield at stage 3, and G-1990 at stage four. FS-25A outyielded G-1990 at the three earlier stages, but at stages 4 and 5, DM yields were similar. A freeze on September 25 hastened leaf loss in both hybrids, so subsequent DM yields were reduced. The yield reduction was greatest for FS-25A.

Chemical analyses for the 12 forage sorghum silages are shown in Table 41.3. The CP content was similar for both hybrids, with the lowest CP at harvest stage six. The fiber fractions (neutral detergent fiber, acid detergent fiber, and hemicellulose) were higher at all harvest stages for G-1990 silages than FS-25A. Harvest stage did not affect the fiber fractions of either hybrid at stages 1 through five. At stage 6, all fractions except cellulose decreased.

Fermentation characteristics for the 12 forage sorghum silages are presented in Table 41.4. All silages were well preserved and had undergone lactic acid fermentations. They had very low pH values, high lactic acid contents, and negligible amounts of buytric acid. The lactic acid content did not appear to be related to harvest stage in either hybrid. Acetic and total fermentation acids increased with advancing maturity in G-1990 silages, but not in FS-25A. The G-1990 silages had consistently lower hot water insoluble nitrogen values than FS-25A.

Results for voluntary intakes and apparent digestibilities are shown in Table 41.5. Since there were no significant hybrid x harvest stage interactions, only data for the main effects are given. Hybrid did not affect intakes or digestibilities of DM, organic matter (OM), or crude protein. Only NDF and ADF digestibilities were significantly affected by hybrid; G-1990 silages were more digestible. Voluntary intakes were highest for the stage 5 silages and lowest for stage 1 silages ($P<.05$). The DM and OM digestibilities were highest for the stages 2 and 3 silages ($P<.05$). Crude protein digestibilities were lowest ($P<.05$) for the stage 1 silages. The NDF and ADF digestibilities were highest ($P<.05$) for the stage 2 silages, but lowest ($P<.05$) for stage 6 silages.

Trial 2. Harvest dates, dry matters, and whole-crop yields for the three hybrids are shown in Table 41.6. All three hybrids increased in DM content as maturity advanced, with Acco 351 being consistently highest at each harvest stage. The DM yield was lowest for all three hybrids at harvest stage 4; Acco 351 and G-1990 reached maximum yields at stage 6 and FS-25E, at stage five.

Chemical analyses of the nine forage sorghum silages are shown in Table 41.7. The CP contents were unusually low for all three hybrids and were not influenced by harvest stage. The fiber fractions followed very consistent patterns. Acco 351 silages had the lowest NDF, ADF, and cellulose values; G-1990 silages had the highest values. Most fiber fractions decreased at the last harvest stage, particularly for Acco 351 and FS-25E silages.

Fermentation characteristics for the nine forage sorghum silages are presented in Table 41.8. All silages were well preserved and had undergone lactic acid fermentations. Differences because of hybrid or harvest stage were small. Acco 351 silages, which had higher DM contents than silages from FS-25E or G-1990, also had the highest pH values, lowest total fermentation acids, and highest hot water insoluble nitrogen levels. The FS-25E silages had the lowest pH values and the highest total acids. Acetic acid content increased and lactic:acetic acid ratios decreased with advancing maturity for all three hybrids.

Results for voluntary intakes and apparent digestibilities are shown in Table 41.9. Since no significant hybrid x harvest stage interactions occurred, only main effects are given. The higher DM, Acco 351 silages were consumed in greater amounts ($P<.05$) than FS-25E or G-1990 silages. The hybrids had similar DM and OM digestibilities. Crude protein and ADF digestibilities were highest ($P<.05$) for the G-1990 silages; ADF digestibility was lowest ($P<.05$) for the Acco 351 silages. Harvest stage did not influence voluntary intakes or digestibilities of DM, OM, and crude protein.

Trial 3. Plant heights, harvest dates, compositions, and yields for the three hybrids are shown in Table 41.10. Pioneer 947 required only 28 days to advance from stage 4 to stage 6; Acco 351 required 35 days, and FS-25E required 44 days.

Whole-crop DM content increased ($P<.05$) at each successive harvest stage for Pioneer 947, ranging from 29.6% at stage 4 to 44.0% at stage seven. For Acco 351, DM content increased with advancing maturity after stage 5 and reached 40.4% at stage seven. The DM content of FS-25E did not change after stage four. That agrees with results obtained in Trial 2. Crude protein generally decreased with advancing maturity, but only in Pioneer 947 and FS-25E was the change statistically significant.

