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Brown Mid-rib and Photoperiod-Sensitive Forage Sorghums

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Introduction

Hay and silage crops are integral parts of beef production in the Great Plains. In the southern Great Plains, a growing dairy industry is adding demand for silage and hay. Corn silage has long served the region well, producing consistent high quality silage. However, many areas of the southern Great Plains no longer have the irrigation capacity to successfully produce corn silage. Forage sorghums are a viable alternative crop under these conditions. They can be planted later than corn, use water more efficiently and hence still produce acceptable silage yields when planting is delayed, irrigation capacity is limited or droughtier growing conditions.

Brown Midrib Genotypes

The *bmr* mutation has been identified in or introduced into corn (Eyster, 1926), sorghum (Porter et al. 1978), sudangrass, and pearl millets (Cherney et al., 1988). The name brown midrib (*bmr*) refers to the reddish-brown pigmentation of the midrib of the leaves of these phenotypes. In sorghums, the dissected stalk has reddish-brown pigmentation in the pith of the stem and is associated with the vascular tissue. The pigmentation in the leaf midrib can fade as the plant matures and hence is not always apparent; however the pigmentation in the stalk remains in mature plants.

The *bmr* trait is recessive. When present in the homozygous state, the *bmr* mutation is associated with reduced lignin content and higher forage digestibility (Porter et al., 1978; Cherney et al., 1986; Pedersen, J.F. 1996; Casler et al., 2003).

Porter et al. (1978) originally produced 19 *bmr* sorghum mutants by chemically treating seed from two grain sorghum lines. These mutants were numbered *bmr* 1 to *bmr* 19; the numbers did not represent different loci. Of these original 19 mutants, 13 were selected for further evaluation in paired field plots with their normal sisters. Based on two years of field evaluation, Porter et al. (1978) suggested that the *bmr*-6, *bmr*-12, and *bmr*-18 should be selected for further evaluation.). However, the *bmr*-6 and *bmr*-12 genotypes are more prevalent than the *bmr-18*. Comparative data for three genotypes from Porter's work are shown in table 1 and illustrate the reduction in lignin content and the concomitant increase in digestibility of the plant fractions. In the introduction to a recent manuscript, Oliver et al. (2004) indicated that *bmr*-12 and *bmr*-18 may be allelic.

Based on contacts with the seed industry, all three of these genotypes are represented in commercially available varieties of forage sorghum (B. Bean, personal communication). However, the *bmr*-6 and *bmr*-12 genotypes seem to be more prevalent.

Table 1. Lignin (%), in vitro dry matter disappearance (%, IVDMD), and in vitro cell wall disappearance (%, IVCWD) of three sorghum *bmr* genotypes and their normal sisters (Porter et., 1978)[b]

	Lignin		IVDMD		IVCWD	
	Leaf	Stem	Leaf	Stem	Leaf	Stem
bmr-6	5.02 [a]	4.38[a]	63.5 [a]	64.0[a]	70.8	61.9
Normal	6.25	6.12	59.5	57.5	68.4	55.4
bmr-12	4.73	3.46 [a]	66.0 [a]	74.0[a]	79.0 [a]	76.9 [a]
Normal	5.56	5.89	55.8	60.4	64.2	53.7
bmr-18	5.23 [a]	3.45 [a]	64.3 [a]	74.4 [a]	72.9 [a]	77.3 [a]
Normal	6.84	6.28	56.3	59.9	58.2	64.5

[a]Normal and *bmr* are different, P<0.05.
[b]Two years of data for lignin and IVDMD of stems; one year of data for all others.

Photoperiod-sensitive Genotypes

The transition from vegetative to reproductive growth in sorghums and sorghum-sudangrasses hastens the decline in quality of the vegetative portion of the plant. Floral initiation is affected by several environmental factors but daylength is probably the most important (Morgan et al., 2002). Regulation of flowering by daylength is referred to as photoperiodism.

The range in maturity classes for sorghums reflect different degrees of photoperiod sensitivity. Six maturity genes have been identified in sorghum and are designated Ma_1, *Ma* Ma_3, Ma_4, Ma_5, and Ma_6 (Morgan et al., 2002). Rooney and Aydin (1999) recently recognized and described the Ma_5 and Ma_6 genes. When both of these are present in their dominant forms, they delay flowering from 60-70 days until 170-190 days (Rooney and Aydin, 1999). Floral initiation will not occur until daylength is less 12 hours and 20 minutes. The Ma_5 and Ma_6 genes have been used to produce hybrid forages that are extremely photoperiod sensitive and do not flower until very late in the growing season (Morgan et al., 2002). To date, these genes have had no pleiotropic effects (Morgan et al., 2002).

