EFFECTS OF HYBRID AND HARVEST STAGE ON THE YIELD, COMPOSITION, AND FEEDING VALUE OF FORAGE SORGHUM SILAGES

by

Susan R. Hamma

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Approved by:

Keith K. Bolsen
Major Professor

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Introduction

Forage sorghums (Sorghum bicolor L. Moench) are important silage crops for beef and dairy cattle production in the High Plains region of the United States. Sorghums have more drought resistance, greater ability to recover from drought, and lower production costs than corn (Zea mays L.) which continues to be the principle silage for the U.S. as a whole.

There were over 100 forage sorghum hybrids and varieties available to Kansas farmers in 1986 (Walter, 1987). Only limited information exists concerning the influence of forage sorghum hybrid (or variety) on silage chemical composition and nutrient intake and digestibility (Black et al., 1980; Dickerson, 1986). Even fewer studies have compared cattle performance from two or more forage sorghums (Kirch et al., 1987a).

Variations due to maturity (early to late), plant height, dry matter (DM) content, forage and grain yields, and crop chemical composition among available forage sorghums offer a wide range of harvesting and feeding value choices to the producer. In earlier studies, Fox et al. (1970) and Black et al. (1980) reported increased DM intake and decreased DM digestibility as maturity advanced. However, Dickerson (1986) showed while DM intakes generally increased at the later harvest stages, apparent DM digestibility was affected by maturity in only one of the five hybrids compared. Dickerson (1986) and Kirch et al. (1987) also reported that whole-crop DM yields for nine forage sorghums were not consistently affected by maturity at harvest or hybrid.

The effects of delayed harvest and prolonged wet field conditions (often a problem with late maturity hybrids) on silage yield and nutritive value needs further study.

These experiments were designed to evaluate silage from different hybrid forage sorghums for yield potential, nutrient composition, and feeding value as influenced by advancing harvest stage from late-milk to a post-freeze, weathered crop.

Chapter 1

REVIEW OF LITERATURE

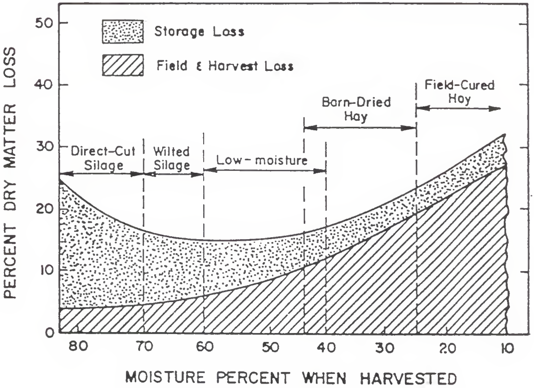
Silage Fermentation: A Review

Silage can be an efficient way to conserve a forage (figure 1). A majority of the time silage preserves a greater amount of available digestible nutrients per hectare than grain or hay (Bolsen, 1985). Woolford (1984) defines silage as "the product formed when grass or other material of sufficiently high moisture content (e.g., forage legumes and forage corn) liable to spoilage by aerobic microorganisms is stored anaerobically." A "good" silage is considered to be one where the predominant acid is lactic acid (Woolford, 1984). Anaerobic conditions must prevail to result in a well preserved, palatable feed.

Qualifications for the ideal forage to ensile include:

1. An adequate level of water soluble carbohydrate (WSC). About 3% WSC on a fresh basis should insure enough substrate for

FIGURE 1. ESTIMATED TOTAL FIELD AND HARVEST LOSS AND STORAGE LOSS WHEN LEGUME-GRASS FORAGES ARE HARVESTED AT VARYING MOISTURE LEVELS AND BY ALTERNATIVE HARVESTING METHODS (Hoglund, 1964)



sufficient acid production during the fermentation process.

2. A relatively low buffering capacity (BC). Two definitions of buffering capacity are: (1) the quantity of lactic acid in mg required to lower the pH of 1 g of herbage DM to 4.0 and (2) milliequivalents of alkali required to increase the pH of 1 kg of herbage DM from 4.0 to 6.0 (Woolford, 1984). Corn, which is easily ensiled, has a relatively low BC of about 200 using the second definition and alfalfa, which is more difficult to ensile successfully, has a high BC of about 480 (Woolford, 1984).

3. A DM content between 25 and 45 percent. Forages with less than 25% DM can result in excessive amounts of effluent, and forages with more than 45% DM are more difficult to pack and achieve anaerobic conditions.

4. A physical structure which facilitates good compaction and air exclusion. For example, forages with hollow stems are predisposed to poor compaction.

5. An effective harvest season to allow enough time to ensile the forage at its optimum maturity.

If all of these qualifications are met, then a successful fermentation should occur, but if conditions are not optimal, then excessive preservation losses can occur (table 1).

The basic steps of a good silage fermentation process are well understood. The first step is an aerobic phase, which starts at the time of cutting the forage and lasts until oxygen in the ensiled mass is excluded or utilized. Plant cells are metabolically active and respiring when the forage is placed in the silo. A compact, high-density forage excludes the oxygen quickly and respiration is held to a minimum. Respiration results in the formation of carbon dioxide, water, and heat by the action of plant enzymes using sugars as substrate. Therefore, it is desirable to make this phase as short as possible, to minimize the competition between the plant enzymes and bacteria for the available substrate. Proteolysis, which is also a plant enzyme process, begins when the forage is cut and placed in the silo. Proteolysis can double the non-protein nitrogen (NPN) content of the ensiled forage (McDonald, 1981). Aerobic pathways of acid production by lactic acid bacteria (LAB) produce lactate, acetate, pyruvate, CO_2, and water. Production of acetate during this phase presents a problem because it has less preservative properties than lactate and can be produced in greater quantities here than in the second anaerobic phase. Acetate is also associated with lower feeding

TABLE 1. SOURCES OF ENERGY LOSSES IN SILAGE-MAKING[1]

Process	Classified as*	Approx. losses (%)	Causing factors
Residual respiration	U	1 - 2	Plant enzymes;
Fermentation	U	2 - 4	Micro-organisms;
Effluent or	M	5 - >7	DM content;
Field losses by wilting		2 -> 5	Weather, technique, management, crop;
Secondary fermentation	A	0 -> 5	Crop suitability, environment in silo, DM content;
Aerobic deterioration during storage	A	0 -> 10	Filling time, density, silo, sealing, crop suitability;
Aerobic deterioration after unloading (heating)	A	0 -> 15	As above, DM content silage, unloading technique, season.
	Total	7 - > 40	

[1]Adapted from Zimmer (1980).
*U=unavoidable, M=mutually unavoidable, A=avoidable.

values (McDonald, 1981 citing Wilkinson et al., 1976).

The second step is an anaerobic phase in which homofermentative LAB dominate. The LAB produce two moles of lactate from each mole of glucose, which is the most efficient acid-producing pathway. Heterofermentative LAB produce only one lactate from each mole of glucose, along with other end products including acetate, ethanol, CO_2, and mannitol. As the lactate concentration increases, the pH drops to a point where most microbial activity ceases.

The third step occurs during feedout when the silage is re-exposed to oxygen. During this aerobic phase, deterioration by aerobic yeasts, molds, and bacteria can occur. The silage usually heats due to the metabolism of available substrate (primary fermentation acids, residual WSC, amino acids, and proteins), accumulating energy and DM losses (Woolford, 1984). Most of this process is attributed to yeasts (Woolford, 1984), but bacteria can be involved, particularly in the latter stages of deterioration. It is universally agreed that silo management is the best way to avoid large losses during silage feedout.

Introduction of Sorghums into the United States

The history of sorghum goes back to Africa about 5,000 to 7,000 years ago and it was reportedly brought to the Western hemisphere with slaves in the 17th and 18th centuries. Cultured sorghum for forage and syrup came from France in the 1850's (Wall and Ross, 1970). In 1956 the first hybrid sorghums were grown commercially in the United States. The development of hybrid sorghums more than doubled the yield compared to the old varieties (Wall and Ross, 1970). Since that time, numerous hybrids have been made available to producers.

Forage Sorghum as a Silage Crop

Many studies have been devoted to comparing grain or forage type sorghums directly with corn as a crop for silage. Comparisons were made using numerous criteria, including animal performance and agronomic traits. In optimal environmental conditions, sorghum can not compete with corn for cattle gains. As irrigation costs accelerate, and in those areas where adequate moisture is borderline, sorghum is a suitable alternative crop. With the development of improved forage sorghum hybrids, their value as a forage continues to grow, especially in areas where double cropping is a possibility. McCullough et al. (1981) reported that the main difference between corn and sorghum silage was grain content. By adding grain to sorghum silages cattle should show a daily gain response because of increased intake of net energy.

Ritchie et al. (1972) in a one year comparison found NK 300 grain sorghum had a 23% higher dry matter (DM) yield/acre than corn, while Pioneer 931 forage sorghum had a 32% higher DM yield/acre than corn. Brethour and Duitsman (1971) comparing a forage sorghum, Frontier 212, and a grain sorghum, Pioneer 846, on an equal moisture basis (70%) had 3.5 tons difference in yield, from 11 tons for the forage sorghum to 7.5 tons/acre for the grain sorghum. Grain yield from sorghums have ranged from sterility (no grain produced) to over 10,000kg/hectare (Nordquist and Rumery, 1967). Plant height, which is an extremely varied trait in forage sorghums, was shown to be negatively correlated with forage quality measurements (Schmid et al., 1976).

Owen et al. (1962) compared corn with Axtell forage sorghum and a sterile forage sorghum, RS 303F, and concluded that steriles were equal to grain-producing hybrids for lactating dairy cows and that grain content should not be used as a criteria in selecting a forage sorghum hybrid. This conclusion was made in spite of lower DM intake of the sterile silage compared with the corn or Axtell. Cattle fed corn silage gained .41 lbs/day faster than those fed forage sorghum silage in research conducted by Brethour (1967).

Chemical composition of forage sorghums also differs from corn. Byers et al. (1965) found higher TDN and percent crude protein (CP) in corn compared with forage sorghum.