Whole-crop DM yield of Acco 351 was influenced less than the other two hybrids by stage of maturity (Table 41.10). The highest yields ($P<.05$) were at harvest stages 4 or 5 for Pioneer 947 and FS-25E, and their lowest yields ($P<.05$) were at stage seven. Grain yield for Pioneer 947 was not affected by harvest stage, but the lowest yield ($P<.05$) for Acco 351 occurred at stage 1 and the lowest yield ($P<.05$) for FS-25E was at the first two stages.

Table 41.1. Composition of Supplements Fed in Trials 1 and 2

Ingredient	Trial 1 A[1]	B[2]	C[3]	D[4]	Trial 2 E[5]	F[6]
	% on a DM Basis					
Rolled Grain Sorghum	—	10.0	26.0	75.0	—	—
Soybean Meal	78.3	67.0	51.0	1.0	75.1	73.4
Urea	8.7	8.8	8.8	8.8	10.5	12.0
Limestone	5.3	6.5	6.3	5.4	6.0	6.1
Dicalcium Phosphate	3.5	3.8	4.1	5.6	3.8	3.9
Salt	2.5	2.5	2.5	2.5	2.5	2.5
Soybean Oil	1.0	1.0	1.0	1.0	1.0	1.0
Trace Mineral Premix	.3	.3	.3	.3	.3	.3
Vitamin and Antibiotic Premix[7]	.4	.4	.4	.4	.8	.8

[1]Fed with FS-25A stage 4, 5, and 6 silages.
[2]Fed with FS-25A stage 2 and 3 and G-1990 stage 6 silages.
[3]Fed with FS-25A stage 1 and G-1990 stage 2, 3, 4 and 5 silages.
[4]Fed with G-1990 stage 1 silage.
[5]Fed with all Acco 351 and FS-25E silages.
[6]Fed with all G-1990 silages.
[7]Formulated to supply 3,000 IU of vitamin A, 300 IU of vitamin D, 3 IU of vitamin E, and 20 mg of aureomycin per lamb day.

Table 41.2. Harvest Dates, Dry Matters, and Whole-Crop Yields for the Two Forage Sorghum Hybrids in Trial 1

Hybrid and Harvest Stage[1]	Harvest Date	DM at Harvest	Whole-crop DM Yield
	1983	%	Tons/Acre
FS-25A			
1	Aug. 29	20.4	5.0
2	Sept. 9	25.1	5.4
3	Sept. 16	26.2	5.8
4	Sept. 26	28.7	5.5
5	Sept. 30	28.8	5.4
6	Nov. 15	29.1	4.8
G-1990			
1	Aug. 29	20.2	4.4
2	Sept. 9	23.4	4.4
3	Sept. 16	24.1	5.2
4	Sept. 26	27.6	5.5
5	Sept. 30	27.6	5.3
6	Nov. 15	29.2	5.4

[1]Harvest stage 1, boot; stage 2, anthesis; stage 3, early-milk; stage 4, late-milk to early-dough; stage 5, late-dough; and stage 6, post-freeze and hard-grain.

Table 41.3. Dry Matter and Chemical Composition for the 12 Forage Sorghum Silages in Trial 1

Hybrid and Harvest Stage	DM	Chemical Component[1]							
		CP	Ash	EE	NDF	ADF	Hemi-cellulose	Cellulose	Lignin
	%	% of the Silage DM							
FS-25A									
1	19.1	7.2	7.9	2.6	64.2	39.6	24.7	31.4	5.3
2	23.0	7.2	8.0	2.3	67.9	38.8	29.1	29.6	5.5
3	23.4	7.4	8.7	3.4	63.1	37.3	25.9	27.5	5.9
4	25.5	7.1	8.8	4.3	64.0	38.0	25.4	28.0	6.1
5	26.5	6.6	8.8	2.5	62.7	38.2	24.5	30.6	3.8
6	28.0	6.2	8.2	2.5	56.5	38.1	18.5	33.2	3.8
G-1990									
1	21.1	7.3	8.5	2.7	67.4	41.3	26.1	33.8	4.9
2	22.1	6.8	8.3	3.6	68.9	41.5	27.2	32.3	5.6
3	23.6	6.8	7.9	3.0	70.5	40.8	29.8	26.9	6.7
4	25.7	7.2	8.7	3.1	67.4	39.6	27.7	30.3	5.1
5	25.7	6.8	8.9	2.8	67.2	41.4	25.8	31.5	5.4
6	26.8	6.2	9.0	2.4	62.6	40.9	21.7	32.7	3.8

[1]CP = crude protein, EE = ether extract, NDF = neutral detergent fiber, and ADF = acid detergent fiber.