A limited number of photoperiod-sensitive (PS) varieties are commercially available. Some are forage sorghums and some are sorghum-sudangrass hybrids. The delayed flowering is proposed to slow the decline in forage quality associated with floral initiation. This would provide flexibility in harvest management for producers. In our trials (discussed later), the PS varieties have not flowered before October 1; many have not flowered by harvest in early to mid-October. The PS varieties have produced high yields of forage but nutritional values have been inferior to normal or brown midrib varieties.

Combined Brown Midrib/Photoperiod-sensitive Genotypes

A limited number of varieties are available that contain both the *bmr* and PS traits. This combination is designed to take advantage of the improved nutritional value of the *bmr* genotype, and the delayed flowering and potentially higher yields of the PS genotype. Because of limited observations, these varieties are not discussed in the following section. Based on the limited observations, the nutritional value and yields of these *bmr*-PS varieties are intermediate the *bmr* and PS types.

Variety Evaluations at Texas A&M University, Amarillo

Since 2000, we have conducted variety tests at the Texas A&M Bush Farm in Bushland, Texas (approximately 10 miles west of Amarillo). The variety trials have included between 53 and 92 varieties depending on the year. All varieties entered were at the discretion of the companies. Varieties included normal and *bmr* forage sorghums, sorghum-sudangrasses and PS varieties. The ensuing discussion on nutritional values focuses only on the forage sorghums.

The varieties were planted in a randomized block design with three blocks. The trials were considered to be fully irrigated with water applied as needed. Irrigation was scheduled by monitoring gypsum blocks placed in the soil at depths of 1, 2, and 3 feet. Moisture blocks were read every two to three days and plots were irrigated when the average of the three moisture blocks fell below 60. Seeding rate was 120,000 seed/acre and fertilizer rate of N and P varied each year depending on soil test analysis. Beginning in late August, grain development of each variety was checked weekly. Each variety was harvested as the grain for that variety reached the soft dough stage. Photoperiod sensitive varieties were harvested on the last harvest date of the season (October 10 - 15).

Corn varieties were planted adjacent to the sorghum silage trial for comparison. This data was not included in the statistical analysis but will be mentioned for comparative purposes. Plots were irrigated based on gypsum block readings at soil depths of 1, 2, and 3 feet. Four samples were collected from each variety plot (strip) for yield and nutrient composition determination when 1/2-2/3 milkline for each variety.

At harvest whole plant subsamples were collected from the yield sample from each replicate plot of each variety and passed through a limb chipper. Samples from replicate plots were not composited. The chopped material was subsampled to determine moisture and pre-ensiled nutrient profiles. Laboratory analyses were conducted by the Dairy One Forage Laboratory, Ithaca, NY. Lab analyses included CP%, NDF%, ADF%, Lignin% (ADL), in vitro true digestibility %(IVTD), indigestibility NDF%. Digestible NDF (%NDF) was calculated using these values. All lab analyses were wet lab procedures.

Detailed information and reports for each year can be found at:
http://amarillo.tamu.edu/programs/agronomy/publications/Forage%20Sorghum/index.htm

Comparison of *bmr*, PS and normal (non-*bmr*) forages

Data compiled for the three types of forage sorghum over 5 production years are presented in table 2. These data represent the means for the categories and may not be indicative of the performance of varieties within each category. Standard deviations around the means for each category are listed below the means to describe the variation within the category. In the discussion, non-*bmr* refers to the normal genotype of forage sorghum.

Yield As a group, the PS varieties produced the highest yields while the *bmr* varieties had the lower average yields. The PS group yielded 20.5% more tonnage than the non-*bmr* group. This average is influenced by high yields in one year of the trials (see figure 1). The 11.8% yield reduction of *bmr* group compared to non-*bmr* group is not unprecedented. Yield drag has been a concern with *bmr* varieties (Kalton, 1988). The standard deviations within each group (Table 1) and the scatter plot in figure 2 illustrate that, although there are statistical differences among groups, overlap occurs between types. Hence, just because a variety is a *bmr* genotype does not mean it will suffer from lower yields. It is possible to select a *bmr* variety with yields comparable to some of the higher non-*bmr* yields.