Differences can also be found between grain and forage sorghums. Grain sorghums tend to have a higher DM content due to the higher contribution from the grain portion of the crop. Burns and Kimbrough (1981) found no differences in the in vitro DM digestibility (IVDMD) when comparing forage sorghum to grain sorghum, sorghum x sudan, and millets.

Ritchie et al. (1972) found .30 lbs greater average daily gain (ADG) when feeding NK 300 grain sorghum as compared with Pioneer 931 forage sorghum. Kansas workers (Brethour and Duitsman, 1966) looking exclusively at the effect of grain on cattle performance did so by adding 250 lbs of grain/ton to a sterile hybrid at ensiling. They improved DM intake by 2.3 lbs/day and ADG from 1.4 to 2.12 lbs/day. Ward and Smith (1968) conducted a similar study and concluded that grain increased DM percentage and DM intake, but the difference between sterile sorghum and grain producing hybrids was not in the nutritive value of the forage but the consumption of the silage. Workers at the Kansas Agricultural Experiment Station (Boren et al., 1962) compared a sterile sorghum with a heading forage sorghum hybrid and achieved higher cattle gains with the heading hybrid, greater feed efficiency, and higher DM yield/acre than for the sterile silage.

In a similar Kansas study (Brethour, 1967) four treatments were compared: a sterile, a sterile + grain, a sterile + grain + water (to equalize DM content), and adding an equivalent amount of grain at the bunk to the sterile silage. These treatments allowed the workers to look exclusively at the effect of grain without comparing the difference in forage from different hybrids. The sterile + grain at ensiling was the most efficient and achieved the highest cattle gains. The original sterile without grain produced the lowest gain, poorest efficiency, and lowest DM intake.

Forage sorghum hybrids and varieties have greatly different grain yield potentials, leafiness, and other plant characteristics. Cummins (1981) suggests that besides selecting for high grain content, selection should also be based on high stalk quality, those which are low in fiber and high in DM digestibility. To evaluate the sorghums, fresh samples should be adequate, except when comparing a sweet stalk to a dry stalk sorghum (Cummins, 1981). Schertz et al. (1978) found no evidence that silage from "juicy" sorghums had superior IVDMD compared with "dry" stalk hybrids, particularly when harvested at a late maturity. Therefore, since the high DM silages are best for handling and preservation traits, this would likely offset any other advantages of juicy hybrids.

Pederson et al. (1982) suggested that the greatest improvement in forage sorghums could occur by basing selection on IVDMD of the fresh dried forage. In contrast to this recommendation, Burns and Kimbrough (1981) report that fermentation generally removes differences in IVDMD when comparing sorghum hybrids. When comparing the average of all sorghum treatments, the difference between the fresh and ensiled IVDMD's was -6.6 percentage units. Marten (1975) (cited by Burns and Kimbrough, 1981) suggests IVDMD is the best prediction of in vivo DM digestibility. Since the correlation between IVDMD and ADF is -0.95, ADF is an adequate and less costly prediction for sorghum silage quality, followed by CF at r = -0.86.

Maturity at Harvest Effects

Changes in Chemical Composition with Maturity

Since the optimum DM for silage is between 25 and 45%, sorghums are often allowed to mature in the field to increase the DM content to within this desired range. Other changes besides an increase in DM content occur with advanced maturity, and the effect of maturity on nutritive value of forage sorghum silage depends upon the sorghum type (Cummins, 1981). Vanderlip and Reeves (1972) description of growth stages of sorghum is in table 2.

It should be noted here that conflicting results have

TABLE 2. IDENTIFYING CHARACTERISTICS OF THE GROWTH STAGES OF SORGHUM[1]

Growth stage	Identifying characteristics
0	Emergence. Coleoptile visible at soil surface.
1	Collar of 3rd leaf visible.
2	Collar of 5th leaf visible.
3	Growing point differentiation. Approximately 8th leaf stage by previous criteria.
4	Final leaf visible in whorl.
5	Boot. Head extended into flag leaf sheath.
6	Half-bloom. Half of the plants at some stage of bloom.
7	Soft dough.
8	Hard dough.
9	Physiological maturity. Maximum dry matter accumulation.

[1]From Vanderlip and Reeves (1972).

been observed for the effect hybrid x maturity on the chemical composition of forage sorghum silage. Cummins (1981) found no significant hybrid x maturity interaction, while Dickerson (1986) found significant interaction. Therefore, comparisons made with one hybrid or variety may or may not hold true for other hybrid or variety comparisons.

Black et al. (1980) found that the forage sorghum DeKalb FS24 decreased in % crude fiber (CF) until late-milk to early-dough, then increased until mature. Others have also shown a decrease in CF with advancing maturity (Owen and Webster, 1963). Neutral detergent fiber (NDF) decreased with maturity, while acid detergent fiber (ADF) decreased after the milk stage (Black et al., 1980). Whether or not a change is seen in the ADF fraction can depend upon the plant portion examined. Percent ADF in the leaves increased with maturity while percent ADF in the stalks remained constant for three of the four hybrids compared by Cummins (1981). Dry matter content increased with maturity (Dickerson, 1986; Owen and Webster, 1963). Crude protein decreased with maturity (Johnson et al., 1971; Schake et al., 1982; Worker and Marble, 1968; Owen and Webster, 1963), cellulose decreased with maturity, and silage pH increased with maturity (Johnson et al., 1971).

Differences can also be found in WSC content of sorghums. Johnson et al. (1971) observed decreasing soluble carbohydrates with advancing maturity from head emergence to hard-dough and post-frost stages. After frost, they observed a decrease in WSC from 16 to less than 5 percent. Dotzenko et al. (1965) found varying trends in the sugar content of different sorghum varieties, peaking at different maturities among varieties. Some peaked at an early maturity, then declined, while sugar content of others increased over all successive harvests. Worker and Marble (1968) found increases in sugar percent with each advancing harvest for the forages used in their experiments.

Mineral content of forage sorghums varies with year (Dotzenko et al., 1965). Differences between hybrids and some general trends in mineral content with maturity were also seen. These data showed that calcium generally declined with advancing maturity as well as potassium and magnesium. Phosphorus content was not affected by maturity.

Silage fermentation acids are also affected by advancing maturity, as Johnson et al. (1971) showed a decrease in lactic acid content with maturity. Pederson et al. (1983) compared lactic acid content of forage sorghums harvested at the mature stage and found no differences.

Quality, measured by the chemical composition, yield, and digestibility, differs among forage sorghum hybrids when measured at the same maturity (Cummins, 1981). Pederson et al. (1982) compared 49 F_1 forage sorghum hybrids harvested on the same day post emergence and found differences in DM, CP, NDF, ADF, IVDMD, and acid detergent lignin. Dickerson (1986) showed significant differences between hybrids in all the Van Soest constituents, except lignin. Early maturity hybrids had lower CP content than medium maturity hybrids in results by Dickerson (1986).

Changes in the Nutritive Value of Forage Sorghums with Maturity

The chemical changes occurring as sorghums mature also affect the animal gain, silage intakes, efficiencies of gain, and silage digestibilities. McCullough et al. (1981) reported that DM digestibility decreased with advancing maturity. Harvesting at four stages (flowered, milk, soft-dough, and mature), Ramsey et al. (1961) found increasing DM intakes of Tracy forage sorghum silage until the soft-dough stage, which was followed by a decrease in intake at the mature stage. Similar increases in intake were noted by Gordon et al. (1961) with alfalfa silage as the DM increased from 30 to 50 percent.

The problem in determining the optimum maturity at which forage sorghum should be harvested and ensiled is finding the balance between maximum DM yield and maximum animal performance. Since daily milk production by the dairy cows was not affected by maturity of the forage sorghum silage, Owen (1962) suggested harvesting at maximum yield. After further studies, Owen (1967) suggested harvesting in the dough stage when the kernel was soft and tonnage yields were near maximum. McCullough et al. (1981) recommended that harvest should begin when anthesis had started so that it is completed by the time the kernel was in the milk stage. Since the high moisture content at early maturity can lead to effluent after ensiling, they suggested the addition of 200 pounds of a dry feedstuff per ton of forage.

When using the forage sorghum variety Atlas, Owen (1962) found that the increased yields with advancing maturity more than compensated for the decreased quality. Schake et al. (1982) recommended harvesting at the hard-dough to mature stages in order to maximize DM yield and preservation.

Decreasing DM digestibilities from the milk stage to physiological maturity were shown for silage made from Atlas, while Rox, a higher grain content variety showed no differences (Owen and Kuhlman, 1967). The ADF and NDF digestibilities decreased with advancing harvest of DeKalb FS24 (Black et al., 1980). Over six harvests from early-bloom to hard-dough stage, ADF digestibility dropped from 57.6 to 38.1% and NDF digestibility dropped from 65.9 to 43.2%, when silages were fed to mature sheep at a fixed level in the diet.

Decreased dairy cattle performance was observed by Helm and Leighton (1960) with Hy Hegari sorghum silage, as less fat corrected milk (FCM) was produced at the hard-grain compared with the bloom stage. Browning and Lusk (1967) showed no differences in FCM production when dairy cows were fed RS610 grain sorghum harvested from milk to mature stages, even though DM intake increased with maturity.

Because harvest is sometimes delayed due to weather, researchers have looked at the effect that freezing has on forage sorghum quality. Freeze did not affect DM digestibility in two studies (Johnson et al., 1971; Smith et al., 1984). Smith et al. (1984) also found that CF digestibility before and after freeze decreased from 50.6 to 32.6% for a heading forage sorghum hybrid and from 49.1 to 36.3% for a non-heading hybrid. The digestibility of CP in forage sorghum increased after frost (Johnson et al., 1971).

Black et al. (1980) reported that gross and digestible energy (DE) yields (Mcal/ha) were highest at the late-milk to early-dough stage and then declined at later harvests. Dry matter accumulation increased and was maximal at the early-dough stage and declined to maturity (McCullough et al., 1981; Black et al., 1980). Webster (1963) starting harvesting at the bloom stage and showed an increase in DM yield by 104% at the mature grain stage of a heading hybrid. Other researchers have also shown an increase in DM yield with advancing maturity (Owen, 1962; Dotzenko et al., 1965; Worker and Marble, 1968). Owen (1962) showed an increase in DM yield of 33% from the milk to mature stage.

