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Forage Sorghum-Sudangrass Varietal Evaluation During a Short Irrigation Season in Fallon, Nevada

Juan K. Q. Solomon, Associate Professor, Department of Agriculture, Veterinary & Rangeland Sciences, University of Nevada, Reno

Akwasi Opoku, Graduate Research Assistant, Graduate Program of Environmental Sciences; University of Nevada, Reno Student

Anuoluwapo Ogunleye, Graduate Research Assistant, Graduate Program of Environmental Sciences; University of Nevada, Reno Student

Scott Huber, Research Coordinator, Nevada Agricultural Experiment Station, University of Nevada, Reno

Sterling Lee, Agricultural Technician, Fallon Research Center, University of Nevada, Reno

Introduction

Crop production in Nevada revolves around hay crops, with an estimated 320,000 acres harvested at the end of 2020 that produced 1.15 million tons of hay (USDA-NASS, 2021). Alfalfa (*Medicago sativa* L.) accounted for greater than 54.7% (175,000 acres) of the harvested hay acreage and 67% of the 1.15 million tons of hay produced in Nevada at the end of 2020 (USDA-NASS, 2021). In addition, the total area cultivated in corn (*Zea mays* L.) for silage in Nevada at the end of 2020 was 13,000 acres that produced 338,000 tons of silage (Nevada Agricultural Statistics Bulletin, 2020).

At the end of 2020, the total number of cattle and calves in Nevada was estimated at 480,000 heads, of which 31,000 were milking cows (Nevada Agricultural Statistics Bulletin, 2020). The quantity of milk produced from dairy operations at the end of 2020 was 765 million pounds (Nevada Agricultural Statistics Bulletin, 2020). In addition to cattle, there were an estimated 65,000 heads of sheep and lambs at the end of 2020 (Nevada Agricultural Statistics Bulletin, 2020). Therefore, to support the ruminant livestock industry, locally produced feed crops are invaluable. For example, to support feed requirements of the dairy industry in Nevada, a major portion of protein (e.g., canola, cottonseed meal, etc.) and energy feeds (e.g., corn silage) are sourced from out of state. This can result in economic instability of the dairy industry due to a lack of locally grown relatively inexpensive feed materials. Further, the number of cattle and calves under confined feeding (feedlot beef operations) for slaughter has declined from 6,000 in 2011 to 3,000 in 2020 (Nevada Agricultural Statistics Bulletin, 2020), partly because of the limitation of relatively inexpensive locally grown feed crops.

Both alfalfa and corn have been deemed integral to a sustainable ruminant livestock industry (dairy and beef production). However, both alfalfa and corn require large amounts of water for optimum production (Benjamin et al., 2015; Gheysari et al., 2015; Xue et al., 2017; Bhattarai et al., 2020). In addition, corn requires a substantial amount of nitrogen input to maximize yield (Marsalis et al., 2010). Therefore, under Nevada's water-limited conditions (e.g., the perennial decline in groundwater) and relatively poor natural soil fertility, these crops are bordering unsustainable because of agronomic input requirements (e.g., water and nitrogen fertilizer) and have led to a decline in their acreages cultivated over the years. This has augmented the need to evaluate suitable alternative feed crops. A viable alternative feed crop is forage sorghum [*Sorghum bicolor* (L.) Moench.] or sorghum-sudangrass (*S. bicolor* × *S. bicolor drummondii*). Forage sorghums, compared to alfalfa and corn, use less water, convert water into biomass more efficiently, are adapted to a wide range of agroecosystems, and require low agronomic input (Getachew et al., 2016; Bhattarai et al., 2020). From a nutritional standpoint, modern forage sorghum hybrids' feed values have been comparable to those of silage corn (Sanchez-Duarte et al., 2018). For example, the brown midrib forage sorghum hybrids can partially or fully replace silage corn in dairy diets (Miron et al., 2005; Cattani et al., 2017; Khosravi et al., 2018). The overarching goal of this study is to augment the intensive integration of forage sorghum into the annual crop production cycle of Nevada's producers by providing local field evaluation performance information on sorghum-sudangrass varieties. This information will support producers' decision-making in selecting forage sorghum varieties adapted to their geographical needs for cultivation. The objective of this study was to evaluate the performance of forage sorghum-sudangrass varieties under a short irrigation season.

