BROWN MIDRIB FORAGE SORGHUM, SUDANGRASS, AND CORN: WHAT IS THE POTENTIAL?

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ABSTRACT

Brown midrib, a genetic mutation in several grassy species, reduces lignin content in the total plant parts. Lignin is mostly indigestible but also plays an important role in plant rigidity. During the past several years the brown midrib (bmr) trait has been incorporated into forage sorghum, sudangrass, and corn. The results have been significant for the most part. IVTD values for bmr sorghum have demonstrated that differences between corn and sorghum silages have been removed. Significant differences among hybrids exist for all of the traits associated with forage quality, as well as for agronomic adaptation traits. Palatability in bmr materials has been improved significantly over conventional sorghums. Animal performance i.e. animal gain from direct pasturage and milk production have improved dramatically with the introduction of bmr into forage sorghums and sudangrasses. These improvements make bmr a very attractive characteristic of forage plants.

Key words: sorghum, forage, sudangrass, brown midrib, quality, water-use, lodging, milk yield

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INTRODUCTION

Brown midrib (bmr) is a visible marker associated with the reduction of lignin in corn, sorghum and pearl millet (Kuc' and Nelson, 1964; Porter etal., 1978; Cherney etal., 1988). Although intensity of the coloration is not a measure of reduction in lignin, it is an indicator that the bmr gene(s) are present. Significant differences exist among cultivars for the amount of lignin reduction and its impact upon quality as a direct pasture or silage resource. Data from large trials show these differences and related issues such as lodging associated with the bmr trait (McCollum etal, 2003). Jung and Fahey, 1983 suggested that bmr plants have lignin, which is less polymerized and contains less phenolic monomers that can affect digestion. According to a public news release from Purdue University in 2003, the bmr gene(s) encodes caffeic acid O-methyltransferase (COMT), a lignin-producing enzyme. COMT in conjunction with CAD (cinnamyl alcohol dehydrogenase) have been shown to produce modified and reduced amounts of lignin when compared to normal plants. In each of these cases improved forage digestibility and animal performance resulted (Lichtenberg etal., 1972 and Fritz etal., 1981).

Brown midrib forage sorghum and sudangrass hybrids are being introduced into the market place at a very fast rate. It has been estimated by the Sorghum Industry that in 5-years as much as 80-

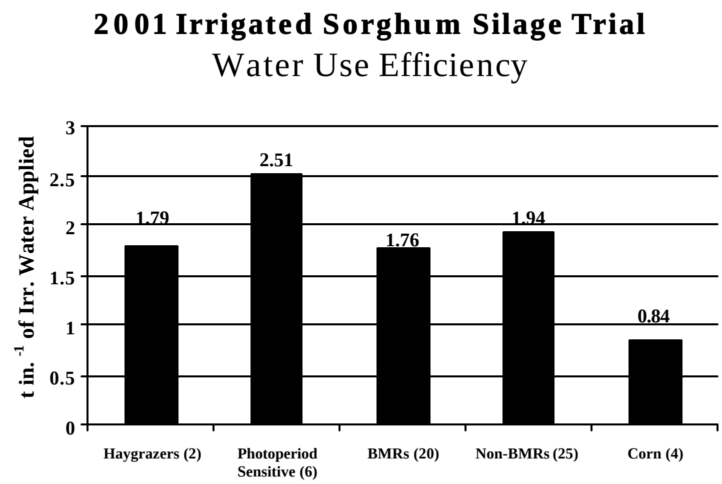
85% of the forage market will be brown midrib. In the current market some hybrids have experienced major defaults, which primarily has been lodging or a lack of stem strength. There also has been a under current suggesting that a yield drag is associated with the bmr trait. Most of these and other problems stem from the fact that little information is in the public arena describing the characteristics and benefits of brown midrib in forage plants. This presentation will show data collected from both private and public trials over the last 4-5 years. There is much to be done within the new brown midrib enhanced forage sorghum/sudangrass market and growers will continue to benefit from the introduction of bmr genes.

