Reevaluating On-farm Inputs in Corn and Forage Sorghum Silage Systems

Mark Marsalis, Extension Agronomist, NMSU Agricultural Science Center at Clovis
(575) 985-2292; marsalis@nmsu.edu

PREVIOUS WORK AND PRESENT OUTLOOK:

Beef and dairy industries form the base of livestock production in New Mexico. In 2003, Curry, Roosevelt, and Chaves counties accounted for over 48% of all livestock cash receipts in the state (New Mexico Agricultural Statistics, 2003). Milk is the state's number one cash commodity, producing over $790 million in 2003; and these three counties accounted for over 63% of milk cow numbers and milk cash receipts (New Mexico Agricultural Statistics, 2003). Cattle numbers are increasing in the area because of recent influxes of dairy operations from other parts of the U.S. It is important to conduct research that is applicable to the dairy industry because it has such a large influence on the agricultural and economic stability of communities in the area.

Forages provide valuable, low-cost feeds that often result in excellent animal weight gains and milk production with a high net return on investment; and forages comprise the majority of dairy feeds. Warm-season annual grasses used as silage and greenchop in dairy and beef feedyard rations are well adapted to the climatic conditions of the Southern High Plains. Of these, corn (*Zea mays* L.) is used most extensively in feeding programs as a feedsource for lactating dairy cows which need high energy feed for maximum milk production. Corn production, however, requires relatively large amounts of water in order to be high yielding and of adequate nutrition for the dairy industry. It has been documented that forage sorghums [*Sorghum bicolor* (L.) Moench] have the potential to produce as much, and in some cases more, dry matter than corn when grown with the same amount of water. Although dependent upon many environmental and management conditions, productivity of forage sorghum, if managed properly, can be as productive and feed-valuable as corn. Just as widely accepted is the assertion that, in general, sorghums are more water-use efficient than corn and require less water to produce a certain amount of dry matter. Even in situations where corn and sorghum water-use efficiencies are similar, corn tends to use more water because of earlier planting dates and longer growing seasons. In addition to the advantage of a later planting date, forage sorghums have the ability to maintain high yields under water stress conditions and resume growth after drought. Several opportunities exist to utilize these forages for livestock, including grazing, ensiling, and cutting for hay; and the flexibility of management options makes them valuable and attractive to growers in regions of extreme climatic instability such as the Southern High Plains of the U.S.

Historically, sorghum silage nutritive value has been inferior to that of corn silage due to low energy and digestibility of the ensiled product; and acceptance among dairies and feedyards has been limited. In more recent years, however, sorghum forage quality has improved through extensive breeding efforts and selection of highly nutritious varieties for use in silage programs. In addition, development of the brown midrib (BMR) trait in sorghum has significantly improved the digestibility of many varieties to a level equal to or greater than that of corn. This was accomplished by reducing lignin, the primary indigestible component of plant cell walls. Lignin concentrations in conventional forage sorghums limit dry matter intake and milk production of cows consuming them. Popularity of the BMR sorghums is growing and more questions from growers and dairymen in the region have led to a great need for research involving these crops, not only for yield data, but for nutritive information as well.

Little information exists on proper seeding and nitrogen fertility rates of corn and forage sorghum grown for silage in the Southern High Plains under limited irrigation. Water and nitrogen resources are becoming more limiting, and these declining resources and their availability will ultimately hinder the traditional productivity of silage systems in the region.

OBJECTIVES:

1. Evaluate the potential of forage sorghum grown on the New Mexico High Plains to provide an acceptable alternative to corn for use as a preserved feed for the dairy and beef industries.
2. Estimate yield and nutritive value of both forage sorghum and corn grown at three seeding rates and two nitrogen levels with a limited amount of irrigation water.

PROCEDURES:

Forage Sorghum vs. Corn Studies

These experiments evaluated the yield and nutritive value of sorghum and corn for feeding livestock. The project was conducted at the Agricultural Science Center at Clovis. Yield of two types of forage sorghum (BMR and Non-BMR) and corn were measured at harvest of the 2007 and 2008 summer growing seasons. Sorghum and corn was harvested at proper times recommended for silage purposes. All plants were watered at a rate that is considered limiting for corn and high producing forage sorghums. Center pivot irrigation was used to irrigate all plants because it is the most common type of irrigation in the region and is the method most growers can relate to. Irrigation amount was limited to about 20 inches for the entire growing season. This amount was chosen because it is a level that would be considered borderline for producers to make a decision on whether or not to grow corn (i.e., ~425 gal. per minute well capacity on 120 acres). It is likely that many farmers would consider this amount too low for adequate corn production at high levels of seed and fertilizer inputs; however, it is also likely that well capacities will continue to decline, and corn silage production should be evaluated at reduced irrigation amounts.