When comparing the plant components of four forage sorghum hybrids, Cummins (1981) found that percent head weight increased with maturity though the hard-dough to mature stages, while the percent of the DM contributed by the leaves and stalks decreased. The increase in DM tonnage with advancing maturity is mainly due to an increase in stalk, while other plant components decrease (Therman et al., 1960).

Animal Performance from Sorghum Silage

Many reasons have been formulated to explain why cattle fed sorghum silages have not always achieved gains equal to those fed corn silage and other feeds. These include: differences in DM intake, grain content of the silage, and chemical composition. Cummins and McCullough (1969) found the intake of sorghum silage to be only 81% that of corn silage.

When feeding sorghum silage, most of the low animal gains can be attributed to low DM intake (Schmid et al., 1976). Owen (1962) suggested that one way to improve intake was to increase the DM content by allowing the crop to mature. Ward et al. (1966) found a positive correlation between DM intake and the DM content of the silage, ranging from 0.93 to 0.95 for lactating cows and beef steers and heifers. They concluded that in order to compare performance from sorghum silages they should be at the same moisture content.

Wilkins et al. (1971) found positive correlations between DM intake and nitrogen (N) content, and lactic acid as a percent of total acids. They found a negative correlation with NH_3-N as a percent of total N with DM intake.

Brethour (1967) concluded that a higher grain content gave better performance by calves fed sorghum silages. Since a higher grain-containing silage tends to be drier, intakes are increased and more gain can be expected. Ritchie et al. (1972) demonstrated a 0.36 lb.day higher gain with a higher grain-containing grain sorghum than a forage sorghum silage. In contrast to these researchers findings, Owen (1967) showed that grain content by itself was a poor indicator of the quality of sorghum silages. Silage quality, according to Cummins and McCullough (1969), was not related to any one crop characteristic, but collectively to all the crop components, such as the ears, heads, leaves, and stalks.

Supporting the idea of improved animal performance with higher grain content was work by Rupp et al. (1975). They compared a limit-fed forage sorghum, DeKalb FS1a to Ora-T, a grain sorghum, and got corresponding DM digestibilities of 65 and 74%, respectively. Brethour and Duitsman (1971) compared a grain sorghum at the hard-dough stage with a forage sorghum at the medium-dough stage of kernel development. They showed that by adding 3 lbs of rolled grain sorghum per day to the forage sorghum silage diet, gains equal to the grain sorghum silage diet could be achieved. Smith et al. (1984) showed that ADF's were lower for a nonheading forage sorghum vs. a heading forage sorghum. Smith et al. (1966) showed increased gains and DM intakes by adding grain to a sterile hybrid.

In contrast to these results, Boren et al. (1963) found no difference in daily gain when comparing high grain-content and low to moderate grain-content sorghum hybrids.

Owen (1967) concluded that an increase in grain content decreased the adverse effects of advancing maturity. Hybrids with higher grain content compensated for the lower fiber digestibility. This researcher recommended harvesting at the mature grain stage to achieve the highest DM yield/acre and greatest silage intake. But others (Owen, 1967) report high numbers of undigested kernels (26 to 49% of the kernels ingested) when feeding sorghum silage harvested at the mature stage. The inability of the animal to digest sorghum grain does not entirely explain the low performance (Schmid et al., 1976).

Fiber component digestibilities have been shown to change with maturity. Cellulose digestibility decreases with maturity (Johnson et al., 1971). Owen (1967) found that the apparent rapid increase of starch in the developing kernel compensated for the decrease in cellulose digestion in higher grain-producing hybrids. Hart (1982) increased the grain content of grain sorghum silage by raising the cutting height and leaving more stalk in the field. The increase in digestibility was not enough to compensate for the 15% decrease in yield from cutting at 4-inch and 16-inch heights.

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Chapter II

EFFECTS OF HYBRID AND HARVEST STAGE ON YIELD, COMPOSIITON, AND FEEDING VALUE OF FORAGE SORGHUM SILAGES

Experimental Procedures

Experiment 1. Three commercial hybrid forage sorghums [Sorghum Bicolor L. (Moench)] were seeded on June 8, 1985 and grown under dryland conditions near Manhattan. The hybrids, Pioneer 947 (medium maturity and high grain producing), Acco Paymaster 351 (medium maturity and high grain producing), and DeKalb FS-25E (late maturity and moderate grain producing), were planted in a randomized complete block design with three replicate plots each. Single plots had 18 rows, .76 m apart and 127 m long. Harvests were made at the late-milk to early-dough stage of kernel development (LM); late-dough stage (LD); post-freeze, hard-grain stage (PFHG); and 2 to 4 weeks post hard-grain stage (PHG).

Crop production practices for the plots included: fertilization with 112 kg of anhydrous ammonia per hectare prior to seeding, Furadan 15G insecticide placed in the furrows at seeding, Ramrod pre-emergence herbicide broadcasted 1 day post-seeding, and Cygon 400 insecticide sprayed July 24 for greenbug control.

At each harvest three rows were chopped as whole-crop forage using a Field Queen forage harvester and heads were hand-cut from two 6.1m random lengths in the fourth row, which also served as a border for the subsequent harvest. The heads were dried, threshed with a stationary thresher, and grain yield adjusted to a 12.5% moisture basis. Samples of the pre-ensiled material were taken from each replicate, frozen, and analyzed later. Plant height was measured prior to the LM stage harvest.

At each harvest, six 208 l metal drum pilot silos lined with 4 mm plastic were filled with fresh, whole-crop material, packed manually, sealed, and incubated at 26 to 27 C for a minimum of 30 days post-filling. The silos were then moved to ambient temperature. During feedout samples were taken from the top, middle, and bottom thirds as each silo was emptied.

Dry matter (DM) content was determined for the pre- and post-ensiled material by drying the samples in a forced-draft oven at 55 C for 72 hours. Dried samples were ground in a Wiley mill to pass through a 1 mm screen in preparation for chemical analyses. Cell wall constituents and hot water insoluble-nitrogen (N) were determined by methods described by Goering and Van Soest (1975). Crude protein (CP) was determined by the Kjeldahl procedure according to AOAC (1984) methods, but using a boric acid modification. Calcium was determined by atomic absorption spectroscopy, potassium by atomic emission spectroscopy, and phosphorus was determined colorimetrically according to AOAC (1984) procedures. A portion of the ensiled material samples not dried was analyzed for pH, lactic acid, volatile fatty acids (VFA), and ammonia-nitrogen. A 25 g aliquot was extracted in 250 ml of distilled water for 2 hours and pH of the supernate determined using an Orion 700 meter. Another 25 g aliquot was extracted in 200 ml of .1N H_2SO_4 for 2 days and the supernate strained through two layers of cheesecloth from the mixture and retained for further analyses. Using the supernate, lactic acid was measured by colorimetric determination (Barker and Summerson, 1941) and VFAs by gas chromatography using a Hewlett Packard 7671A automatic sampler. The VFAs were separated on a 2 mm by 2 m glass column packed with Carbopack B using a flash vaporization inlet, hydrogen flame detection, and an oven temperature of 170 C and nitrogen was the carrier gas. Ammonia-N was determined by the Conway microdiffusion method (Conway, 1957). Buffering capacity (BC) of the forage was determined by methods described by Playne and McDonald (1966).

Thirty crossbred wether lambs were allotted by weight to the 12 diets for the first two periods of a three period digestion trial. Five observations per diet were obtained in the first two periods (three observations for six of the diets and two observations for the remaining six diets in each period). For the third period the lambs were re-weighed and 24 lambs were allotted, two per diet. Diets consisted of 90% silage and 10% supplement on a DM basis and all were formulated to 11.5% crude protein (CP) and to meet the minimum NRC requirements (NRC, 1985) for sheep of their weight (table 1).

Each 22 to 24 day period consisted of an 8 to 10 day acclimation to the diet, a 5 day voluntary intake (VI) determination, a 2 day adjustment to 90% of VI, and a 7 day collection phase. Lambs were housed individually in metal digestion crates and fitted with a canvas harness to collect feces. Daily fecal collections were weighed and a 10 % aliquot was dried and compiled with the other daily aliquots to be ground and sampled for chemical analyses. Dried fecal samples were treated similarly to the dry forage and silage samples.

Experiment 2. Whole-crop silages were made from four forage sorghum hybrids (Pioneer 947, Acco Paymaster 351, DeKalb FS-25E, and Buffalo Canex (an early maturity, high grain producing hybrid) and one grain sorghum (DeKalb DK-42Y), a yellow endosperm, middle maturity, and high grain producing hybrid. Each hybrid was harvested at the late-dough stage of kernel development, with an additional harvest at the post-freeze, hard-grain stage for Pioneer 947. Acco 351, Canex, and DeKalb 42Y were ensiled in concrete stave silos; early-cut (LD) Pioneer 947 and DeKalb 25E were ensiled in Ag Bags; and the late-cut (PFHG) Pioneer 947 was ensiled in an oxygen limiting silo.

The six silages were compared in diets which contained 87.6% silage and 12.4% supplement on a DM basis. Supplement composition is presented in table 1. Each diet was fed to 8 crossbred steer and heifer calves (two pens of three steers and one heifer with an initial average weight of 244.5 kg). Each diet was formulated to contain 12% CP (DM basis), provide 200 mg of monensin/calf daily, and supply required amounts of vitamins and minerals.

To minimize ruminal fill differences, the calves were fed a common forage sorghum silage diet at an intake level of 1.75% of body weight (DM basis) for 1 week prior to starting the experiment. Calves were weighed on 2 consecutive days after 16 hours without feed or water at the beginning and end of the 70-day feeding period (December 6, 1985 to February 14, 1986).

Silage was sampled twice weekly and handled similarly to those in Exp. 1. Feed offered was recorded and adjusted daily to insure ad libitum intakes of fresh, complete-mixed diets. Refused feed in the bunks was collected, weighed, and discarded as necessary.