RESULTS AND DISCUSSION

There are at least four genes that exist in sorghum which produce a brown midrib reaction, three of these genes were identified at Purdue University in 1978 and others exist in the World Collection of Sorghum. It is believed that at least three of these genes are being used in private industry in both sorghum forages and sorghum sudangrass hybrids. Brown midrib reduces the lignin content in leaves and stems, and probably throughout the whole plant. Though the gene is named "Brown midrib", its brownish-red discoloration is not limited to the midrib of the leaf but is clearly visible throughout the plant, especially in the stem rind, pith and vascular tissues. In some hybrids the discoloration tends to disappear in intensity with advancing maturity. This brownish-red discoloration varies in intensity among hybrids, such variation from deep color to light color is not an indication of quality.

It is essential that everyone understand that hybrids containing the bmr gene should be handled in the same agronomic fashion as normal sorghums including fertilization, seeding rates, irrigation, and harvest technology. If anything were to change, a slight reduction in planting rates would be in order to help keep stem size sufficiently large to help in lodging reduction. Furthermore, harvest heights can be much lower to the soil since the whole plant is more digestible. Harvest heights for bmr sudangrass can be as low as 2-4 inches from the soil surface. Harvesting sorghum forages for silage can be as low as the harvest machine can handle since unlike conventional forage sorghum the bmr types have much less lignin in the lower portion of the stem. Custom harvesters suggest that for each 1-inch of stem left in the field, as much as 1-ton/acre of useful material is lost.

Water use. During 2001 at Bushland, Texas the Texas A&M University Research Center grew 53 sorghum hybrids for forage and 4 corn hybrids used for silage in an irrigated trial utilizing 4-row plots with 3-replications. Water use was measured and compared to total fresh weight yields. Figure 1 shows that sudangrass hybrids produced an average of 1.79 tons/inch of water used while bmr and non-bmr forage sorghums produced 1.76 and 1.94 tons/inch, respectively.



Courtesy of TAMU Research Center, Bushland, TX http://soilcrop.tamu.edu/research/crops/com-sorghum/croptesting

The photoperiod sensitive forage sorghums produce 2.51 tons/inch of water consumed. Corn was the greatest user of water producing only .84 tons of fresh weight per inch of water used or 53% less efficient than the average sudangrass hybrids. These data show that the photoperiod sensitive sorghums are the most efficient and corn is by far the most inefficient water user. In general, other sorghum types produce about the same yield of fresh weight per inch of water used.

Quality. From the same 2001 trial at Bushland, samples were taken from each of the 53 sorghum and 4 corn hybrids and sent to Dairy One Laboratory, Ithaca, New York for analysis. In Table 1, mean values for the sorghum and corn hybrids are given with ranges for each of the measured parameters.

2001 Irrigated Sorghum Silage Trial Bushland, TX
Quality Analysis

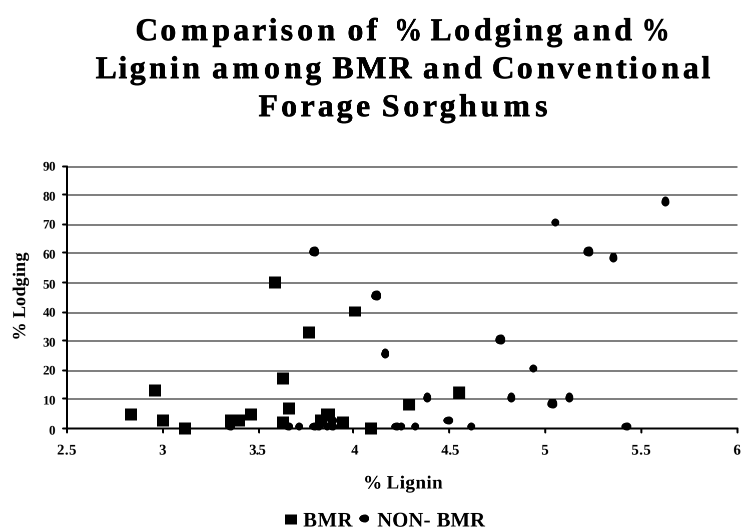
Type	CP%	ADF%	NDF%	Lignin%	IVTD%
BMR	9.2	27.6	45.9	3.6	81.3
Range	6.9-10.5	24.3-35.0	40.7-60.1	2.8-4.5	75.1-84.22
Non-BMR	8.3	29.9	49.1	4.4	75.5
Range	6.3-10.8	21.3-41.7	33.9-67.5	2.7-6.4	60.9-83.6
Corn	9.0	23.9	41.2	3.5	82.7
Range	8.4-9.7	18.2-27.4	33.7-45.8	2.7-4.2	78.3-88.1