Corn silage yields averaged 8.5 tons DM/ac over the years of evaluation. So under the conditions of these trials, there a varieties of both non-*bmr* and *bmr* forage sorghum that have produced yields comparable to corn for silage. On average the PS varieties have produced higher yields than corn. The forage sorghums have produced these yields on less seasonal irrigation. Irrigation water use efficiency, defined as tons of 65% moisture forage/acre-inch of irrigation water, averaged 1.01 tons/ac-in for corn, 1,65 tons/ac-in for non-*bmr* forage sorghum, 1.5 tons/ac-in for *bmr* forage sorghum, and 2.2 tons/ac-in for PS forage sorghum.

Table 2. Forage sorghum characteristics by type (2000-2004).

Characteristic		Non-BMR[1]	BMR	PS	SEM	P value
Yield, tons DM/ac	Mean	8.5[a]	7.5[b]	10.7[c]	0.45	<0.001
	s.d.	1.8	1.8	2.9		
CP, % DM	Mean	7.3[a]	7.9[b]	6.0[c]	0.27	<0.001
	s.d.	1.2	1.0	0.9		
NDF, % DM	Mean	46.6[a]	45.5[a]	64.4[b]	1.36	<0.001
	s.d.	6.1	4.9	4.8		
ADF, % DM	Mean	28.0[a]	27.0[a]	39.4[b]	0.94	<0.001
	s.d.	4.1	3.3	4.8		
IVTD, % DM	Mean	76.2[a]	80.7[b]	68.5[c]	0. 90	<0.001
	s.d.	4.3	2.3	2.6		

[1]Non-BMR, n = 154 entries; BMR, n = 99 entries; PS, n = 17 entries.

When comparing yield to in vitro true digestibility (IVTD; Figure 1), varieties containing the BMR trait maintained a higher digestibility compared to Non-BMR and PS varieties. The PS varieties have a lower digestibility compared to the other forage sorghum varieties; however, the high yielding capability of this variety indicates that it may have a place in feeding operations where quality is of lesser importance.