Table 41.4. Fermentation Characteristics for the 12 Forage Sorghum Silages in Trial 1

Hybrid and Harvest Stage	DM	pH	Fermentation Acids			Lactic: Acetic	Hot Water Insoluble Nitrogen[1]
			Lactic	Acetic	Total		
	%		% of the Silage DM				
FS-25A							
1	19.1	3.71	8.7	2.5	11.2	3.6	43.5
2	23.0	3.90	6.8	1.4	8.2	4.9	50.0
3	23.4	3.75	8.4	2.4	10.6	4.0	50.8
4	25.5	3.89	6.6	2.5	9.2	2.7	59.6
5	26.5	3.82	7.5	2.7	10.3	2.7	59.4
6	28.0	3.95	5.3	2.4	7.7	2.2	51.5
G-1990							
1	21.1	3.79	6.8	1.3	8.1	5.4	44.4
2	22.1	3.85	7.2	1.4	8.6	5.2	43.1
3	23.6	3.81	5.7	2.5	8.1	2.3	39.8
4	25.7	3.88	6.3	3.7	9.9	1.7	51.3
5	25.7	3.75	7.0	3.2	10.2	2.2	55.0
6	26.8	3.77	7.0	3.2	10.2	2.2	42.9

[1]Expressed as a % of the silage total nitrogen.

Table 41.5. Effects of Forage Sorghum Hybrid and Stage of Maturity on Ration Voluntary Intakes and Apparent Digestibilities in Trial 1*

Hybrid and Harvest Stage	VI		Digestibility, %				
	g DM/Day	g DM/kg Body Wt$^{.75}$	DM	OM	CP	NDF	ADF
Hybrid							
FS-25A	581	40.0	58.8	51.1	68.8	48.4^{b}	44.7^{b}
G-1990	578	42.3	56.7	52.1	70.2	52.2^{a}	49.9^{a}
Harvest Stage							
1	510^{d}	34.3^{e}	55.5^{cd}	51.3^{cd}	64.5^{d}	51.8^{d}	49.6^{cd}
2	601^{cd}	39.5^{de}	57.8^{cd}	53.4^{c}	70.3^{c}	58.2^{c}	55.2^{c}
3	605^{cd}	44.0^{cd}	58.1^{c}	53.5^{c}	69.3^{c}	50.1^{de}	49.0^{cde}
4	580^{cd}	41.8^{cd}	56.5^{cd}	51.7^{cd}	71.0^{c}	48.8^{de}	44.6^{de}
5	625^{c}	47.1^{c}	55.0^{cd}	50.1^{cd}	69.7^{c}	48.9^{de}	43.3^{de}
6	557^{cd}	39.9^{de}	54.6^{d}	49.6^{d}	72.1^{c}	44.1^{e}	42.1^{e}

*VI = voluntary intake, DM = dry matter, OM = organic matter, CP = crude protein, NDF = neutral detergent fiber, and ADF = acid detergent fiber.

[a,b]Means in the same column with different superscripts differ ($P<.05$).

[c,d,e]Means in the same column with different superscripts differ ($P<.05$).

Table 41.6. Harvest Dates, Dry Matters, and Whole-Crop Yields for the Three Forage Sorghum Hybrids in Trial 2

Hybrid and Harvest Stage[1]	Harvest Date	DM at Harvest	Whole-crop DM Yield
	1984	%	Tons/Acre
Acco 351			
4	Sept. 21	29.2	4.6
5	Oct. 4	33.1	4.7
6	Oct. 19	36.7	5.0
FS-25E			
4	Sept. 24	23.3	5.2
5	Oct. 8	26.2	6.1
6	Oct. 19	26.5	5.6
G-1990			
4	Sept. 24	24.9	5.0
5	Oct. 8	25.2	4.5
6	Oct. 19	25.3	5.4

[1]Harvest stage 4, late-milk to early-dough; stage 5, late-dough; and stage 6, post-freeze, hard-grain.

Table 41.7. Dry Matter and Chemical Composition for the Nine Forage Sorghum Silages in Trial 2

Hybrid and Harvest Stage	DM	CP	Ash	EE	NDF	ADF	Hemi-cellulose	Cellulose	Lignin
		Chemical Component[1]							
	%	% of the Silage DM							
Acco 351									
4	27.8	5.6	8.7	2.3	60.0	38.2	21.8	27.2	5.9
5	32.5	5.6	8.6	1.9	59.8	36.9	22.5	24.4	7.1
6	35.3	5.9	8.6	1.8	53.5	38.1	15.5	27.1	6.1
FS-25E									
4	22.7	6.3	8.3	2.9	63.0	41.1	23.0	30.5	6.0
5	24.6	6.1	8.1	2.0	66.7	41.5	25.7	31.3	6.4
6	24.4	6.4	8.6	1.9	56.8	39.7	17.1	28.3	7.1
G-1990									
4	23.4	4.6	8.6	2.1	68.1	45.0	23.2	34.5	6.7
5	24.6	4.4	8.8	1.8	68.3	45.8	22.5	35.8	6.5
6	24.6	4.3	9.1	1.8	65.2	48.4	16.8	35.6	8.6

[1]CP = crude protein, EE = ether extract, NDF = neutral detergent fiber, and ADF = acid detergent fiber.

