EVALUATING VARIETY CHOICES AND NOVEL GENES FOR FORAGE SORGHUMS IN CALIFORNIA

Jeff Dahlberg, Robert Hutmacher, Steve Wright, Mark Keeley, Gerardo Banuelos, Julie Sievert, Sonia Rios, and Raul Delgado[1]

ABSTRACT

Key Words: sorghum, drought tolerance, forage, silage, brown mid-rib, quality, yield

INTRODUCTION

Sorghum [*Sorghum* bicolor (L.) Moench] is a drought tolerant cereal crop that has multiple uses, one of which is as a livestock feed. Brown and white durra sorghums were introduced as animal feed into California in 1847. Since that time, sorghum has been adapted and refined and several different types are currently available for use in the U.S. These include hybrid grain sorghums, hay type sorghums referred to as sudans, sudangrass, or sudangrass x sorghum hybrids, sweet sorghums used for molasses or syrup production, grazing sorghums, forage sorghums used primarily for silage, and more recently biomass sorghums as feedstocks for renewable fuels. All these sorghums can be used in a wide variety of products. Grain sorghum is an excellent animal feed, but is also a gluten free cereal that can be used in human food systems. The other sorghums are used primarily as animal feed, but have been evaluated for their use as renewable feedstocks for biofuels.

Kansas and Texas remain the leading states for sorghum acreage and production, with a little grain and some forage production located in California (USDA NASS, 2013). California is dealing with multiple water issues and sorghum forages can play a significant role in reducing some of the inputs, including water, that are needed to supply high quality forage for the dairy industry. Despite limited production in California, sorghum, especially forage sorghum is an attractive crop for the state because of its ability to remain productive under limited water and nutrient conditions (Marsalis and Bean, 2010). Research conducted over the last 15 years at the Texas AgriLife Extension Center in Amarillo, TX has consistently shown that forage sorghums can be effectively grown under limited irrigation and still produce high yielding and good quality forages (see http://amarillo.tamu.edu/amarillo-center-programs/agronomy/forage-sorghum/). UC-ANR has begun evaluating sorghum forages at both KARE and the Westside Research and

[1] J. Dahlberg (jadahlberg@ucanr.edu), Director and J. Sievert (jasievert@ucanr.edu), SRA, UC-ANR-KARE, 9240 S. Riverbend Ave., Parlier, CA, 93648; R. Hutmacher (rbhutmacher@ucdavis.edu), Univ. CA Cooperative Extension Specialist, UC Davis Plant Sci Dept and Director, UC West Side REC, P.O. Box 158, Five Points, CA 93624; S. Wright (sdwright@ucanr.edu), Univ. CA Coop. Extension Farm Advisor; G. Banuelos (gbanuelos@ucanr.edu), SRA, S. Rios (sirios@ucanr.edu), SRA, Univ. CA Cooperative Extension Tulare County, 4437 S. Lapina St., Ste. B., Tulare, CA 93274; M. Keeley (mpkeeley@ucdavis.edu), SRA; R. Delgado (rdelgado@ucdavis.edu), Princ. Ag. Tech. UC Davis Plant Sci. Dept., Shafter R&E Ctr, 17053 Shafter Avenue, Shafter, CA, 93263. **In**: Proceedings, 2013 Western States Alfalfa and Forage Symposium, Reno, NV, 11-13 December, 2013. UC Cooperative Extension, Plant Sciences Department, University of California, Davis, CA 95616.(See http://alfalfa.ucdavis.edu for this and other alfalfa symposium Proceedings.)

Extension Centers for adaptability and quality parameters to provide farmers with alternative forage sources for silage production.

PROCEDURES

Experimental. In 2011 and 2012, 80 and 38 sorghum forage hybrids from various seed companies were grown in replicated field trials at the Kearney Agricultural Research and Extension Center and the Westside Research and Extension Center in the San Joaquin Valley. These included traditional forage sorghums, Photoperiod (PS) forage sorghums, brown mid-rib (BMR) derivatives of both traditional and PS sorghums, and Sudangrass x Sorghum bmr hybrids. Hybrids were planted in a randomized block design in four row plots planted on 30-inch raised beds. Irrigation was applied using furrow irrigation and fertility applications followed recommendation from research conducted in Arizona on forage sorghums. Of these hybrids, 22 forages from 8 companies were in grown both years, and these combined years were analyzed as a split-split-plot design using the statistical program SAS.