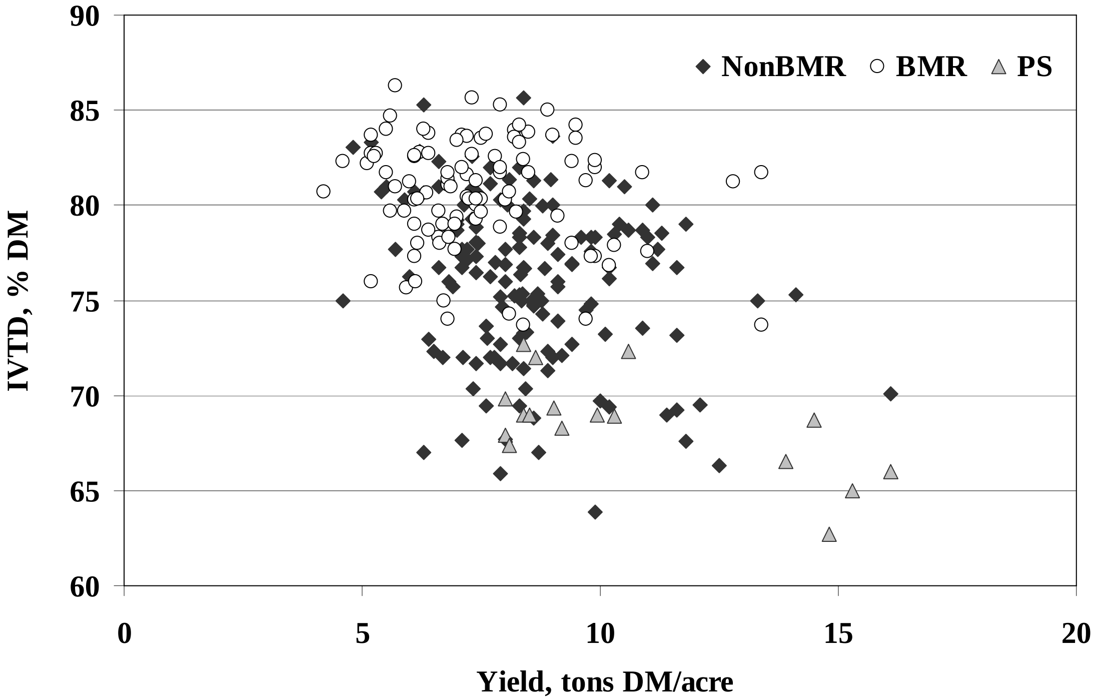

Figure 1. Yield and in vitro true digestibility for in pre-ensiled normal (non-BMR), brown midrib (BMR), and photoperiod-sensitive (PS) forage sorghums prior to ensiling in years 2000-2004. Each point represents the value of one variety in one year.

<u>Fiber components</u> The fiber components of *bmr* and *non-bmr* forage sorghums were not different (Table 2). The NDF and ADF fractions were higher for the PS group than for the other two groups of forage sorghums. Lignin analysis was conducted in four of the five years. Over this time, the average lignin concentration was 23% lower for the *bmr* group compared to non-*bmr* group (ave. 4.3% lignin), and 21% higher in the for PS group compared to the non-*bmr* group. Pre-ensiled corn forage averaged 43% NDF and 3.1% lignin over the same time period.

The average NDF values for the forage sorghums were numerically higher than those observed for corn. The range of NDF values over the past three years of the trials are shown on the x-axis in figure 2. Using the corn NDF value as an index, these scatter plots demonstrate that there are opportunities to select varieties with similar or lower NDF concentrations if that is an objective.

<u>In vitro true digestibility (IVTD)</u> IVTD values are shown in Table 2. IVTD was determined using a 48 h incubation in ruminal fluid followed by an NDF extraction. IVTD values are higher than in vitro dry matter disappearance values measured using a two stage rumen fluid-pepsin method. IVDMD can generally be estimated by subtracting 11.9 from IVTD (Dairy One, 2005).

The *bmr* group was 5.3% more digestible than the non-*bmr* group while IVTD for the PS group was 10.1% lower than the non-*bmr* group. The range of IVTD observed over the five years are shown in Figure 1. As with yield, the ranges of IVTD overlap among the *bmr* and non-*bmr*. Hence, the *bmr* label on a variety does not guarantee superior digestibility and nutritional value, and the normal or non-*bmr* label should not imply that a variety has inferior digestibility and nutritional value. Our data suggest that decisions should be made based on the variety and not the genotype designation.

Over the years, pre-ensiled corn forage averaged 81.5% IVTD; ranging from 77.7 to 84.1% IVTD. As seen in figure 1, a number of observations for the *bmr* sorghum forages were within this same range and similar to or higher than the average for corn. Based on IVTD, there are *bmr* forage sorghum varieties that can replace corn silage.