Secondly, plant matter was collected from harvested plots to determine nutritive value of the limited irrigated sorghum and corn. Corn silage harvested at optimal stage (60-65% moisture) served as the standard for comparison. Forage samples were subjected to laboratory analyses for quality and estimates of feeding value potential. Data of all measured parameters was summarized immediately following harvest and when forage analyses were completed. A major component of this research will be the effort to inform the agricultural community of the results and to present outcomes in a concise, understandable manner through producer meetings, field days, and publications (extension and peer-reviewed). This will be done in a timely manner so that implementation of water conservation practices is not delayed if benefits of sorghum production are apparent. At least 2 more years of data will be collected from this project to provide reliable, multi-year information and to evaluate even lower seed and fertilizer inputs.

The project is evaluated on the basis of crop productivity, with respect to both yield and feeding nutritive value. Research plots were harvested and chopped by a forage harvester and plot weights will be taken to estimate tonnage on a per acre basis. These estimations will give local growers an idea of how productive each system may be under limited irrigation conditions and how much plant material they can expect to have to contribute to ensiling facilities. Sorghum and corn was evaluated on end product nutritive value as predicted by laboratory procedures that estimate parameters such as crude protein (CP), net energy (NE_L), fiber concentrations (NDF and ADF), and neutral detergent fiber digestibility (NDFD). Success of the project will be determined by its effectiveness to yield reliable, unbiased, and accurate data that farmers can use toward more efficient cropping endeavors. Forage crops should be the focus of research efforts because of existing beef cattle operations and the large presence of the dairy industry in the region. The combination of field productivity and feed value data along with economic examinations of this research should make it appealing to local producers and may allow for a broader acceptance of nutritious, water conserving sorghums in the future.

METHOD SUMMARY:

Location:	Agricultural Science Center at Clovis, Clovis, NM
Elevation:	4,435 feet (1,348 m)
Soil Type:	Olton clay loam; pH = 7.0
Experimental Design:	Randomized Complete Block with Split Plot Arrangement, 4 Reps
Plot size:	2, 30-inch rows, 100 feet long

Irrigation

- Applied through center pivot system
- 0.65 inches every 3.5 days (~ 20 inches over 120 days, 120-acre circle)
- Simulate 425 gal/min capacity on 120 acres

Fertility (NR)

	High NR	Low NR	P_2O_5	Sulfur	Zinc
			lb/acre		
- Corn	260	195	60	20	10
- F. Sorghum (Conventional)	260	195	60	20	10
- F. Sorghum (BMR)	125	95	60	20	10

Planting Rates (PR)

	Low	Medium	High
		1,000 seeds/acre	
- Corn	22.5	27.0	30.0
- F. Sorghum (Conventional)	75.0	87.0	101.0
- F. Sorghum (BMR)	75.0	87.0	101.0

Harvests

Optimum Harvest

- Direct cut silage corn at 50% starch/milk line (60-65 moisture)
- Cut forage sorghums at soft dough stage (60-65% moisture)
- Measure crop yields on overall tonnage and amount of dry matter produced; analyze forage nutritive value prior to ensiling.