Table 41.8. Fermentation Characteristics for the Nine Forage Sorghum Silages in Trial 2

Hybrid and Harvest Stage	DM	pH	Fermentation Acids: Lactic	Acetic	Total	Lactic: Acetic	Hot Water Insoluble Nitrogen[1]
	%	% of the Silage DM					
Acco 351							
4	27.8	3.95	6.0	2.2	8.2	2.8	56.8
5	32.5	3.99	6.1	2.4	8.5	2.6	55.6
6	35.3	4.08	5.6	2.8	8.4	2.1	52.1
FS-25E							
4	22.7	3.81	7.9	2.3	10.1	3.7	46.5
5	24.6	3.84	7.4	3.0	10.4	2.5	49.0
6	24.4	3.79	6.7	3.2	9.9	2.1	40.8
G-1990							
4	23.4	3.85	6.7	2.9	9.5	2.4	45.2
5	24.6	3.94	5.9	3.5	9.4	1.8	47.9
6	24.6	3.92	6.0	3.3	9.4	1.9	80.9

[1]Expressed as a % of the silage total nitrogen.

Table 41.9. Effects of Sorghum Hybrid and Stage of Maturity on Ration Voluntary Intakes and Apparent Digestibilities in Trial 2*

Hybrid and Harvest Stage	VI		Digestibility, %				
	g DM/Day	g DM/kg Body Wt$^{.75}$	DM	OM	CP	NDF	ADF
Hybrid							
Acco 351	639[a]	48.0[a]	57.1	55.9	68.1[b]	53.2	34.2[c]
FS-25E	547[b]	42.7[b]	55.9	54.3	67.3[b]	50.2	41.7[b]
G-1990	527[b]	40.8[b]	56.7	55.3	70.5[a]	55.2	48.7[a]
Harvest Stage							
4	584	44.0	56.9	55.8	68.0	58.2[d]	42.8[d]
5	552	42.9	56.3	54.8	68.2	51.5[de]	38.7[e]
6	577	44.6	56.6	55.0	69.6	48.9[e]	43.0[d]

*VI = voluntary intake, DM = dry matter, OM = organic matter, CP = crude protein, NDF = neutral detergent fiber, and ADF = acid detergent fiber.

[a,b,c]Means in the same column with different superscripts differ (P<.05).

[d,e]Means in the same column with different superscripts differ (P<.05).

Table 41.10. Plant Heights, Harvest Dates, Dry Matters, Crude Proteins (CP), and Whole-crop Forage and Grain Yields for the Three Forage Sorghum Hybrids in Trial 3

Hybrid and Harvest Stage	Harvest Date	Whole-crop		Whole-crop DM Yield	Grain Yield[3]
		DM	CP[2]		
	1985	%	%	Tons/Acre	Bu/Acre
Pioneer 947					
4 (116)[1]	Sept. 16	29.6[d]	9.1[a]	6.32[b]	64
5	Sept. 25	32.3[c]	9.2[a]	7.04[a]	77
6	Oct. 14	37.6[b]	8.6[ab]	5.02[c]	62
7	Nov. 18	44.0[a]	7.8[b]	4.00[d]	70
Acco 351					
4 (74)	Sept. 19	24.4[c]	9.6	6.26[ab]	38[b]
5	Oct. 1	26.4[c]	9.2	6.82[a]	71[a]
6	Oct. 24	36.3[b]	9.1	6.64[ab]	64[a]
7	Nov. 19	40.4[a]	9.0	6.12[b]	74[a]
FS-25E					
4 (128)	Sept. 24	22.8[b]	8.8[a]	7.09[a]	32[b]
5	Oct. 7	25.7[a]	8.2[ab]	6.44[ab]	33[b]
6	Nov. 7	27.8[a]	8.3[ab]	6.36[b]	40[ab]
7	Nov. 19	27.2[a]	7.5[b]	4.70[c]	50[a]

[1]Plant height at harvest stage 4, inches.
[2]100% dry matter basis.
[3]Adusted to 12.5% moisture.

[a,b,c,d]Means within a hybrid with different superscripts differ (P<.05).