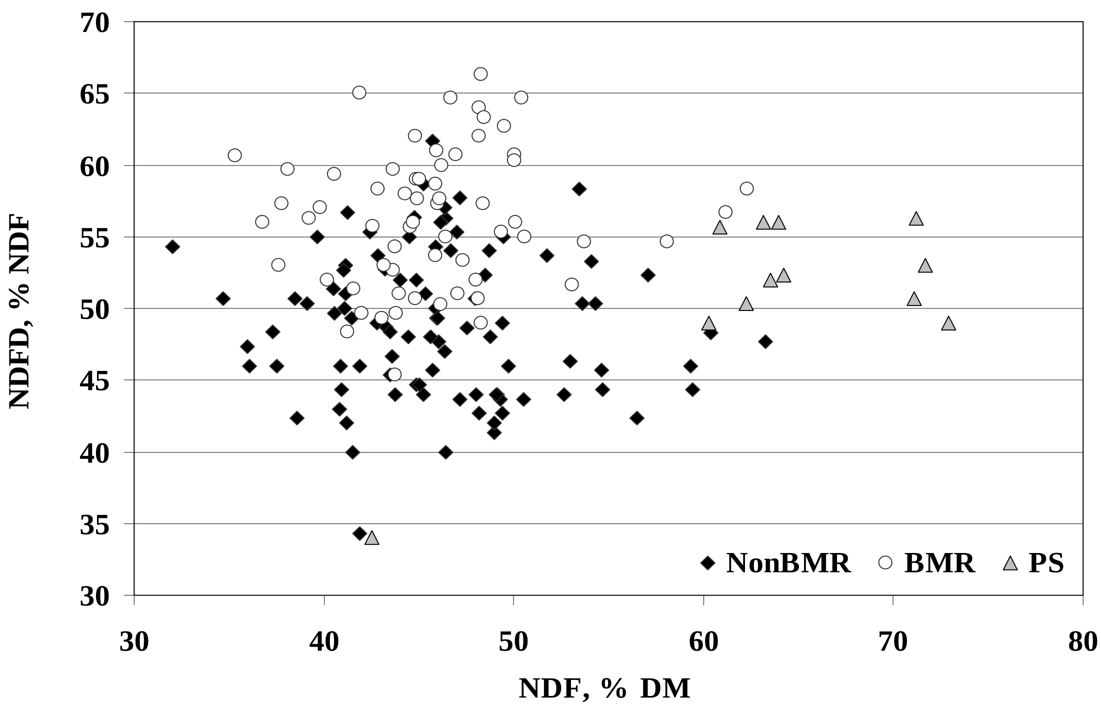

Figure 2. Neutral detergent fiber (NDF) and NDF digestibility (NDFD) in pre-ensiled normal (non-BMR), brown midrib (BMR), and photoperiod-sensitive (PS) forage sorghums in years 2002-2004. Each point represents the value of one variety in one year.

Figures 2 and 3 illustrate the mechanisms behind the improved IVTD in the *bmr* group. In general, at any level of NDF, the NDFD tends to segregate the groups; the *bmr* forage sorghums with improved NDFD compared to the non-*bmr* forage sorghums (Figure 2); this reflects the reduced lignification in the *bmr* forage. Higher NDFD is associated with higher IVTD tends to segregate the *bmr* group tends from the non-*bmr* group (Figure 3).

The higher NDF, ADF, and lignin in the PS group resulted in a pronounced difference in IVTD. The NDFD for the PS varieties was in the midrange of NDFD values for the *bmr* and non-*bmr* forages (Figures 2 and 3). However, the average NDFD could not offset the high NDF concentrations and IVTD was depressed.