<u>Statistical analyses.</u> Yield data was statistically analyzed using analysis of variance (ANOVA) procedure, and the remaining data were analyzed using General Linear

Models (GLM) procedure (SAS, 1982). Means for comparing differences were determined by the PDIFF (predicted difference) option of the GLM procedure.

Results

Experiment 1. Agronomic data, including harvest dates, dry matter contents, whole-crop DM and grain yields, and grain:forage ratios are shown in table 2. Whole-crop DM yields and DM contents are also presented graphically in figures 1 and 2, respectively. The hybrid x harvest stage interaction is reported separately from main effects in the appendix, and was used as the data points for all figures. Due to hybrid x harvest stage interaction, in several cases there were no main effects exhibited. Pioneer 947 required only 28 days to advance from LM to PFHG stage, while Acco 351 required 35 days and DeKalb 25E required 44 days. The greatest difference among harvest dates at any of the four stages of maturity was 23 days for Pioneer 947 versus DeKalb 25E at the PFHG stage (October 14 vs. November 7). Whole-crop DM content increased with each successive harvest stage for Pioneer 947, and the DM content of Acco 351 increased after the LD stage. In contrast, DeKalb 25E increased ($P<.05$) in DM content only between the LM and LD harvests, and it increased by only 1.5 percentage units from LD to PHG stage.

Pioneer 947 experienced the greatest drop in whole-crop DM yield as maturity advanced, decreasing by 43.0% from the highest yield of 15.8 metric tons/ha at the LD harvest, to 9.0 metric tons/ha at the PHG harvest. Yield of Acco 351 was the least affected by harvest stage, declining by only 10.5% from the LD to PHG harvest. The drop in DM yield of DeKalb 25E was similar to Pioneer 947, dropping 34% from the LM to PHG harvest. DeKalb 25E had its highest ($P<.05$) DM yield at the LM harvest stage, while both Pioneer 947 and Acco 351 had their highest ($P<.05$) yields at the LD harvest stage.

Grain yields generally increased with harvest stage for Acco 351 and DeKalb 25E, however yield for Pioneer 947 was not affected ($P<.05$) by harvest stage. The grain content of DeKalb 25E increased sharply (28.6%) from the PFHG to the PHG stage. Although grain:forage ratios were not significantly affected by harvest stage, they tended to increase with successive harvests for all three hybrids.

The effects of hybrid and harvest stage on nitrogen fractions and Van Soest constituents are shown in table 3. Presented in figures 3 and 4 are the CP and ADF values, respectively, for the three hybrids at each harvest stage. Acco 351 maintained a higher CP content and ammonia-N (as a % of total N) than the other hybrids. The average of the three hybrids showed decreasing ($P<.05$) CP content with advancing maturity. Hot water insoluble N (as a percent of total N) appeared to decrease with harvest stage, but this trend was not significant. Conversely, ammonia-N increased with advancing maturity.

Percent NDF was highest (P<.05) for Acco 351 and DeKalb 25E silages, but NDF was not affected by harvest stage. Acid detergent fiber values among the three hybrids were highest (P<.05) for DeKalb 25E silages (37.8%) and ADF increased (P<.05) with advancing maturity though the PFHG stage. Hemicellulose content was highest (P<.05) for Acco 351 silages (25.0%).

Nitrogen fractions and Van Soest constituents for the 12 forage sorghum silages in Exp. 1 are presented in appendix table 2.

The effects of hybrid and harvest stage on DM content, pH, and fermentation acids are shown in Table 4. Presented in figures 5, 6, and 7 are pH, lactic, and acetic acid contents, respectively, for the three hybrids at each harvest stage. Dry matter content for the three hybrids were different (P<.05), with Pioneer 947 silages being the driest and DeKalb 25E being the wettest. The DM content of the silages also increased with each harvest stage (P<.05).

Dry matter content, pH, and fermentation acids for the 12 forage sorghum silages in Exp. 1 are presented in appendix table 3.

The effects of hybrid and harvest stage on voluntary intake and apparent digestibility are shown in table 5. Presented in figures 8 and 9 are voluntary intake (as g of DM/kg of metabolic body wt.) and DM digestibility, respectively, for the three hybrids at each harvest stage. The Acco 351 silages had the highest ($P<.05$) voluntary intake, followed in decreasing ($P<.05$) order by Pioneer 947 and DeKalb 25E silages. Voluntary intake was not affected by harvest stage. The three hybrids had similar DM, NDF, and ADF digestibilities; however the DeKalb 25E diets had higher ($P<.05$) CP digestibilities than the Acco 351 diets. Harvest stage did not influence digestibilities of DM, NDF, or ADF; but CP digestibility was highest ($P<.05$) for the PHG silage diets and lowest for LD silage diets.

Voluntary intake and apparent digestibility for the 12 forage sorghum silages in Exp. 1 are presented in appendix table 4.

Experiment 2. Chemical analyses for the six sorghum silages are shown in table 6. The grain sorghum, DeKalb 42Y, had the highest DM (44.0%) and CP (10.0%) contents; Canex, the lowest DM (28.0%); and DeKalb 25E, the lowest CP (4.99%). Van Soest fiber fractions were all lowest for DeKalb 42Y silage. DeKalb 42Y had an ADF value of 19.1% compared with an average ADF of 33.4% for the five forage sorghum silages. Among the forage sorghums, Buffalo Canex silage had the lowest ADF (28.9%) and DeKalb 25E, the highest (37.8%). The lignin content of DeKalb 42Y was less than half the value for the forage sorghum silages.

Performance by the calves fed the six silage diets is presented in table 7. Average daily gain (ADG) was lowest ($P<.05$) for calves receiving DeKalb 25E and PFHG stage Pioneer 947 silages. Although not statistically different, DeKalb 42Y grain sorghum silage supported a 17% higher ADG (on average) than the three high grain-containing forage sorghums (Pioneer 947, Acco 351, and Canex). The PFHG Pioneer 947 silage gave a 25% slower ADG than the LD stage Pioneer 947 silage diet. Calves fed DeKalb 42Y had the highest ($P<.05$) DM intake (8.23 kg/day) and those receiving DeKalb 25E silage, the numerically lowest DM intake (5.78 kg/day). The three high grain-containing forage sorghum silages gave similar DM intakes. Although feed:gain ratios were not different at the $P<.05$ level, the DeKalb 25E silage diet resulted in the poorest feed conversion at the $P<.10$ level of significance. Calves receiving the PFHG Pioneer 947 silage diet required 1.51 more kg of diet DM/kg of gain than those receiving the LD Pioneer 947 silage.

Relative feeding values (RFV), based upon DeKalb 42Y set at 100, showed that the high grain-containing forage sorghum hybrids at the LD stage were within 4.2% (on average) of the grain sorghum silage. The moderate grain-containing DeKalb 25E and the PFHG Pioneer 947 silages had RFV's of 66.2 and 73.9%, respectively.

Discussion

Hybrid maturity differences produced an 8-day range in harvest dates at the LM stage, increasing to a 24-day range in harvest dates by the PFHG stage. The medium-maturity hybrids, Pioneer 947 and Acco 351, required 28 and 35 days, respectively, to advance from the LM to the PFHG stage, while DeKalb 25E required 44 days. The light freeze on September 30 affected grain development in the DeKalb 25E more than the medium-maturity hybrids. The larger increase in grain yield from the LM to LD stage for Acco 351 was mainly due to harvesting the LM stage a few days early. The fluctuations in grain yields within all hybrids with advancing maturity could be explained, in part, by inefficiency of the stationary thresher and/or sampling error within the grain yield rows in the plots. The significant increase in grain yield from the PFHG to PHG stage for DeKalb 25E can not be explained.

The effect of harvest stage on whole-crop DM yield was different for each of the hybrids. For Pioneer 947 the DM yield decreased by 28% from the LD to the PFHG stage and another 20% by the PHG stage. Whole-crop DM yield of DeKalb 25E did not decline until after the PFHG stage, when DM yield dropped by 27% at the last harvest. In contrast, whole-crop DM yield of Acco 351 was not affected by harvest stage and its yield declined only 10% during the 7-week period from October 1 to November 19.

These decreases in DM yield after the LD stage for Pioneer 947 and the PFHG stage for DeKalb 25E agrees with work by Black et al. (1980) who found decreasing yields with advancing maturity after the early-dough stage, but contradicts results by Owen (1962) and Webster (1963) who reported increasing yields with advancing harvest stage.

The wide differences in DM content among the three forage sorghum hybrids is consistent with data reported by Pederson et al. (1982) and Dickerson (1986). The increase in DM content for Pioneer 947 and Acco 351 with advancing harvest stage agrees with results of other researchers (Browning and Lusk, 1967; Danley and Vetter, 1973; Cummins, 1981). The consistently low DM content of DeKalb 25E throughout the harvest stages was also observed by Dickerson (1986). Numerous other late-maturity hybrids have displayed low DM contents (Walter, 1985 and 1986; Kirch et al., 1987).

Whole-crop CP content differed among the hybrids, with Acco 351 having the highest CP and DeKalb 25E, the lowest. Pederson et al. (1982) also found that hybrid affected the amount of CP in forage sorghum hybrids. A similar effect of decreasing CP with advancing harvest stage was reported by several researchers (Johnson et al., 1971; Danley and Vetter, 1973; Schake et al., 1982). The CP content of Pioneer 947 was affected more by harvest stage than the other hybrids, as it lost 2.46 percentage units between the LM and PHG harvest stages.

Hybrid significantly affected all the fiber fractions measured, but the numerical differences were quite small. Harvest stage affected both NDF and ADF values. Although both NDF and ADF increased with advancing maturity in Pioneer 947, Smith (1986) reported no harvest effects from the early-dough to the hard-grain stages for the same hybrid. The decrease in NDF content in Acco 351 at the later harvests agrees with a previous study with this hybrid (Dickerson, 1986). Both Cummins (1981) and Pederson et al. (1982) found that maturity affected Van Soest constituents differently among sorghum hybrids. Black et al. (1980) observed decreasing NDF and ADF values from the milk to hard-dough stages of maturity.