Methods

This forage sorghum-sudangrass varietal evaluation was carried out at the Fallon Research Center in Fallon, Nevada, during the 2021 summer growing season. The soil at the field site is characterized as Sagouspe loamy sand (a coarse-loamy, mixed, superactive, mesic Oxyaquic Haploxerolls). Before initiation of the varietal evaluation, soil samples were collected for analysis, and mean soil pH was 7.0, with organic matter of 0.7%, CEC of 6.3 meq/100 g, and NO_3-N, Olsen extractable P, K, Mg, Ca, Na, and S were 11, 20, 216, 161, 853, and 3 mg kg^{-1}, respectively. Total precipitation during the growing season (June – September) was minimal (0.15 inch).

Study design and plot establishment

A total of 13 forage sorghum-sudangrass varieties (Table 1) were laid out in a randomized complete block design experiment with four replications of each variety. Before land preparation and seeding, weed control in the plot area was carried out using glyphosate [active ingredient (a.i.), N-(phosphonomethyl) glycine] at an application rate of 1.0 pound a.i. ac^{-1}. The plot area was plowed, disked and leveled before seeding. Each plot measured 30 feet long by 5 feet wide and was separated by a 5-foot alleyway between plots and 15 feet between blocks. Pre-plant irrigation was carried out one week before sowing. Plots were seeded on June 2, 2021, using a Wintersteiger Plotseed XL seeder in eight rows spaced 8 inches apart. The seeding rate used was based on pure live seed (PLS) of the maximum rate recommended by forage sorghum seed companies for irrigated areas (Table 1).

Table 1. Forage sorghum-sudangrass characteristics and recommended seeding rate for irrigated areas.

Company	Variety	Forage type	Trait	Seeding rate Pounds/acre	Relative maturity¶ (days)
Alforexseeds	PhotoKing	Sorghum × Sudan	BMR (Brown midrib)†	40	Multiple harvests
Alforexseeds	DwarfKing	Forage Sorghum	Brachytic BMR	12	95
Alforexseeds	CW 7700	Forage Sorghum	Conventional	20	120
Alforexseeds	ForageKing	Sorghum × Sudan	BMR	40	Multiple harvests
Alforexseeds	SilageKing	Forage Sorghum	Conventional	20	115
Arrow Seed	Grazex BMR	Sorghum × Sudan	BMR	35	Medium
Farm Valley Brand	Threepeat	Sorghum × Sudan	BMR	12	Medium
Gayland Ward	Super Sugar	Sorgo Sorghum-Sudan	Conventional	60	80-85
Gayland Ward	Sweet Six	Sorgo Sorghum-Sudan	BMR	55	110
Gayland Ward	Silo-Pro BMR	Forage Sorghum	Brachytic BMR Dwarf‡	14	100-115
Gayland Ward	19040	Forage Sorghum	Brachytic	14	110-115
Gayland Ward	19011	Sorgo Sorghum-Sudan	BMR Dwarf	35	70-80
Coffey Forage	Xtragraze BMR-6	Sorghum × Sudan	BMR	35	Multiple harvests

†Brown midrib (BMR) is a mutant trait (BMR-6 gene) linked to lower lignin synthesis and was introduced into forage sorghums to increase their biomass digestibility compared to conventional forage sorghums (Jung & Allen, 1995).
‡Brachytic BMR dwarf sorghum has reduced internode (stem) length, hence decreasing susceptibility to lodging. Brachytic BMR sorghum is characterized as compact and leafy and has greater forage quality potential than conventional sorghum.
¶Relative maturity based on days to soft dough stage.

Crop management

The plot area was flood-irrigated one day after sowing to a depth of 2 inches/acre. Thereafter, irrigation was carried out at an average of nine-day intervals and terminated on day 68 after sowing. An estimated 1.3 acre-foot of water was applied during the truncated irrigation season. Phosphorus was applied to the experimental area using a fertilizer spreader a day before sowing. The application rate was 40 pounds/acre P_2O_5 based on soil test recommendations using triple superphosphate. Thereafter, nitrogen was applied once, three weeks after germination at a rate of 80 pounds/acre using urea (46-0-0). In crop, broadleaf weed control was carried out once using 2,4-D amine at a rate of 0.95 lb./acre a.i. (active ingredient).