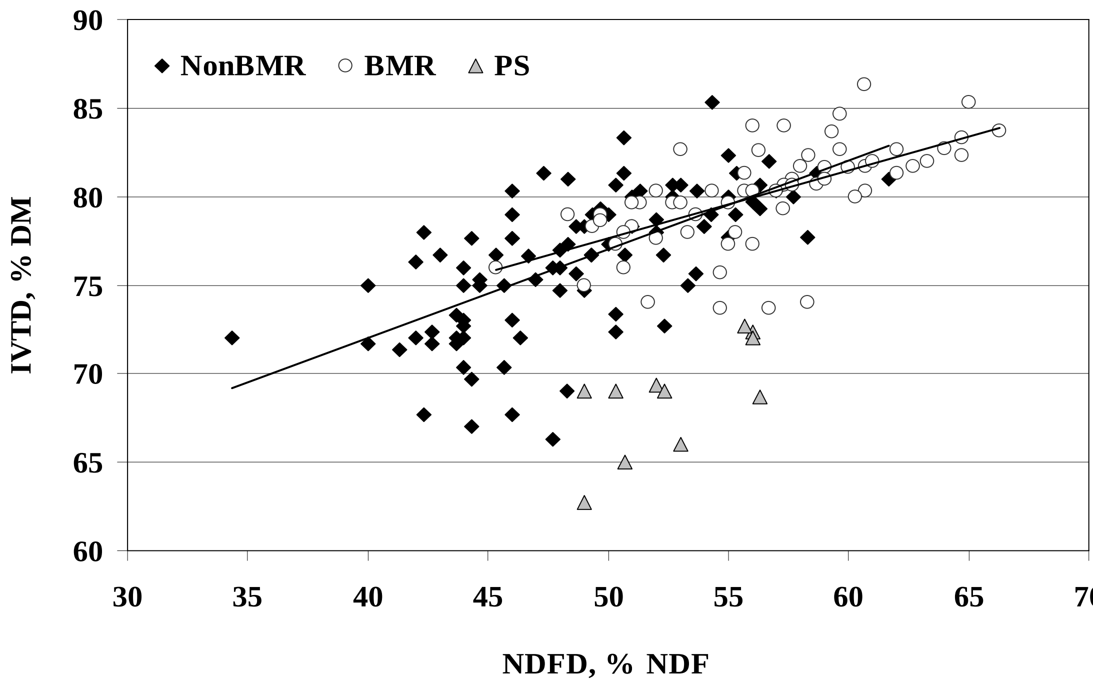

Figure 3. Neutral detergent fiber digestibility (NDFD) and in vitro true digestibility (IVTD) of pre-ensiled normal (non-BMR), brown midrib (BMR), and photoperiod-sensitive (PS) forage sorghums prior to ensiling for years 2002-2004. Each point represents the value of one variety in one year.

The relatively high concentrations of fiber and lignin in the PS group does not negate the concept that delayed flowering aids in maintaining higher forage quality. That question must be addressed by harvesting at various plant ages (days since emergence). Our data simply show that at the point we harvested the PS varieties, they were more fibrous than the other two forage sorghum groups. If we had harvested the PS varieties at an earlier age, fiber levels might have been lower. However, our objective was to harvest forage at a stage for ensiling. The harvest moisture levels in the PS group averaged 71.8, 73.3, 73.9, 67.6, and 74.4% for each of the five years despite delaying harvest until mid-October. Harvest at an earlier age might decrease fiber and increase digestibility, but the moisture levels will require the forage to be wilted before ensiling.

It is interesting to note that the IVTD of the PS varieties is not that different than the stover portion of corn silage. The PS varieties might potentially trade with corn silage on an NDF basis in finishing rations.

ADF, IVTD and energy estimation The acid detergent fiber (ADF) fraction contains the more indigestible portion of the plant: cellulose, lignin, and silica. If lignin content is lower as with the *bmr* forage sorghums, then the ADF fraction should be more digestible and the energy value of the forage would be improved.

Many laboratories will report an energy value based on ADF. Because ADF is negatively related to forge digestibility, and digestibility is the primary factor affecting the energy value of a forage, ADF is often the single variable in prediction equations to estimate the energy value of forage. Using these types of prediction equations will underestimate the energy value of forages such as the *bmr* varieties.

Figure 4 shows that regardless of forage sorghum type, IVTD declines as ADF increases. However, there appears to be different associations for the *bmr* and non-*bmr* types. An energy value estimated based solely on the ADF value would not reflect the differences. The relationships between ADF and IVTD for the *bmr* and non-*bmr* types were evaluated using indicator regression. The regression equations for the *bmr* and non-*bmr* forages are different (intercept, P=0.09; slope, P<0.01). Consequently, energy values predicted using equations derived from "normal" forage ADF-energy relationships would not reflect the higher digestibility and would under estimate the energy value of the *bmr* forages. Prediction equations should incorporate measures of fiber digestibility as well as fiber concentration.