Growing Seasons. The 2012 growing season was quite different than the 2011 season. Winter/spring rains were very sporadic and temperatures were very high throughout most of the growing season. Trials at both Kearney and Westside were irrigated as needed. Kearney received a total of 16.2 inches of applied irrigation, 4 inches more than the previous year. Rainfall totals from January through June, 1 2012 prior to planting at KARE were 8.04 inches, while rainfall totaled less than 1.0 inches during the growing season. Rainfall totals from January through June 26 prior to planting at Westside were 3.94 inches. No measureable rainfall was recorded between planting and harvest at the West Side location. At the West Side REC site, pre-plant irrigation with sprinklers totaled 1.3 inches, with an additional 2.8 inches of water applied by sprinkler post-planting for early irrigation and stand establishment. Furrow irrigations (four in July, August and early September totaled an additional 15.6 inches, for a total irrigation application of 19.7 inches for the full growing season plus pre-plant sprinkling. This was 0.7 inches more applied water than the previous year.

Each hybrid was harvested for forage yield when grain reached soft dough stage or in the case of the PS sorghum, with the last harvest of late forage sorghum producing some grain. A forage chopper and modified weigh wagon were used to collect samples, with sub-samples taken from each plot to measure moisture content and provide samples for nutritional analysis.

Other cultural practices and study information are listed below:

Trial Location:	Kearney Agricultural Research & Extension Center, Parlier
Cooperator:	UC-ANR
Previous Crops:	Winter forage (Oats) both years
Soil Type:	Hanford sandy loam
Plot Size:	Four, 30 inch rows by 20 ft
Replications:	3
Study Design:	Split-Split-Plot
Planting Date:	June 16, 2011 and June 1, 2012
Planting Rate:	100,000 seed acre^{-1}
Seed Method:	John Deere Max-emerge Planter

Fertilizer:	NPK 15x15x15 at 500 lbs acre^{-1} applied in 2011 and NPK 21x7x14 R 600 lbs acre^{-1} applied in 2012
Herbicide:	None
Irrigation:	See narrative above
Silage Harvest Date:	Plots were checked weekly and harvested when grain was in the soft dough stage.

Trial Location:	Westside Research and Extension Center, Five Points
Cooperator:	UC-ANR Extension
Previous Crop:	Silage wheat both years
Soil Type:	Panoche clay loam
Plot Size:	Four, 30 inch rows by 20 ft
Replications:	3
Study Design:	Split-Plot
Planting Date:	July 11, 2011 and June 26, 2012
Planting Rate:	100,000 seed acre^{-1}
Seed Method:	John Deere Max-emerge Planter
Fertilizer:	NPK 15-15-15 at 300 lbs/acre applied July 7, 2011; 0-46-0 at 125 lbs/ac applied 7/26/2011 and N-P-K 21-7-14 at 600 lbs acre-1 applied pre-plant in 2012
Herbicide:	None in 2011 and Prowl-H20 at layby @ 3 pts/ac in 2012
Irrigation:	Sprinklers for pre-irrigation and stand establishment, gated pipe furrow irrigation subsequent irrigations
Silage Harvest Date:	Plots were checked weekly and harvested when grain was in the soft dough stage.

Data Collected.