The pH and acid content of the silage was affected by hybrid with the wetter hybrid, DeKalb 25E, having the lowest pH and the highest lactic, acetic, and total acids. While total acid content was affected by hybrid, the lactic:acetic ratio was unaffected. Harvest stage affected the pH, total acids, and lactic:acetic ratio of the forage sorghum silages. The pH increased with advancing harvest, while lactic acid, total acids, and lactic:acetic ratio decreased. In contrast, Dickerson (1986) observed much smaller changes in pH and fermentation end products with Acco 351 and DeKalb 25E silages from the late-milk to the post-freeze, hard-grain stages. However, Jackson and Forbes (1970) and Hinds (1983) found that with increasing DM content the fermentation was restricted and resulted in a higher pH and lower acid containing silage.

Hybrid affected DM intake, with Acco 351 silages having the highest DM intakes/kg metabolic body weight; DeKalb 25E silages, the lowest. The increase in DM intake with increase in DM content of forage sorghum silages observed by Ward et al. (1966) and Brethour (1967) and of grass silages by Wilkins et al. (1971) do not agree with the results obtained with the 12 silages compared here. Although Pioneer 947 silages had higher overall DM contents, Acco 351 silages had higher DM intakes at all four harvest stages. Harvest stage, as a main effect, did not influence DM intake across the three hybrids. This is due to the consistent DM intakes of Acco 351, while intakes of Pioneer 947 decreased drastically for the PHG harvest stage and DeKalb 25E had fairly consistent intakes with the numerically highest intake at the PHG stage. Other authors have reported increases in intake with advancing maturity (Browning and Lusk, 1967; Owen, 1962) but this did not include a "weathered" crop.

Digestibility of fiber fractions and DM were unaffected by hybrid or harvest stage, unlike the findings of Owen and Kuhlman (1967) and Black et al. (1980). Dickerson (1986) also found no differences in the DM or

NDF digestibilities of the Acco 351 and DeKalb 25E, but differences were noted between the ADF digestibilities of DeKalb 25E and Acco 351, with DeKalb 25E having a 7.5 percent higher NDF digestibility than Acco 351. The higher SBM supplementation for the lower CP silages accounted for the more digestible CP values. This does not agree with research by Black et al. (1980) or Owen and Kuhlman (1967), who showed decreasing CP digestibility with advancing maturity, but agrees with work by Dickerson (1986) who showed no change in CP digestibility from anthesis to the post-freeze, hard-grain harvest.

Experiment 2. Grain sorghum silages had a higher DM content than the forage sorghum silages at the same maturity. This was partly due to a later than intended harvest for the DeKalb 42Y, nevertheless this does agree with previous research by Kirch et al. (1987) showing higher DM's for grain sorghum silages. Although not statistically analyzed, CP content was higher and Van Soest fiber fractions lower for the grain sorghum than the forage sorghum silages, which agrees with results by Smith (1986) and Kirch el al. (1987). Fiber fractions and CP for the three forage sorghums in Exp. 1 were generally within standard errors of those in Exp. 2, except for the lower CP content for the LD stage DeKalb 25E silage in Exp. 2.

Performance by the calves fed the six forage and grain sorghum silage diets followed similar trends reported by other researchers. Kirch et al. (1987) also set the RFV of DeKalb 42Y silage at 100 and showed a higher RFV for DeKalb 25E, 88 versus the 66 here, but showed a similar RFV for Canex, 95 versus the 97 here. Pioneer 947, also used in the studies by Kirch et al (1987), had a similar RFV (94 versus 93 in Exp. 2) when compared with the grain sorghum hybrid DeKalb E67. Grain content has been shown to increase the DM intake of forage sorghum silages (Jacques et al., 1986), and in Exp. 1 and 2 intake did not always increase with increasing DM content of the silages. For example, in Exp. 2 Canex had a higher DM intake than DeKalb 25E, which had a higher DM content and a visibly lower grain content. There were no significant differences ($P<.05$) in the DM intake between the Pioneer 947 silages harvested at the LD or at PFHG stages. However, the dry stalk of Pioneer 947, the only one of the five hybrids studied with an extensive woody characteristic, was not readily consumed by either cattle or sheep, especially at the later stage harvested silages.

Average daily gain was affected by hybrid and harvest stage. The medium grain producing hybrid, DeKalb 25E, and the more mature PFHG Pioneer 947 silages gave the slowest gains and the poorest efficiencies.

Results from the first experiment show that forage sorghum hybrid affected forage and grain yields, weathering losses, CP contents, and voluntary intakes. But the DM, ADF, and NDF digestibilities were similar, with the only differences occurring in the digestibility of the CP component. Results from Exp. 2 confirmed differences in voluntary intakes, and showed differences in cattle gains and efficiencies of gain among sorghum hybrids. Harvest stage affected CP digestibilities, with the lower CP silages having more of their dietary nitrogen supplied by highly digestible soybean meal in the supplement. Harvest stage also affected voluntary intakes, especially with the wetter DeKalb 25E and the dry stalk Pioneer 947 silages in both Exp. 1 and 2. Harvest stage did not affect the digestibilities of DM or the Van Soest fractions and harvest stage interacted differently with each hybrid to influence DM intakes in Exp. 1.

In conclusion, large differences in nutrient composition and animal performance occurred among the five forage and grain sorghum hybrids. Since neither hybrid nor harvest stage affected DM digestibilities, harvest stage should optimize silage DM yields and DM intakes, particularly when the silage is to be the major component of growing ruminants' diets.

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TABLE 1. COMPOSITION OF SUPPLEMENTS FED IN EXP. 1 AND 2

Ingredient	Exp. 1			Exp. 2		
	A[1]	B[2]	C[3]	D[4]	E[5]	F[6]
	------------% on a DM basis----------					
Grain sorghum, rolled (IFN 4-20-893)	--	23.6	38.8	74.15	29.65	9.5
Soybean meal (IFN 5-20-637)	75.0	50.8	35.2	13.5	58.7	79.2
Limestone (IFN 6-01-069)	5.9	5.9	5.9	1.85	2.2	2.3
Urea (IFN 5-05-070)	3.3	3.3	3.3	2.5	2.5	2.5
Dicalcium phosphate (IFN 6-01-080)	2.7	3.2	3.5	4.35	3.3	2.85
Salt (IFN 6-04-152)	2.3	2.3	2.3	2.0	2.0	2.0
Soybean oil	.9	.9	.9	--	--	--
Tallow (IFN 4-00-376)	--	--	--	1.00	1.00	1.00
Vitamin and antibiotic premix	.6[a]	.6[a]	.6[a]	.2[b]	.2[b]	.2[b]
Trace mineral premix[6]	.5	.5	.5	.25	.25	.25
Monensin	--	--	--	.185	.185	.185

[1]Fed with Pioneer 947 and DeKalb 25E at the PHG stage.
[2]Fed with Pioneer 947 at the PFHG stage, DeKalb 25E at the LM, LD, and PFHG stages, and Acco 351 at the PHG stage.
[3]Fed with Pioneer 947 at the LM and LD stages and Acco 351 at the LM, LD, and PFHG stages.
[4]Fed with DeKalb 42Y.
[5]Fed with Canex, Acco 351, and Pioneer 947.
[6]Fed with DeKalb 25E.
[a]Formulated to supply 3,000 IU of vitamin A, 300 IU of vitamin D, 3 IU of vitamin E, and 20 mg of aureomycin/lamb/day.
[b]Formulated to supply 25,000 IU of vitamin A, 3,500 IU of vitamin D, 30 IU of vitamin E.
[c]Contained 11% Ca, 10% Mn, 10% Zn, 1% Cu, .3% I, and .1% cobalt.

TABLE 2. HARVEST DATES, PLANT HEIGHTS, DRY MATTER CONTENTS, WHOLE-CROP FORAGE AND GRAIN YIELDS, and GRAIN TO FORAGE RATIOS FOR THE THREE FORAGE SORGHUM HYBRIDS CUT AT FOUR HARVEST STAGES IN EXP. 1

Hybrid and harvest stage[3]	Harvest date	Whole-crop DM	Whole-crop DM yield[1]	Grain yield[1,2]	Grain: forage
	1985	%			
Pioneer 947					
LM (295)	Sept. 16	29.6^d	14.2^b	4.0	.34
LD	Sept. 25	32.3^c	15.8^a	4.8	.37
PFHG	Oct. 14	37.6^b	11.3^c	3.9	.46
PHG	Nov. 18	44.0^a	9.0^d	4.4	.90
Acco 351					
LM (188)	Sept. 19	24.4^c	14.1^{ab}	2.4^b	.18
LD	Oct. 1	26.4^c	15.3^a	4.5^a	.35
PFHG	Oct. 24	36.3^b	14.9^{ab}	4.0^a	.32
PHG	Nov. 19	40.4^a	13.7^b	4.6^a	.49
DeKalb 25E					
LM (325)	Sept. 24	22.8^b	15.9^a	2.0^b	.12
LD	Oct. 7	25.7^a	14.5^{ab}	2.1^b	.14
PFHG	Nov. 7	27.8^a	14.3^b	2.5^b	.19
PHG	Nov. 19	27.2^a	10.5^c	3.2^a	.40
Standard error		.8	.26	.8	NS

[1]Metric tons/hectare.
[2]Adjusted to 12.5% moisture.
[3]Plant height (cm) at the LM harvest stage in parenthesis.
[abcd]Means within a hybrid with different superscripts differ (P<.05).