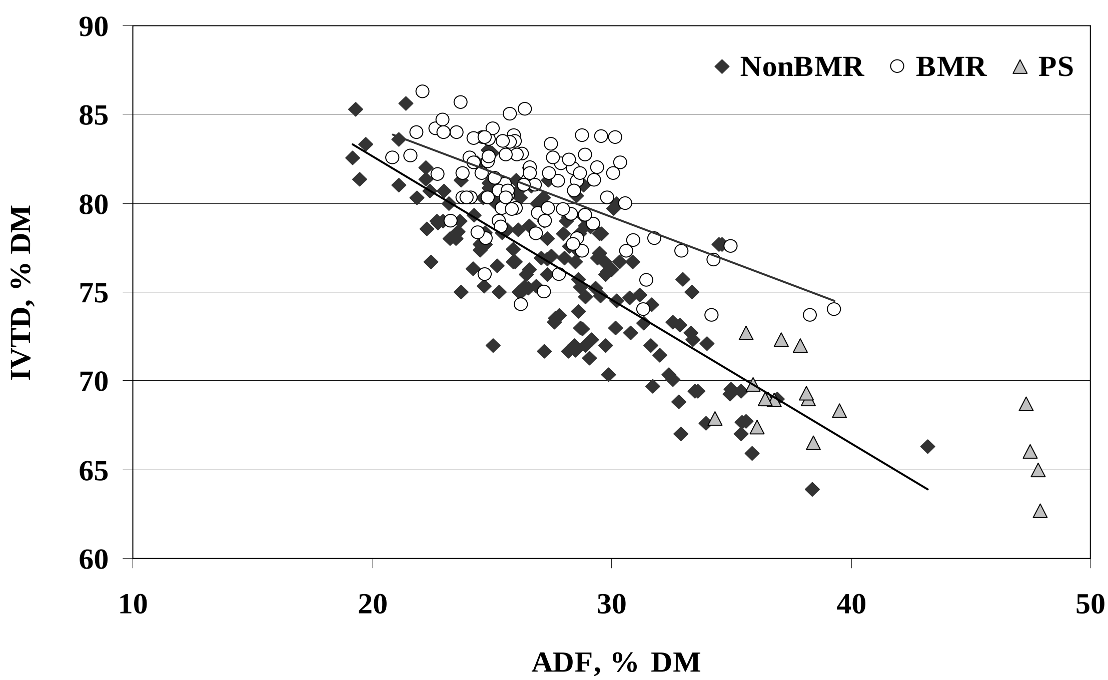

Figure 4. Acid detergent fiber (ADF) and in vitro true digestibility (IVTD) relationships for in pre-ensiled normal (non-BMR), brown midrib (BMR), and photoperiod-sensitive (PS) forage sorghums prior to ensiling in years 2000-2004. Each point represents the value of one variety in one year.

Grain content The grain production potential varies widely among the forage sorghums. Typically, it is presumed that higher grain content will improve the nutritional value of silage. However, this presumption is usually based on observations within a variety (i.e. silages from a single variety but with varied amounts of grain). This same concept may not apply to comparisons among varieties with differing forage quality.

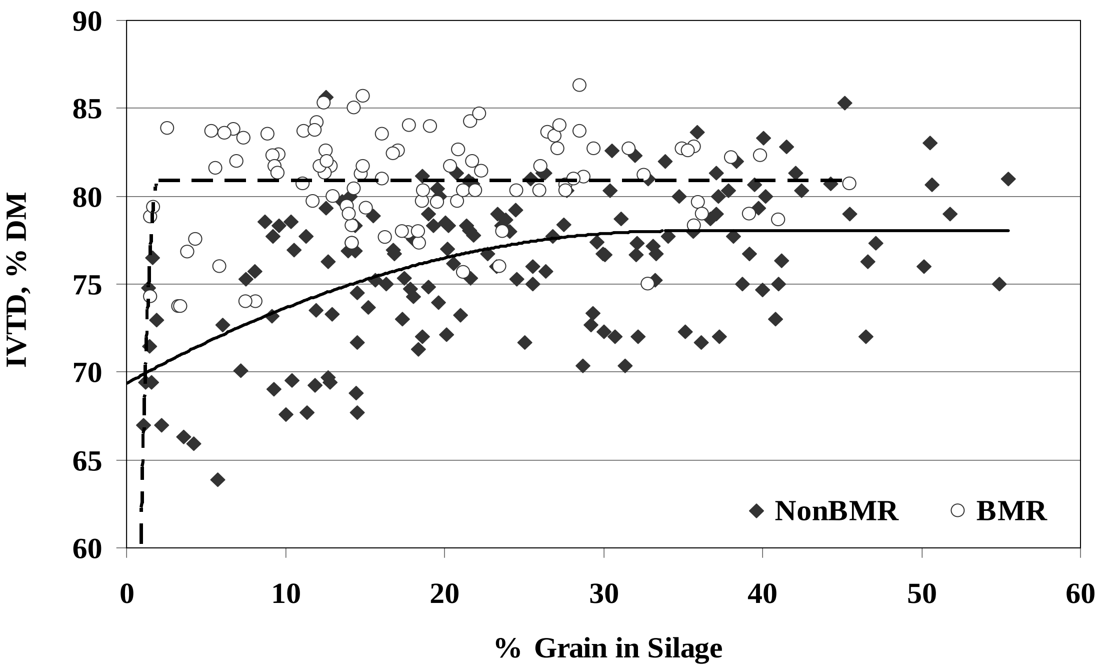

Figure 5. Grain content and in vitro true digestibility (IVTD) relationships for in pre-ensiled normal (non-BMR), brown midrib (BMR), and photoperiod-sensitive (PS) forage sorghums prior to ensiling in years 2000-2004. Each point represents the value of one variety in one year.