1. Plant stands
2. Plant height (ft) at silage harvest
3. Lodging at silage harvest. Percent of fallen or significantly leaning plants per plot.
4. Moisture Content at Harvest.
5. Forage (silage) yield. The middle two rows of each plot were harvested with a John Deere forage chopper and placed into a modified weigh wagon. Yields are reported at 65% moisture in tons/acre.
6. Nutrient analysis: Samples were collected from the forage chopper in the field, weighed and then placed in forced air Gruenberg oven (Model T35HV216, Williamsport, PA) at 60º C until dried. These sub-samples were sent to Dairyland Laboratory, Inc, Arcadia, WI for analysis.
7. Key Nutrient Analysis Definitions
    a. Crude Protein: 6.25 times % total nitrogen
    b. TDN: Estimate of Total Digestible Nutrients
    c. NDF: Neutral Detergent Fiber; cell wall fraction of the forage
    d. ADF: % Acid Detergent Fiber; constituent of the cell wall includes cellulose and lignin; inversely related to energy availability
    e. NEl: Estimate of Net Energy for lactation
    f. NEm: Estimate of Net Energy for maintenance

g. NEg: Estimate of Net Energy for gain
h. IVTD: % In Vitro True Digestibility; positively related to energy availability
i. RFV: Relative Feed Value is an index for comparing forages based on digestibility and intake potential. RFV is calculated from ADF and NDF. An RFV of 100 is considered the average score and represents alfalfa hay containing 41% ADF and 53% NDF on a dry matter digestibility.
j. RFQ: Relative Forage Quality is an index for comparing forages. RFQ is calculated from CP, ADF, NDF, fat, ash and NDF digestibility measured at 48 hours. It should be more reflective of the feeding value of the forage. RFQ is based on the same scoring system as RFV with an average score of 100. The higher the RFQ score the better the quality.
k. Milk lbs/ton: A projection of potential milk yield per ton for forage dry matter.

RESULTS AND DISCUSSION

Forage yields averaged over the two locations ranged from a high of 36.35 to 16.64 tons acre^{-1} with an average of 24.94 tons acre^{-1} (see table 1). The yields were slightly lower in 2012 than yields report from 2010 research and may be attributed to a smaller range of hybrids evaluated and the dry weather. Forage yields were adjusted to 65% moisture. The non-BMR Photoperiod forages were on average more productive than their BMR counterparts. Lodging was a major issue in the trials over the both years. Lodging ranged from 1.0 to 83% (table 1). There was no consistent trend in the 2 year analyses, but the photoperiod non-BMR sorghums lodged the least of the different forage types; however, even some of these forages had lodging issues. In observations of the trials, both germinated and grew quite rapidly in what could be described as ideal growing conditions, hot dry conditions with excellent water availability. Different management schemes are being contemplated to better understand the lodging issues seen at both locations. Little stem breakage was observed in the plots, rather the plants tended to bend over from the base of the stem. Irrigating early and not allowing moisture stress during the first 6 weeks of sorghum development will encourage brace root development and greater root penetration; strategically managed nitrogen applications; and cultivating to bring soil up around the stalks and brace roots are practices that will reduce the percentage of lodging in future research trials.

Digestibility as measured by ADF, NDF, TDN, NDFD and overall forage quality as measured by lbs. of milk per dry ton tended to be the highest in the BMR sorghums (Table 1), though there were some excellent non-BMR forages as well.

Genetic Improvement. Sorghum genetics in forages have made tremendous strides since the discovery of the brown mid-rib trait in the 1970s, which lowers lignin and produces a more palatable and digestible forage (Porter et al., 1978). One earlier-observed side affect that often came along with use of these genetics was greater lodging, which has been a major complaint from farmers using these bmr forages. The seed industry rushed to incorporate these genetics into their forage lines; however, normal forages with poor standability became even more susceptible to lodging issues with the incorporation of the bmr trait into their genetics. The use of the brachytic height genes in bmr sorghums is a mechanism that is trying to address the lodging issue. This particular set of genes impacts internode elongation by primarily inhibiting internode elongation until after floral initiation. This tends to create short internodes that give more stability to the bmr sorghums (see Morgan and Finlayson, 2000). Several new hybrids with this trait are coming into the market.