FIGURE 1. EFFECTS OF HYBRID AND HARVEST STAGE ON WHOLE-CROP DM YIELD (METRIC TONS/HA) FOR THE FORAGE SORGHUM SILAGES IN EXP.1

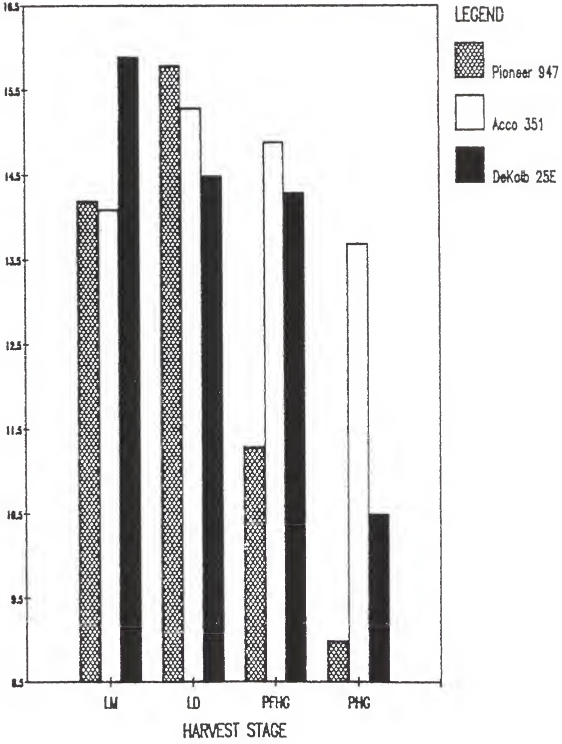

FIGURE 2. EFFECTS OF HYBRID AND HARVEST STAGE ON DM CONTENT (%) FOR THE FORAGE SORGHUM SILAGES IN EXP. 1

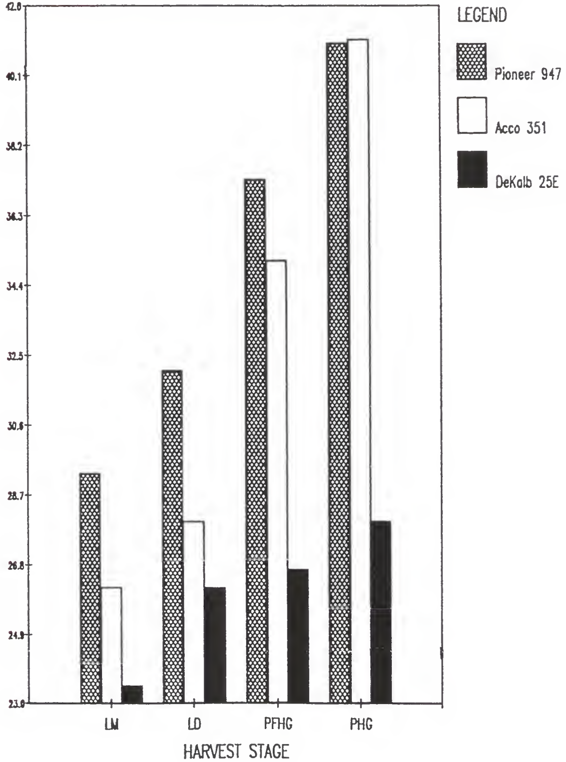

TABLE 3. EFFECTS OF HYBRID AND HARVEST STAGE ON NITROGEN FRACTIONS AND VAN SOEST CONSTITUENTS FOR THE FORAGE SORGHUM SILAGES IN EXP. 1

Hybrid and harvest stage	Chemical component[12]						
	CP	Total N	HWIN	NH_3N	NDF	ADF	HC
Hybrid							
Pioneer 947	7.84[b]	1.25[b]	62.4	5.57[b]	59.1[a]	35.5[b]	23.6[b]
Acco 351	8.59[a]	1.37[a]	54.4	7.70[a]	60.3[a]	35.2[b]	25.0[a]
DeKalb 25E	7.18[c]	1.15[c]	57.8	5.18[b]	60.2[a]	37.8[a]	22.7[b]
Standard error	.04	.01		.3	.4	.3	.4
Harvest stage							
LM	8.40[a]	1.34[a]	79.0	4.84[a]	61.0	35.5[b]	25.3[a]
LD	8.14[b]	1.30[b]	70.0	5.53[a]	59.4	34.4[c]	24.9[a]
PFHG	7.70[c]	1.23[c]	72.0	6.72[b]	60.3	37.0[a]	23.3[b]
PHG	7.25[d]	1.16[d]	63.7	7.51[b]	59.3	37.7[a]	21.5[c]
Standard error	.04	.01		.4	NS	.4	.5

[1]CP=crude protein, N=nitrogen, HWIN=hot water insoluble-nitrogen, NH_3=ammonia, NDF=neutral detergent fiber, ADF=acid detergent fiber, HC=hemicellulose.
[2]CP, Total N, NDF, ADF, and HC expressed as a % of the silage DM; HWIN and NH_3-N as a % of total nitrogen.
[abcd]Means with different superscripts differ ($P<.05$).

FIGURE 3. EFFECTS OF HYBRID AND HARVEST STAGE ON CRUDE PROTEIN CONTENT (% OF THE SILAGE DM) FOR THE FORAGE SORGHUM SILAGES IN EXP.1

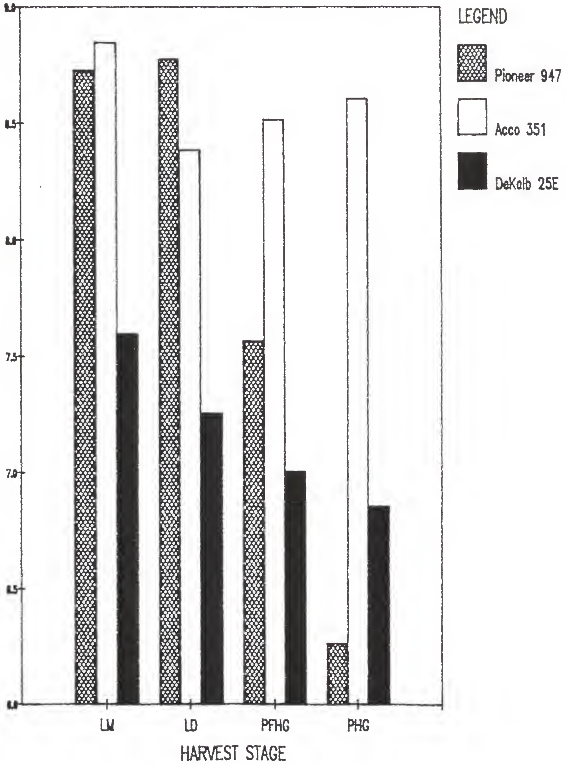

FIGURE 4. EFFECTS OF HYBRID AND HARVEST STAGE ON ADF CONTENT (% OF THE SILAGE DM) FOR THE FORAGE SORGHUM SILAGES IN EXP. 1

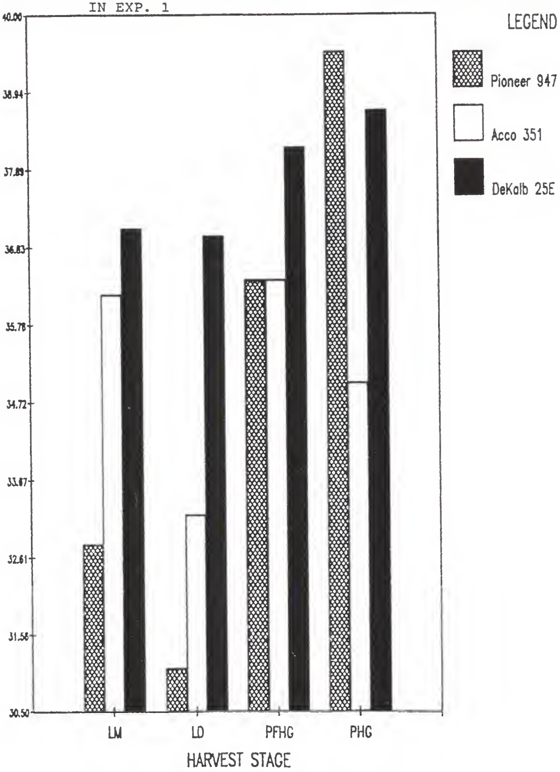

TABLE 4. EFFECTS OF HYBRID AND HARVEST STAGE ON DRY MATTER CONTENT, pH, AND FERMENTATION ACIDS FOR THE FORAGE SORGHUM SILAGES IN EXP. 1

Hybrid and			Fermentation acids			Lactic:
harvest stage	DM	pH	Lactic	Acetic	Total	acetic
	%		---% of the silage DM---			
Hybrid						
Pioneer 947	34.9[a]	4.09[b]	4.3[a]	1.54[a]	5.87[b]	3.2
Acco 351	32.6[b]	4.17[a]	4.6[a]	1.59[a]	6.25[b]	3.3
DeKalb 25E	26.1[c]	3.86[c]	5.8[b]	1.97[b]	7.80[a]	3.2
Standard error	.1	.02	.2	.06	.20	NS
Harvest stage						
LM	26.3[d]	3.88[a]	6.0[a]	1.71	7.75[a]	3.9[a]
LD	28.8[c]	4.06[b]	5.1[b]	1.54	6.68[b]	3.7[a]
PFHG	33.0[b]	4.05[b]	4.5[c]	1.80	6.38[bc]	2.7[b]
PHG	36.7[a]	4.18[c]	4.0[c]	1.75	5.76[c]	2.5[b]
Standard error	.1	.03	.2	NS	.23	.2

[abc]Means with different superscripts differ ($P<.05$).