The percent grain in the pre-ensiled forages from our trials was compared to the IVTD of the pre-ensiled forage (Figure 5). The relationships were evaluated using nonlinear regression techniques. IVTD of the non-*bmr* forage sorghums increased quadratically and plateaued at 78.0% IVTD at 34.5% grain. In contrast, IVTD plateaued at 80.8% IVTD when grain content was 2.0%. Varietal differences in grain content appeared have greater influence on the non-*bmr* forage sorghums than on the *bmr* forage sorghums

Feeding Studies

Few feeding studies comparing *bmr* silage to other silages have been reported. Most are with dairy cattle.

Lusk et al. 1984 fed corn silage or *bmr* sorghum silage in two short (54-56 days) lactation studies. Daily intake of silage and concentrate intake were relatively similar for the treatment groups. Actual and fat-corrected milk production did not differ among treatments. Grant et al. (1995) compared *bmr* sorghum silage to alfalfa, corn, and normal sorghum silages for midlactation dairy cows. Diets contained 65% (DMB) silage and 35% concentrate. Although milk production was not different for the *bmr* silage,corn, and alfalfa silage diets, efficiency (FCM:DMI) was lower for the *bmr* silage diet (1.04) compared to corn (1.16). The normal sorghum silage supported less milk production at a lower efficiency than the other three silages.

Aydin et al. (1999) fed 65% (DMB) silage diets to cows in early lactation. Cows on the corn silages diets produced more milk and were more efficient than cows on the *bmr* sorghum or alfalfa silage diets; normal sorghum silage diets supported the least production with lowest efficiency. In a second trial, Aydn et al. (1999) fed diets containing 17.5% alfalfa silage and 35.3% (DMB) of either corn silage, normal sorghum silage or *bmr* sorghum silage . Milk production was not different for corn or *bmr* silage. FCM:DMI was 3.8% higher for *bmr* silage compared to either corn or normal sorghum silage. Cows on the normal sorghum produced less milk than cows on the *bmr* silage, but production was not different than the cows on corn silage.

Oliver et al. (2004) fed lactating cows diets containing 10% alfalfa with 40% (DMB) of corn silage , normal sorghum, or one of two different *bmr* forage sorghum silages. Milk production was not different among the corn silage or the two *bmr* sorghum silages. The normal sorghum silage supported the lowest milk production. FCM:DMI was highest for the normal sorghum silage; there wre no differences among the two *bmr* sorghum silage and corn silage.

Corn silage and a *bmr* silage were compared in finishing diets at the Texas A&M University Research Feedlot , Bushland, Texas (unpublished data). Corn silage was fed at 10% (DMB) with 80.2% steam-flaked corn, 2.3% white grease, and 7.7% supplement. The *bmr* silage was fed at either 10.0% (DMB) to directly replace corn silage or at 7.5% (DMB) to contribute the same amount of NDF as the corn silage. Corn was added to the 7.5% diet. The feeding trial was repeated in two consecutive years using silages produced at Bushland in each year. Data were pooled across years. There were no differences in feed intake, daily gain, feed efficiency, or carcass traits among the treatments.

Conclusions

New genetic materials in the forage sorghums can provide some alternatives for harvested forages in the southern Great Plains. The photoperiod-sensitive forage sorghums appear to yield well and utilize water efficiently. However, the relatively low digestibility and high fiber may limit their broad application. This type may be best placed in situations where cattle have lower nutrient requirements. They might also fit into a finishing program in which they trade with corn silage on an NDF basis and corn is added back to the diet. On average, the *bmr* varieties have higher average IVTD and fiber digestibility than the non-*bmr* varieties. However, there is a great del of variation among individual varieties and decisions must be made based on individual varieties rather than a broad type category. Inside the varieties we have tested, there are potential alternatives to corn silage for growers with limited irrigation capacity or greater risk aversion. Feeding trials with lactating dairy cows and finishing cattle have demonstrated the potential to replace corn silage with the *bmr* forage sorghums without losing production. However, the variation in nutrient profiles suggest that the same potential exists to lose production if the varieties are not scrutinized. Based on nutrient profiles relative to corn forage grown at our site, a variable pricing scale would be appropriate for sorghum silages. This scale could be based upon IVTD or NDFD with corn silage as the base for pricing.

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