The bmr and brachytic genes are not the only improvements that have been made in sorghum forages. For yield production, photoperiod sensitive forages can produce very high tonnage of biomass with limited water (Bean et al., 2002). They reported for each acre inch of water, photoperiod sensitive forage sorghum could produce 2.51 wet tons of forage, while corn silage produced 0.84 tons per acre inches of water. Rooney and Aydin (1999) described two new dominant maturity genes in sorghum that made the development of photoperiod offspring relatively easy in that the parental lines could be grown in a temperate climate and their hybrid offspring would then be photoperiod sensitive. Ottman and Walworth (2010) reported that sorghum forage yields plateaued with roughly 150 lbs of nitrogen and others have observed that nitrogen levels much greater than this can lead to extensive lodging. Clearly, greater work is needed to understand the correct application of nitrogen to optimize yield and standability in sorghum. Sorghum breeders have also identified genes that impart various levels of drought tolerance in sorghum and forage companies are using these genes to improve sorghum's ability to use limited and timely water applications to improve yields (see Rosenow and Clark, 1981).

Our test results indicate that sorghum forages do have the yield and the quality to meet the needs of dairy farms in the San Joaquin valley, especially under dry environmental conditions and relatively low water inputs. Sorghum seed companies are also working with a broad range of genetics to improve forages for both yield and quality parameters. It is also quite clear that additional research is needed to identify the proper planting dates, densities, fertilization, and water that will optimize sorghum forage yields and quality without lodging issues. Given the limited amount of irrigation used in these studies, low inputs and high yields, the potential does exist in sorghum forages to save both water and fertilizer, both costly inputs in the production of forages in the State. Forage selection should be a combination of factors that optimize quality, yield and standability and further research should be able to identify those forages that will benefit the farmers of California.

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Table 1. Multiple year comparison (2011-12) of sorghum forage hybrids for agronomic characteristics and yield and nutritional value at KARE and Westside Research and Extension.

Hybrid	Company	Type	Maturity	Height (cm)	% Lodging	Ton ac^{-1} 65% Moist
SS 506	Sorghum Partners, LLC.	FS	L	319.90 a	40.83 d	36.35 a
1990	Sorghum Partners, LLC.	FS	PS	272.58 g	46.67 c-d	34.57 a-b
Pacesetter BMR-Red	Richardson Seeds	FS	PS	285.05 d-g	60.83 b-c	31.69 a-c
SS 405	Sorghum Partners, LLC.	FS	ML	300.52 a-d	35.83 d	31.66 a-c
SS 304	Sorghum Partners, LLC.	FS	M	277.56 e-g	60.00 b-c	30.170 b-d
Sordan Headless	Sorghum Partners, LLC.	FS	PS	301.33 a-d	20.83 e	29.11 c-e
NK 300	Sorghum Partners, LLC.	FS	ME	208.79 i-k	11.25 e-f	26.25 d-f
Silo 700D	Richardson Seeds	FS	L	219.51 i	5.00 f	24.88 d-f
AS781	AR-B-Seeds	FS	ML	187.48 k-l	1.25 f	24.86 d-g
Silo 700D BMR	Richardson Seeds	FS	L	219.89 i	11.25 e-f	24.20 e-g
9500	Richardson Seeds	FS	ML	196.56 k-l	9.58 e-f	23.97 e-h
Trudan Headless	Sorghum Partners, LLC.	FS	PS	315.40 a-b	13.75 e-f	23.90 e-h
Hikane II	Sorghum Partners, LLC.	FS	ME	291.27 c-f	80.83 a	23.34 f-i
BH211 SBD	B-H Genetics	FS	L	246.71 h	4.17 f	22.82 f-i
Grazex BMR 801	Sharp Brothers Seed	FS	ML	296.92 b-d	77.92 a	22.47 f-i
Alta 7401	Advanta	FS	L	186.49 l	2.50 f	21.96 f-j
BH312 FBD	B-H Genetics	FS	ML	189.18 j-l	5.83 f	21.81 f-i
Alta 6402	Advanta US, Inc.	FS	ME	264.89 g-h	11.67 e-f	21.60 f-j
Maxi Gain bmr-6	Coffey Seed	SS	PS	270.84 f-g	70.42 a-b	19.45 g-j
Sordan 79	Sorghum Partners, LLC.	FS	E	307.90 a-c	78.33 a	18.77 h-j
Great Scott BMR	Scott Seed	FS	ML	209.83 i-j	13.33 e-f	18.11 i-j
Trudan 8	Sorghum Partners, LLC.	FS	E	268.71 g-h	82.92 a	16.64 j

Table 1. continued.