FIGURE 5. EFFECTS OF HYBRID AND HARVEST STAGE ON THE pH FOR THE FORAGE SORGHUM SILAGES IN EXP. 1

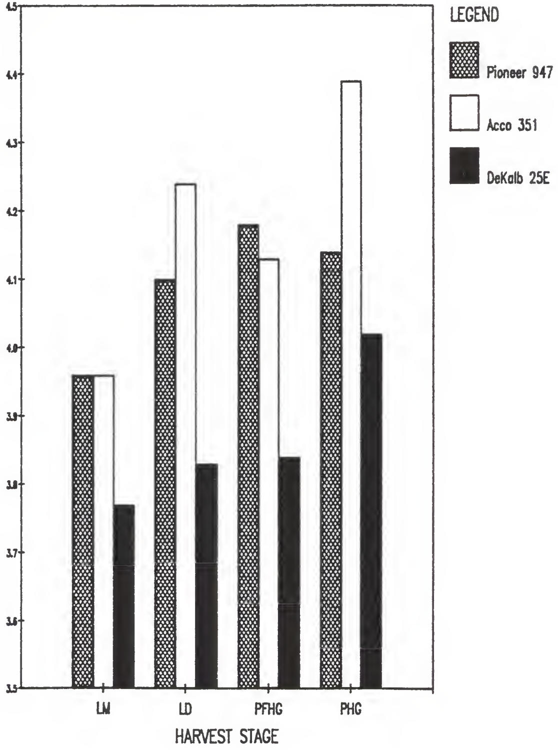

FIGURE 6. EFFECTS OF HYBRID AND HARVEST STAGE ON LACTIC ACID CONTENT (% OF THE SILAGE DM) FOR THE FORAGE SORGHUM SILAGES IN EXP. 1

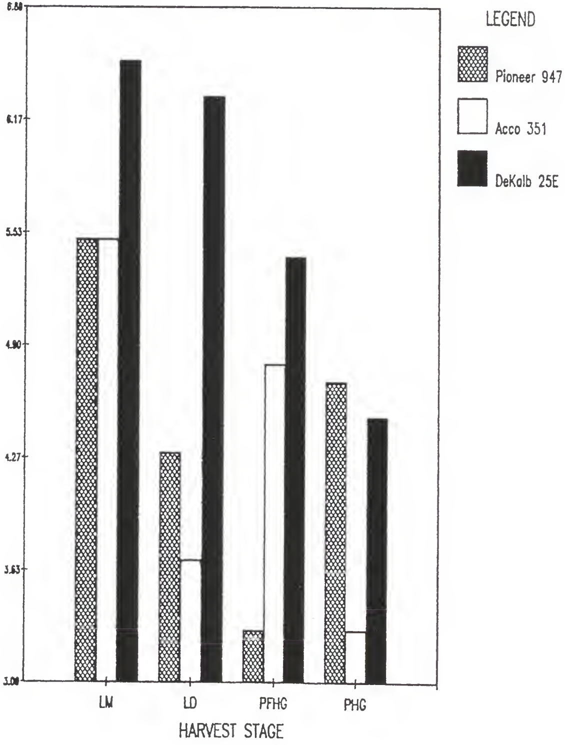

FIGURE 7. EFFECTS OF HYBRID AND HARVEST STAGE ON ACETIC ACID CONTENT (% OF THE SILAGE DM) FOR THE FORAGE SORGHUM SILAGE IN EXP. 1

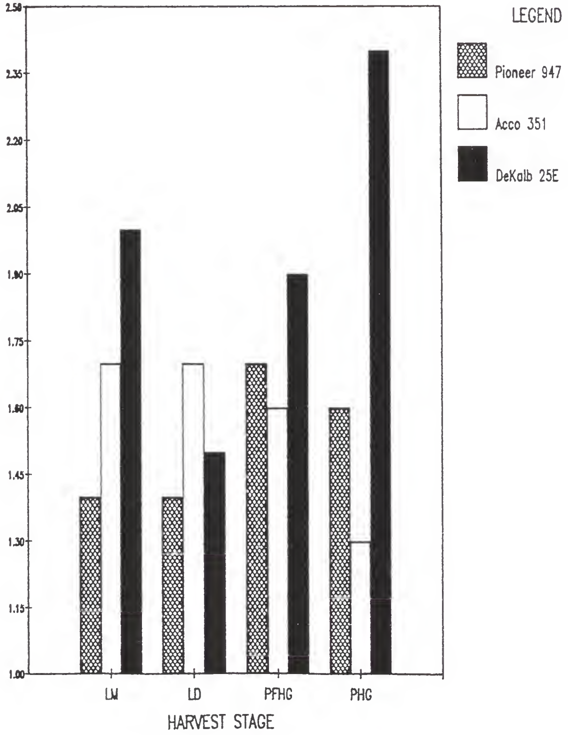

TABLE 5. EFFECTS OF HYBRID AND HARVEST STAGE ON VOLUNTARY INTAKE AND APPARENT DIGESTIBILITY FOR THE FORAGE SORGHUM SILAGE DIETS IN EXP. 1

Hybrid and harvest stage	VI[1] g DM/ d	VI[1] g DM/ kg MBW[1]	Digestibility, % DM[1]	Digestibility, % CP	Digestibility, % NDF	Digestibility, % ADF
Hybrid						
Pioneer 947	509[b]	30.0[b]	55.2	58.6[b]	44.9	36.8
Acco 351	585[a]	34.7[a]	54.8	60.5[ab]	44.0	38.7
DeKalb 25E	457[c]	26.7[c]	55.2	62.6[a]	40.7	35.6
Standard error	16.6	.9	NS	1.0	NS	NS
Harvest stage						
LM	480	28.2	55.0	58.6[bc]	43.5	34.5
LD	543	32.1	54.8	56.0[c]	43.4	35.1
PFHG	533	31.2	54.7	61.2[b]	43.6	38.4
PHG	511	30.1	54.2	66.4[a]	42.3	40.2
Standard error	NS	NS	NS	1.1	NS	NS

[1]VI=voluntary intake, MBW=metabolic body wt. (wt.$^{.75}$), DM=dry matter, CP=crude protein, NDF=neutral detergent fiber, ADF=acid detergent fiber.

[abc]Means with different superscripts differ ($P<.05$).

FIGURE 8. EFFECTS OF HYBRID AND HARVEST STAGE ON VOLUNTARY INTAKE (g OF DM/kg MBW) FOR THE FORAGE SORGHUM SILAGE DIETS IN EXP. 1

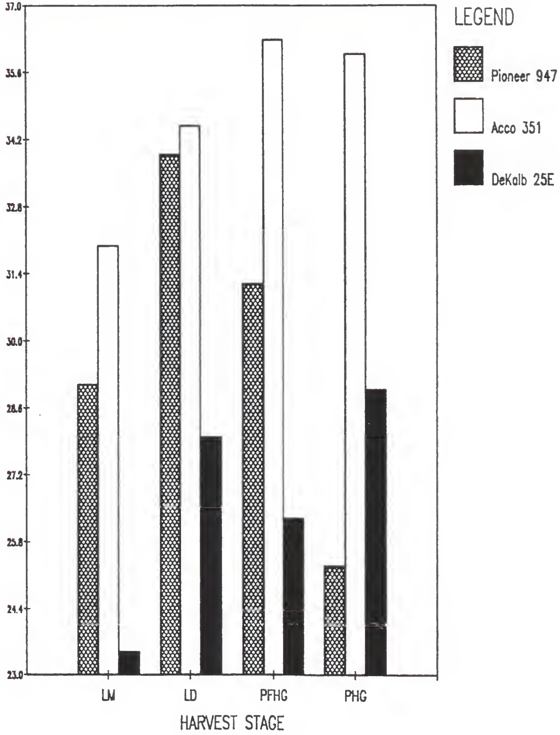

FIGURE 9. EFFECTS OF HYBRID AND HARVEST STAGE ON DM DIGESTIBILITY (%) FOR THE FORAGE SORGHUM SILAGE DIETS IN EXP. 1

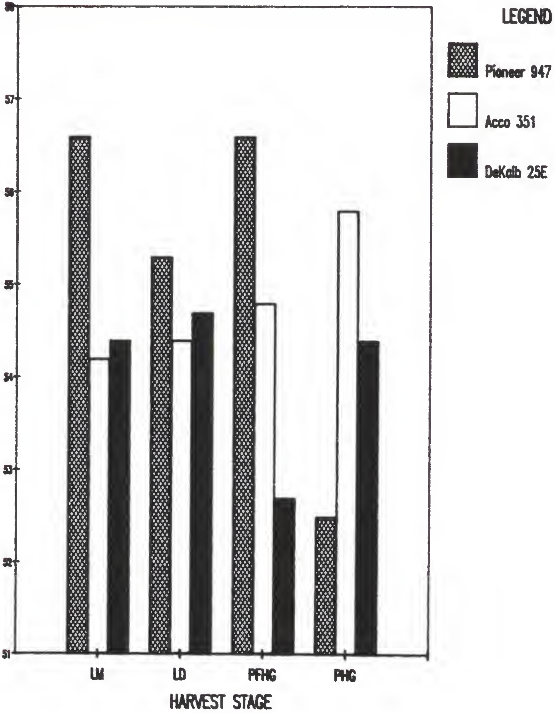

TABLE 6. CHEMICAL ANALYSES FOR THE SIX FORAGE AND GRAIN SORGHUM SILAGES IN EXP. 2

Hybrid and harvest stage[1]	DM	CP[2]	NDF	ADF	HC	CELL	LIGNIN
	%	-----------% of the silage DM-----------					
Pioneer 947 LD (Sept. 27)	37.0	7.8	54.1	32.6	21.5	22.4	7.5
PFHG (Oct. 21)	47.0	7.6	62.0	35.1	25.8	25.9	8.1
Acco 351 (Sept. 26-27)	32.6	8.3	61.3	32.5	28.8	22.8	7.0
DeKalb 25E (Oct. 8)	30.4	5.0	58.6	37.8	20.8	27.4	7.5
Canex (Sept. 16)	28.0	8.8	54.1	28.9	25.2	20.6	6.1
DeKalb 42Y (Oct. 7)	44.0	10.0	36.9	19.1	17.8	13.8	3.1

[1]Harvest date in parenthesis (1985).

[2]CP=crude protein, NDF=neutral detergent fiber, ADF=acid detergent fiber, HC=hemicellulose, Cell=cellulose.

TABLE 7. PERFORMANCE BY CALVES FED THE SIX SILAGE DIETS IN EXP. 2

	Hybrid						
	Pioneer 947[1]		Acco	DeKalb		DeKalb	
Item	LD	PFHG	351	25E	Canex	42Y	SE
No. of calves	8	8	8	8	8	8	
Initial wt, kg	244	244	242	246	245	246	
Avg daily gain, kg	.92[a]	.69[b]	.98[a]	.61[b]	.95[a]	1.11[a]	.06
Daily DM intake, kg	6.64[bc]	5.96[cd]	6.82[b]	5.78[d]	6.52[bcd]	8.23[a]	.25
Feed/gain	7.19[e]	8.70[ef]	6.99[e]	9.61[f]	6.91[e]	7.45[e]	.60
RFV[2]	93.2	73.9	97.4	66.2	96.7	100	

[1]Harvested at the late-dough (LD) and post-freeze, hard-grain (PFHG) stages.
[2]RFV=relative feeding value.
[abcd]Means with different superscripts differ ($P<.05$).
[ef]Means with different superscripts differ ($P<.10$).