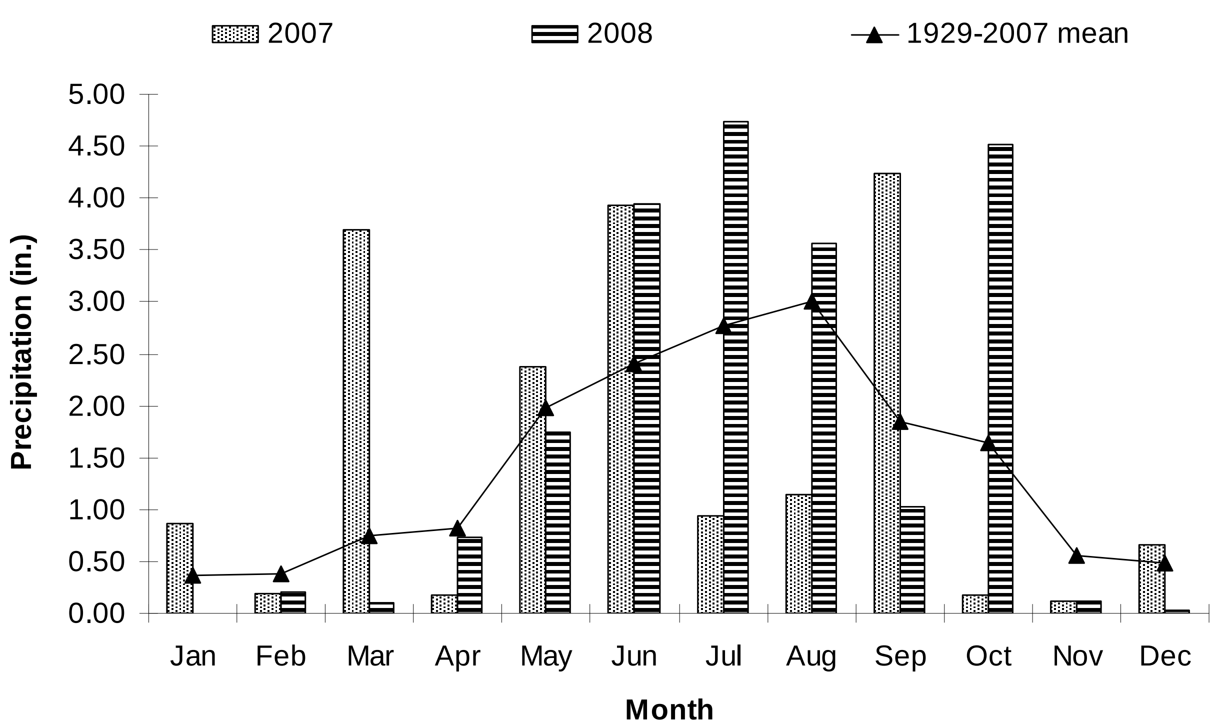

Figure 1. Mean monthly 2007, 2008, and long-term (1929-2007) precipitation at experimental location near Clovis, NM, USA.

RESULTS

Crop Yield

Forage dry matter (DM) yield of all three crops was similar in spite of reducing planting (PR) and N (NR) rates by 25%, suggesting that the high rates are not needed in limited irrigation situations. There were no interactions of crop, PR, or NR for DM yield, with the exception of a PR x NR interaction that resulted from a change in rank of medium and high PR between low and high NR. However, the change in rank resulted from a 0.3 Ton ac^{-1} difference and was not statistically different when PR x NR means were analyzed by the LSD test. Because PR and NR had no effect on DM yield, main effect of crop was analyzed over all PR and NR (Table 1). Previous research has also shown no effect of PR on FS DM yield at similar PR used in our study. Yields of all crops (>9.0 Ton DM/ac, or >25 Ton/ac at 65% moisture) were considered adequate for the amount of water applied; however, BMR-FS yields were lower ($P < 0.05$) than those of corn and C-FS which did not differ ($P > 0.05$) over 2 years and all PR and NR treatments (Table 1).

Typical yields for corn silage in the region are near 10 Ton ac^{-1} DM; however, this amount generally is obtained with 25 to 30 in. of irrigation in addition to precipitation. During the two years of this study, water applied averaged 17.5 in. (30% less than regional normal), and crops met or exceeded typical yields. These results support the relatively high water-use efficiency of sorghum; however, comparable corn yields were likely due to the high amounts of seasonal rainfall (14.2 in.) over the 2 years, especially 2008 (Figure 1). Previous research at this location with the same corn and C-FS varieties and irrigation schedule exhibited higher DM yields of C-FS over corn and BMR-FS from 2005 to 2006. Growing season rainfall was lower in the 2005-2006 study than 2007-2008 and contained exceptionally dry June and July months. In contrast to corn, C-FS had similar yields in both studies, implying greater stability with fluctuating precipitation. Therefore, with the amount of irrigation applied, corn yields will depend significantly on in-season precipitation.

Low yields associated with certain BMR forage sorghums have been reported by other studies and were substantiated by the yield results of this study, when compared with corn and C-FS. It is doubtful that N was limiting to BMR-FS as results indicate that there was no DM yield difference between low and high NR. New, improved releases of BMR-FS may help to alleviate low yields associated with older germplasms. Likewise, the development of more drought tolerant corn varieties will lead to greater competitiveness with C-FS in limited water situations; and the expansion of silage-specific corns may contribute to improved performance in high plant population situations.