Courtesy of TAMU Research Center, Bushland, TX http://soilcrop.tamu.edu/research/crops/com-sorghum/croptesting

Brown midrib sorghums had the highest mean crude protein and a very high IVTD%. Normal sorghum had the lowest crude protein, highest lignin content, as well as the highest ADF% and NDF% values. Normal sorghums had the lowest IVTD%. It is significant to add that ranges of values overlapped dramatically for each of the quality components measured. This clearly demonstrated that with proper selection hybrids with individual quality traits could be chosen that are superior in each of the classes of sorghum or corn. However, it should be noted that corn is an annual crop that must be harvest just once during its growth cycle, sorghum forage can be harvested once or twice and sudangrass can be harvested two to five times during each cycle.

In 1999 at Bushland a selected group of bmr forage hybrids were compared to their normal counterparts from 10 different seed companies. When crude protein values were compared bmr hybrids averaged 9.21% (7.7-9.85%) and normal counterparts were 6.55% (8.7-3.9%). The structural carbohydrate lignin average 3.1% for the bmr as compared with 4.6% in the normal hybrids. IVTD% for the bmr hybrids was 78.6% (83.5-74.7%) and the normal forage hybrids averaged 65.6% (73.0-55.9%).

Lodging. Lodging scores were taken in the 2001 trial at Bushland on all 53 sorghum and 4 corn hybrids. The sudangrass types sustained a 29.2% lodging score, photoperiod sensitive forage sorghums lodged only 6.4%, the brown midrib forage sorghums lodged 10.8% overall, while the normal forage sorghums averaged 18.7% lodged. These mean values clearly suggest that lodging is not the great problem that some have attributed to the characteristic. Figure 2 is presented to show the relationship between lodging % and lignin % for these same hybrids.



Courtesy of TAMU Research Center, Bushland, TX http://soilcrop.tamu.edu/research/crops/com -sorghum/croptesting

From this scatter diagram it is clear that all hybrids are not the same, whether bmr or normal. What is clear is that bmr hybrids are clustered more closely to the lower lignin contents and normal types are concentrated near the mid-range of lignin values or toward the high end of the graph. If one chooses a 10% lodging score as being acceptable, there are 12 normal types and only 6 bmr hybrids above this value. Three of these 6 hybrids come from the same gene pool. Eight of the normal type hybrids had less than 4% lignin, as compared to 16 bmr hybrids. These data and those taken from a similar trial in 2002 strongly suggest that lodging is not a clear problem associated with the genetics of brown midrib but with the genetic backgrounds that breeders place the gene into for utilization.

Yield and quality. During the past 5-years MMR Genetics has conducted yield and quality determinations on its hybrids and other available hybrids as checks. These trials have been conducted in 4-row plots with 3 replications under irrigation and high agronomic management. Following harvest a sample is taken and dried to determine percentage dry matter. These dry samples are then sent to Dairy One Laboratory for quality analysis. Data presented in Tables 2 and 3 are representative.

Sudangrass hybrid data are shown in Table 2.

2002

Designation	Days Until Harvest	TDMD lbs ac^{-1}	Milk lbs t^{-1}DM	DM Yield lbs ac^{-1}	Milk Yield lbs ac^{-1}	DM %
MMR 327/27	87	8,929.91	1,878.33	12,521.69	11,759.93	21.56
MMR 352/40	87	8,379.26	2,141.00	11,170.59	11,958.12	21.83
BR201 BMR	80	8,149.70	2,346.67	10,104.44	11,855.89	20.90
MMR 327/38 BMR	74	7,674.76	2,572.00	9,246.39	11,890.86	20.06
S X 17	80	7,476.04	1,988.33	10,155.67	10,096.41	22.10
MMR 327/52 BMR	71	7,129.46	2,565.33	8,522.82	10,931.92	19.08
Piper	56	2,642.09	2,251.67	3,401.76	3,829.82	18.39
Pr>F		0.0010	0.0001	0.0001	N/A	0.0015
LSD .05		627.55	197.85	1040.30	N/A	6.18
% C.V.		5.14	5.18	6.56	N/A	18.58
Grand Mean		7112.59	2226.53	9245.75	N/A	20.34