APPENDIX

APPENDIX TABLE 1. BUFFER CAPACITY (BC), AND MINERAL ANALYSES FOR THE PRE-ENSILED FORAGE SORGHUMS IN EXP. 1

Hybrid and harvest stage	BC	Minerals Ca	P	K
	---------% of the silage DM---------			
Pioneer 947				
LM	24.5	.206	.258	.91
LD	28.2	.204	.346	.89
PFHG	19.8	.193	.243	1.43
PHG	18.7	.170	.252	1.07
Acco 351				
LM	29.0	.262	.374	1.30
LD	33.2	.234	.289	.79
PFHG	----	.195	.282	1.10
PHG	23.1	.177	.283	.84
DeKalb 25E				
LM	28.4	.196	.301	1.10
LD	26.6	.195	.256	1.30
PFHG	24.9	.200	.258	1.32
PHG	21.1	.182	.223	1.31
Standard error[1]		.009	NS	.108

[1]Standard error of the hybrid x harvest interaction term.

APPENDIX TABLE 2. NITROGEN FRACTIONS AND VAN SOEST CONSTITUENTS FOR THE 12 FORAGE SORGHUM SILAGES IN EXP. 1

Hybrid and harvest stage	Chemical component[1,2]						
	CP	Total N	HWIN	NH_3N	NDF	ADF	HC
Pioneer 947							
LM	8.73[ab]	1.39[ab]	65.3	4.20	57.3[a]	32.8[a]	24.5
LD	8.78[ab]	1.40[ab]	57.3	5.66	57.2[a]	31.1[a]	24.1
PFHG	7.57[e]	1.21[e]	63.0	6.29	60.3[bc]	36.4[cde]	23.9
PHG	6.27[h]	1.00[h]	64.6	6.11	61.6[cd]	39.5[g]	22.1
Acco 351							
LM	8.85[a]	1.42[a]	53.7	5.64	63.2[d]	36.2[cd]	27.0
LD	8.39[d]	1.34[d]	53.7	6.32	60.2[bc]	33.2[ab]	27.0
PFHG	8.52[cd]	1.36[cd]	57.7	8.62	60.1[bc]	36.4[cde]	23.7
PHG	8.61[bc]	1.39[bc]	51.2	10.21	57.6[a]	35.0[bc]	22.6
DeKalb 25E							
LM	7.60[e]	1.22[e]	46.6	4.68	62.3[bc]	37.1[def]	25.2
LD	7.26[f]	1.16[f]	50.1	4.60	61.0[bcd]	37.0[def]	24.0
PFHG	7.01[g]	1.12[g]	54.3	5.26	60.4[bc]	38.2[efg]	22.2
PHG	6.86[g]	1.10[g]	49.7	6.20	58.8[abc]	38.7[fg]	20.1
Standard error	.08	.01	.01	NS	.9	.7	NS

[1]CP=crude protein, N=nitrogen, NH_3=ammonia, NDF=neutral detergent fiber, ADF=acid detergent fiber, HC=hemicellulose.

[2]CP, Total N, NDF, ADF, and HC expressed as a % of the silage DM; HWIN and NH_3-N as a % of total nitrogen.

[abcdefghi]Means within a column with different superscripts differ (P<.05).

APPENDIX TABLE 3. DRY MATTER CONTENT, pH, AND FERMENTATION ACIDS FOR THE 12 FORAGE SORGHUM SILAGES IN EXP. 1

Hybrid and harvest stage	DM	pH	Fermentation acids: Lactic	Fermentation acids: Acetic	Fermentation acids: Total	Lactic: acetic
	%		-------% of the silage DM-----			
Pioneer 947						
LM	29.3^{e}	3.96^{bc}	5.7	1.4^{ab}	7.1	4.3^{f}
LD	32.1^{f}	4.10^{de}	4.4	1.4^{ab}	5.8	3.5^{def}
PFHG	37.3^{h}	4.18^{ef}	3.6	1.7^{bcd}	5.3	2.6^{abc}
PHG	41.0^{i}	4.14^{def}	3.6	1.6^{abc}	5.2	2.4^{ab}
Acco 351						
LM	26.2^{b}	3.96^{bc}	5.7	1.7^{bcd}	7.4	3.9^{ef}
LD	28.0^{d}	4.24^{f}	4.6	1.7^{bcd}	6.3	3.2^{bcde}
PFHG	35.1^{g}	4.13^{def}	4.6	1.7^{abc}	6.4	2.8^{abcd}
PHG	41.1^{i}	4.39^{g}	3.6	1.3^{a}	4.9	3.2^{bcde}
DeKalb 25E						
LM	23.5^{a}	3.77^{a}	6.6	2.0^{de}	8.7	3.3^{cde}
LD	26.2^{bc}	3.83^{ab}	6.4	1.5^{ab}	7.9	4.4^{f}
PFHG	26.7^{c}	3.84^{ab}	5.5	1.9^{cd}	7.5	2.9^{abcd}
PHG	28.0^{d}	4.02^{cd}	4.8	2.4^{e}	7.2	2.0^{a}
Standard error	.18	.05	NS	.14	NS	.3

[abcdefghi]Means within the same column with different superscripts differ ($P<.05$).

APPENDIX TABLE 4. EFFECTS OF FORAGE SORGHUM HYBRID AND HARVEST STAGE ON DIET VOLUNTARY INTAKE AND APPARENT DIGESTIBILITY IN EXP. 1

Hybrid and harvest stage	VI[1] g DM/ d	VI[1] g DM/ kg MBW[1]	Digestibility, % DM[1]	CP	NDF	ADF
Pioneer 947						
LM	496[bcde]	29.1[bc]	56.6	55.8	44.6	31.4
LD	571[efgh]	33.9[de]	55.3	53.3	45.0	34.3
PFHG	530[cdefg]	31.2[cd]	56.6	61.4	46.4	42.7
PHG	437[ab]	25.3[ab]	52.5	64.0	43.5	38.9
Acco 351						
LM	535[defg]	32.0[cde]	54.2	58.4	36.9	44.8
LD	588[fgh]	34.5[de]	54.4	54.6	34.7	42.4
PFHG	621[h]	36.3[e]	54.8	60.0	37.7	45.3
PHG	595[h]	36.0[e]	55.8	69.0	45.7	43.6
DeKalb 25E						
LM	410[a]	23.5[a]	54.4	61.7	35.3	41.2
LD	471[abcd]	28.0[bc]	54.7	60.3	36.5	42.7
PFHG	449[abc]	26.3[ab]	52.7	62.0	34.8	39.2
PHG	500[bcdef]	29.0[bc]	54.4	66.3	35.9	39.8
Standard error	31.5	1.6	NS	NS	NS	NS

[1]VI=voluntary intake, MBW=metabolic body wt. (wt.$^{.75}$), DM=dry matter, CP=crude protein, NDF=neutral detergent fiber, ADF=acid detergent fiber.

[abcdefgh]Means with different superscripts differ ($P<.05$).

EFFECTS OF HYBRID AND HARVEST STAGE ON YIELD, COMPOSITION, AND FEEDING VALUE OF HYBRID FORAGE SORGHUM SILAGES

by

SUSAN R. HAMMA

B.S., Kansas State University, 1985

AN ABSTRACT OF A MASTER'S THESIS

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Abstract

In Experiment 1, three hybrid forage sorghums (Sorghum bicolor L. Moench), Pioneer 947, Acco Paymaster 351, and DeKalb FS-25E, were grown under dryland conditions in 1985. The hybrids were assigned in a randomized complete block to three replicate plots each. Harvests were made at four maturities: late-milk to early-dough (LM), late-dough (LD), post-freeze, hard-grain (PFHG), and 2-4 wks post hard-grain (PHG). Each forage was ensiled in pilot silos and fed to mature wethers in a three-period voluntary intake and digestion trial. Plant heights ranged from 1.88m for 351 to 3.25m for 25E. Silage dry matter (DM) content increased (P<.05) with advancing maturity for 947 and 351, but 25E did not exceed 28% at any harvest stage. Silage CP content decreased (P<.05) with advancing maturity for 947 and 25E, but not for 351. Whole-crop DM yields were highest at the LM or LD stages; lowest at PHG stage. The range from highest to lowest yield (metric tons of DM/ha) within hybrids were: 947, 15.8 to 9.0; 351, 15.3 to 13.7; and 25E, 15.9 to 10.5. These reductions were due to loss of leaves. Hybrid and harvest stage did not affect DM digestibility (P<.05) and the range within hybrids was: 947, 53.4 to 57.7%; 351, 53.9 to 56.5%; and 25E, 53.5 to 57.2%. Intake as g/kg of body wt$^{.75}$ was highest (P<.001) for 351 (34.7), followed by 947 (29.9) and 25E (26.7). Intake generally increased with maturity for 351 and 25E, but not for 947.

In Experiment 2, six silage diets were compared in a 70 day trial using 48 calves. Included were the three hybrids from Exp. 1, Buffalo Canex (hybrid forage sorghum), and DeKalb DK-42Y (hybrid grain sorghum) which were all harvested at the LD stage, plus 947 harvested at the PFHG stage. The 42Y silage supported the highest gain and DM intake; 25E and 947 (PFHG), the lowest ($P<.05$) gains and intakes. Calves fed 42Y, 947,351, and Canex had similar feed:gain ratios.

In summary, hybrid affected yield, composition, and cattle performance; but not digestibility of the silage diets. Harvest stage affected yield, composition, and cattle gains; but not intake or feed conversion. The 351 was less affected by weather exposure than 947 or 25E.