Nutritive value – Crude protein

Although CP is an important quality parameter in dairy rations, it was analyzed in this experiment also as a potential indicator of NR effects. It has been reported that corn frequently contains comparable or higher CP than FS. In this study, there were only minor differences in CP among crops (Table 2).

In contrast to DM yield and all other quality parameters, NR had an effect on whole crop CP (Table 2). In addition, a PR x NR interaction led to interpretation of results for each of the treatment combinations (Table 2). There was no effect of PR on CP values of any of the crops.

Conventional FS was the only crop that showed a reduction in CP at the low NR. It is uncertain why C-FS was the only crop affected by low NR. Again, low N (compared to treatments used on corn and C-FS) did not appear to be limiting to BMR-FS, as CP values did not differ between the N treatments. When averaged over all crops, increasing PR from low to medium or high resulted in reduced plant CP, but only at the low NR. This implies the low NR-low PR treatments were an optimum combination and N became limiting as plants/ac increased. These results support other research that shows reduced CP in high plant populations (116,000 vs. 80,000 plants ha^{-1}) at several different N levels. This effect appears to be consistent across more than one type of crop and environment.

Nutritive value – NDF, NDFD, and NE_L

There were differences among crops for neutral detergent fiber (NDF), neutral detergent fiber digestibility (NDFD), and net energy (NE_L). Average NDF concentration of corn was lower than both FS (Table 3) and all three crops were within the range of NDF reported in the literature. Lower NDF in corn than FS agrees with other research findings. Between the two FS, there was no difference in NDF concentration. This similarity in fiber composition between the FS is consistent with some reports, but conflicts with others that report higher NDF for conventional FS than BMR-FS. Neither PR nor NR affected NDF of the crops (Table 3). Although NDF was numerically lower for the high NR than the low NR, the difference was not significant. It is likely that the variation (25%) between the low and high PR and NR treatments used in this study was not great enough to significantly alter plant cell wall content (i.e., stem size or proportions).

Despite higher NDF concentration of FS than corn, the digestibility of the NDF fraction (NDFD) was greater for both FS (Table 3). In particular, BMR-FS NDFD was especially high compared to the other two crops. This is likely the result of reduced lignin associated with BMR plants. Lower lignin concentration of the BMR mutation is associated with greater digestibility of the cell wall. High NDFD of BMR-FS may contribute to high estimated milk production shown in other studies. Neutral detergent fiber digestibility was not affected by varying PR or NR (Table 3).

Net energy for lactation was different among the crops, but there was no effect of PR or NR on NE_L (Table 3). Corn NE_L was lower than that reported in NRC (2001); however, NE_L for FS was similar to reported values. Although corn exhibited the lowest NDFD and low NE_L in general, it contained the greatest NE_L of the crops tested when averaged over all PR and NR (Table 3) which is consistent with other studies conducted at the same location. Greater NDFD for BMR-FS did not lead to greater NE_L, as it contained similar NE_L to C-FS and was lower than corn (Table 3). There seemed to be no direct relationship between NDFD and NE_L. The calculation of NE_L encompasses several parameters and the negative impact of low NDFD may be offset by other estimates (e.g., high non-starch-non-fiber carbohydrates and starch) in the equation when predicting corn NE_L.

In general, forage nutritive value was lower in this experiment compared to results from a study conducted 2 years prior with similar management and crop cultivars. It is likely that higher yields achieved with all crops in this study resulted in lower quality compared with quality obtained at lower yields reported with the same crop, even when harvested at the same maturity.

CONCLUSIONS

Results of this research indicate that seed and N fertilizer inputs can be reduced significantly without detrimental effects to yield and nutritive value of commonly used silage crops. In addition, producing high DM yield forage, but with lower amounts of water than fully-irrigated corn grown traditionally in semi-arid environments is possible. Common recommendations of inputs should be altered to fit into limited irrigation situations so that silage feeding systems are more sustainable and profitable. High PR do not necessarily contribute to increased yields and feed quality and may even result in low CP when other inputs such as N and water are limiting. Future studies should focus on variable irrigation rates to more completely assess the effects of declining water on corn and FS yield and quality. A wider range of PR and NR should be studied also to develop silage crop response curves to these inputs, which will help in assessing optimum input levels. In addition, morphological characteristics are currently being assessed in a new, similar experiment that potentially will help determine the degree to which different plant components affect yield and nutritive value of chopped material from each system.