Hybrid	Company	Type	Maturity	% ADF	% NDF	% TDN	48 hr NDFD	Milk Lbs ton^{-1}
SS 506	Sorghum Partners, LLC.	FS	L	42.99 b-d	63.14 b-d	53.34 g-h	35.84 f-g	1711.77 f-g
1990	Sorghum Partners, LLC.	FS	PS	45.29 a	66.69 a	52.26 h	35.90 f-g	1579.76 g-h
Pacesetter BMR-Red	Richardson Seeds	FS	PS	43.01 b-d	65.65 a-b	54.59 f-g	45.60 b-c	1975.11 d-e
SS 405	Sorghum Partners, LLC.	FS	ML	40.89 d-f	59.92 d-e	54.60 f-g	36.96 f	1819.38 e-f
SS 304	Sorghum Partners, LLC.	FS	M	39.18 f-g	57.75 e-f	55.71 c-f	41.10 e	1910.21 d-e
Sordan Headless	Sorghum Partners, LLC.	FS	PS	43.84 a-c	63.96 a-c	51.34 h	34.20 g	1463.04 h-i
NK 300	Sorghum Partners, LLC.	FS	ME	35.05 i	51.39 h-j	58.47 a-b	41.68 d-e	2162.40 b-c
Silo 700D	Richardson Seeds	FS	L	34.33 i	50.78 i-j	58.96 a-b	39.86 e	2071.22 c-d
AS781	AR-B-Seeds	FS	ML	33.65 i	49.32 j	59.62 a	47.30 a-b	2360.38 a
Silo 700D BMR	Richardson Seeds	FS	L	34.99 i	53.29 g-i	58.78 a-b	47.05 a-b	2267.29 a-b
9500	Richardson Seeds	FS	ML	33.78 i	49.03 j	59.86 a	41.94 d-e	2204.55 a-c
Trudan Headless	Sorghum Partners, LLC.	FS	PS	44.44 a-b	64.29 a-c	51.84 h	34.66 f-g	1405.84 i
Hikane II	Sorghum Partners, LLC.	FS	ME	39.21 f-g	57.16 e-f	55.61 d-f	41.06 e	1967.62 d-e
BH211 SBD	B-H Genetics	FS	L	37.58 g-h	55.39 f-g	57.95 a-b	45.99 a-c	2251.13 a-b
Grazex BMR 801	Sharp Brothers Seed	FS	ML	40.52 e-f	60.19 d-e	55.15 e-g	40.89 e	1960.43 d-e
Alta 7401	Advanta	FS	L	34.89 i	51.37 h-j	58.73 a-b	47.19 a-b	2251.12 a-b
BH312 FBD	B-H Genetics	FS	ML	35.07 i	51.57 h-j	57.83 a-c	48.29 a	2296.28 a-b
Alta 6402	Advanta US, Inc.	FS	ME	37.59 g-h	55.65 f-g	57.79 a-d	46.62 a-b	2161.56 b-c
Maxi Gain bmr-6	Coffey Seed	SS	PS	41.95 c-e	61.51 c-d	53.07 g-h	43.86 c-d	1861.90 e-f
Sordan 79	Sorghum Partners, LLC.	FS	E	41.70 c-e	60.37 d-e	53.37 g-h	36.08 f-g	1701.61 f-g
Great Scott BMR	Scott Seed	FS	ML	35.48 h-i	53.18 h-g	58.41 a-b	47.23 a-b	2238.88 a-b
Trudan 8	Sorghum Partners, LLC.	FS	E	37.72 g-h	54.62 f-h	57.17 b-e	35.97 f-g	1936.56 d-e