Designation	IVTD %	Lignin %	TDN %	ADF %	NDF %
MMR 327/52 BMR	83.67	4.63	63.00	35.40	60.90
MMR 327/38 BMR	83.00	4.07	63.00	36.60	61.37
BR201 BMR	80.67	4.63	59.33	37.00	60.50
Piper	77.67	5.30	57.67	35.87	61.60
MMR 352/40	75.00	5.43	54.67	38.03	60.03
S X 17	73.67	6.07	52.67	40.00	64.17
MMR 327/27	71.33	6.07	50.33	41.03	65.87
Pr>F	0.0001	0.0010	0.0001	0.0453	0.1772
LSD .05	3.02	0.95	3.34	3.34	4.28
% C.V.	2.27	10.59	3.43	5.12	4.02
Grand Mean	77.43	5.23	56.77	38.00	62.07

Each hybrid was harvested at the boot stage, except for MMR327/27 (photoperiod sensitive) that was cut the same day as the late maturing hybrid MMR352/40. Dairy One provides an estimate of milk produced per ton of dry matter consumed. It is clear from these data that bmr hybrids produced the largest amount of milk for dry matter consumed. Yield of dry matter was greatest for the photoperiod sensitive and late maturing sudangrass hybrids. However, bmr hybrids were not unacceptable. Piper sudangrass was very low yielding, less than half that of the other hybrids. IVTD% values clearly show the advantage of the bmr hybrids, ranging from 83.67 to 80.67%. Values for lignin averaged 4.4% for the bmr hybrids compared to 5.7% for the conventional sudangrasses. TDN, ADF and NDF values for the bmr hybrids were more desirable than those of the standard genotype.

Forage sorghum hybrid data are presented in Table 3.

2002

Designation	Days Until Harvest	TDMD lbs ac^{-1}	Milk lbs t^{-1}DM	DM Yield lbs ac^{-1}	Milk Yield lbs ac^{-1}	DM %
MMR 327/70 BMR PS	163	20,090.31	2,759.00	24,500.38	33,798.27	28.81
4 EVERGREEN	163	18,339.45	2,305.00	24,802.94	28,585.39	25.33
FS5	121	14,170.11	3,428.67	16,607.01	28,469.98	39.43
MMR 327/36 BMR	143	14,004.66	3,247.67	16,403.06	26,635.86	34.05
MMR 310/45	121	12,937.51	2,872.33	16,396.34	23,547.85	36.89
MMR 327/23 BMR	102	12,361.62	3,175.67	14,598.93	23,180.69	29.10
BR 100 BMR	121	12,254.32	3,122.33	14,746.85	23,022.27	35.03
MMR 323/45	102	10,953.14	3,099.00	13,451.45	20,843.02	35.48
Pr>F		0.0001	0.0001	0.0001	n/a	0.0001
LSD .05		2,016.52	339.95	2,220.41	n/a	2.83
% C.V.		8.33	6.52	7.58	n/a	5.13
Grand Mean		14,289.35	3,079.86	17,309.06	n/a	32.64

Designation	IVTD %	Lignin %	TDN %	ADF %	NDF %
MMR 327/36 BMR	85.33	2.77	70.00	25.97	46.33
FS5	85.33	3.57	71.33	24.57	38.87
MMR 327/23 BMR	84.67	4.03	69.00	26.83	44.17
BR 100 BMR	83.00	3.83	67.67	28.67	44.03
MMR 327/70 BMR PS	82.00	3.47	64.33	33.47	58.17
MMR 323/45	81.33	3.60	67.33	25.53	40.60
MMR 310/45	79.00	4.00	64.33	31.03	49.30
4 EVERGREEN	74.00	4.67	56.33	37.17	62.40
Pr>F	0.0001	0.0177	0.0001	0.0001	0.0001
LSD .05	3.9903	1.1882	4.7224	3.4365	5.2832
% C.V.	2.84	19.58	4.13	7.11	6.60
Grand Mean	82.92	3.58	67.47	28.53	47.25