Indications from this study are that while corn and C-FS may produce similar DM when harvested at optimum stage under restricted irrigation, corn may maintain nutritive value better; and corn's similarity with C-FS yield is dependent upon in-season precipitation in this environment. It is important to note that even when corn was irrigated with an amount of water considered limiting, it exhibited yields and forage quality characteristics similar to or superior to both FS: comparable CP, lower NDF, and higher NE_L. High yields of corn were likely due to above average rainfall during the 2 years. Much speculation exists about the suitability of corn yield and nutritive value compared to FS in limited water situations. Previous research at this location has shown that there is a tradeoff in yield and nutritive value between FS and corn when precipitation was below average. Producers must assess the risk of annual variation and need for either high yielding, lower quality FS or a lower yielding, higher quality corn in years when in-season precipitation is below normal.

Table 1. Total seasonal dry matter (DM) yields of corn, conventional (C-FS), and brown midrib (BMR-FS) forage sorghum at three planting rates (PR) and two nitrogen rates (NR).

	DM Yield					
	Mean	PR[a]			NR[b]	
Crop		Low	Med	High	Low	High
			Ton ac^{-1}			
Corn	10.9 a	11.0	11.2	10.5	10.9	11.0
C-FS	10.9 a	11.4	10.5	10.7	11.0	10.7
BMR-FS	9.4 b	9.1	9.4	9.8	9.4	9.4
LSD (0.05)	1.4		NS		NS	

Means within a column followed by the same letter are not significantly different according to the LSD test (*P* > 0.05).
NS, non-significant
[a] PR: Low = 22,500 and 75,000; Med = 27,000 and 87,000; High = 30,000 and 101,000 plants ac^{-1}, for corn and FS, respectively.
[b] NR: Low = 195, High = 260 lb N ac^{-1} for corn and C-FS; Low = 95, High = 125 lb N ac^{-1} for BMR-FS.

Table 2. Whole plant crude protein (CP) of corn, conventional (C-FS), and brown midrib (BMR-FS) forage sorghum at three planting rates (PR) and two nitrogen rates (NR), and averaged over all crops for the PR*NR interaction.

	Crude Protein				
	PR[a]			NR[b]	
Crop	Low	Med	High	Low	High
			%		
Corn	7.6	7.3	7.3	7.3 a	7.5 a
C-FS	7.2	7.1	7.2	7.0 b	7.4 a
BMR-FS	7.2	7.2	7.2	7.2 a	7.2 a
LSD (0.05)		NS		0.3	

	NR	
PR	Low	High
	%	
Low	7.4 a	7.3 ab
Med	7.1 bc	7.4 a
High	7.1 bc	7.4 a
LSD (0.05)	0.2	

Means within a column followed by the same letter are not significantly different according to the LSD test (*P* > 0.05).
NS, non-significant
[a] PR: Low = 22,500 and 75,000; Med = 27,000 and 87,000; High = 30,000 and 101,000 plants ac^{-1}, for corn and FS, respectively.
[b] NR: Low = 195, High = 260 lb N ac^{-1} for corn and C-FS; Low = 95, High = 125 lb N ac^{-1} for BMR-FS.

Table 3. Whole plant neutral detergent fiber (NDF), neutral detergent fiber digestibility (NDFD), and calculated net energy for lactation (NE_L) of corn, conventional (C-FS), and brown midrib (BMR-FS) forage sorghum for main effects of crops, three planting rates (PR) and two nitrogen rates (NR).

	Quality Parameter		
Treatment	NDF	NDFD	NE_L
	% DM	% NDF	Mcal kg^{-1}
Corn	46.6 b	62.0 c	1.15 a
C-FS	50.4 a	65.1 b	1.03 b
BMR-FS	50.3 a	74.5 a	1.02 b
LSD (0.05)	1.9	1.4	0.03
Low PR[a]	48.9	67.2	1.07
Med PR	48.6	67.1	1.07
High PR	49.8	67.3	1.05
LSD (0.05)	NS	NS	NS
Low NR[b]	49.4	67.3	1.06
High NR	48.7	67.1	1.07
LSD (0.05)	NS	NS	NS

Means within a column followed by the same letter are not significantly different according to the LSD test ($P > 0.05$).
NS, non-significant
[a] PR: Low = 22,500 and 75,000; Med = 27,000 and 87,000; High = 30,000 and 101,000 plants ac^{-1}, for corn and FS, respectively.
[b] NR: Low = 195, High = 260 lb N ac^{-1} for corn and C-FS; Low = 95, High = 125 lb N ac^{-1} for BMR-FS.