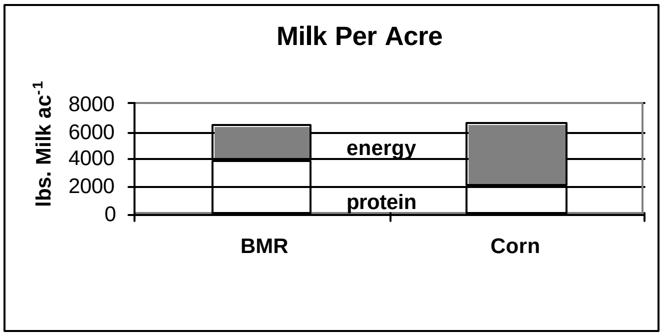
All these hybrids were harvested only once at soft-dough stage, except for MMR327/70 and 4EverGreen which are photoperiod sensitive. These latter hybrids were harvested near to 70% moisture for the whole plant. MMR327/70 and 4EverGreen produced no grain, MMR327/36 is partially sterile and all other hybrids are high grain producers. TDMD in lbs per acre was highest for the photoperiod sensitive hybrids, one of which is bmr. All the other hybrids except for MMR323/45, a short 2-dwarf brown normal forage, are clustered together and are significantly different. However, IVTD% clearly shows the high quality associated with the bmr trait. FS5 is a very high grain yield normal hybrid.

Taking the data from Tables 2 and 3 plus information from Bushland trials over the past 4 years, yield of forage from the brown midrib types does not appear to be lagging behind that of normal types. As breeding and evaluation continues into the future, considering the quality improvement in reduced lignin, greater IVTD values, etc that are known to be established it seems clear that the brown midrib trait will be a standard part of high quality sorghum forages. Yield and other quality improvements will be enhanced also.

Milk yield. When one considers the full impact of yield of dry matter from the various forms of sorghum, there are differences. In Tables 2 and 3 the forage sorghums show yields of near 50% superiority over sudangrass types. On average bmr forage hybrids yielded 0.13 tons/acre less than their normal counterparts, whereas bmr sudangrass hybrids were equal to their normal counterparts. In comparing the bmr forage hybrids to normals for milk yield in lbs per ton of dry matter consumed, the bmr forage hybrids produced 152 lbs more and the bmr sudangrass hybrids out produced normals by 430 lbs. In the forage hybrids the bmr photoperiod sensitive hybrid MMR327/70 produced 33,798 lbs of milk per acre, much more than any other hybrid. Comparing the two forage types for average milk yield per acre of dry matter produced, the bmr type showed 1,296 lbs more milk. While the bmr sudangrass hybrids produced 2,148 lbs more milk per acre than the normal type. One must recognize that the forage sorghums produced approximately 148% more milk per acre than the sudangrass types.

Finally, data developed at Cornell University (Figure 3) showed that a 6,500 lb milk yield per acre required 15 tons of corn silage and only 13 tons of a brown midrib sorghum silage.

Milk yield per acre for a 13-ton BMR sorghum crop will produce the same as a 15- ton corn silage crop.



A larger portion of milk produced from the brown midrib sorghum came from protein, but in corn the greater portion of milk came from energy (carbohydrate) consumption.

There appears to be consistent pattern emerging that shows brown midrib in sorghum has a major impact upon quality. This comes at little or no loss in total yield of plant material but with much greater digestibility, higher protein level, and significantly increased palatability. All of these components contribute to significantly greater weight gains in animals on direct pasture and increased milk yields. The brown midrib trait in forage sorghum, sudangrass etc appears to have a very bright future. Sorghum has the advantage of being a perennial plant, which allows for greater production flexibility as a forage resource. The future of the brown midrib trait in corn however, is not yet clear since there is little acceptance of these new hybrids.

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