Data collection

Plant height (from ground to top of grain head) was measured on the day of harvest (100 days after germination; Sept. 22) from three randomly selected plants in each plot. Forage sorghum biomass was determined from an area of 20 feet long by 3 feet wide (60 $ft.^2$ / 5.6 m^2) using a forage harvester set to 3-inch residual stubble height. The freshly harvested sample from each plot was weighed and a subsample of approximately 500 g was collected for dry matter determination and nutritive value analysis. The subsamples were oven-dried at 60 C for 72 hours. Subsequently, each subsample was ground separately using a Wiley mill (Model 4, Thomas Scientific, Swedesboro, NJ) to pass a 1mm screen and stored in Whirl-Pak sample bags. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) analyses were done according to the ANKOM procedure using the ANKOM 2000 Fiber Analyzer (ANKOM Technology, Macedon, NY, USA). Relative feed value (RFV) was determined for each sorghum variety based on the formula: RFV = DDM × DMI/1.29; DDM (Digestible Dry Matter) = 88.9 - (.779 x %ADF); DMI (Dry Matter Intake) = 120 / %NDF.

Statistical analysis

The data were analyzed using the PROC MIXED procedure of SAS version 9.4 (SAS Institute, 2015). Sorghum variety was the fixed effect, while replication (block) was treated as the random effect. Variety means were compared using the PDIFF option of the LSMEANS procedure in SAS and considered different $P \leq 0.05$ unless otherwise stated. Correlation coefficients were generated among plant height, forage dry matter and biomass using the PROC CORR procedure of SAS version 9.4 (SAS Institute, 2015).

Results and discussion

Table 2. Forage sorghum production parameters under a short irrigation season at the University of Nevada, Reno Fallon Research Center, Fallon, Nevada 2021.

Variety	Plant height	DM	Biomass	Silage[†]	Silage[‡]	ADF[¶]	NDF[§]	RFV[ǁ]	RFV
	(cm)	%	ton DM/acre	(ton/acre)	(ton/acre)	%	%		Quality Designation
SOR19011	137^{d}[ǂ]	31.3^{dc}	3.9^{bcde}	12.7^{abc}	11.2^{bcde}	32.6	57.3	103	Utility
SOR19040	93^{f}	30.9^{dc}	2.7^{e}	8.7^{c}	7.8^{e}	34.3	57.4	101	Utility
CW 7700	132de	34.8^{bcd}	4.9^{abc}	14.0^{ab}	14.0^{abc}	31.8	56.3	106	Utility
DwarfKing	119^{def}	36.2^{abc}	4.1^{bcd}	11.4^{abc}	11.6^{bcd}	27.1	51.5	126	Utility
ForageKing	190^{ab}	37.6^{ab}	3.4^{de}	8.9^{c}	9.7^{de}	32.9	55.7	107	Utility
Grazex BMR	188^{ab}	41.5^{a}	3.9^{bcde}	9.8^{bc}	11.2^{bcde}	36.6	58.9	99	Utility
PhotoKing	174^{bc}	31.2^{dc}	3.8^{cde}	12.2^{abc}	10.9^{cde}	33.3	57.0	103	Utility
SilageKing	151^{dc}	32.7^{bcd}	5.1^{ab}	15.7^{a}	14.5^{ab}	31.1	53.1	113	Utility
Silo-Pro BMR	105^{ef}	33.6^{bcd}	4.2^{abcd}	12.5^{abc}	11.9^{abcd}	29.5	55.6	111	Utility
Super Sugar	187^{ab}	35.3^{bcd}	5.4^{a}	15.3^{a}	15.4^{a}	32.0	52.4	114	Utility
Sweet Six BMR	197^{ab}	33.0^{bcd}	3.9^{bcdc}	12.0^{abc}	11.1^{bcde}	31.4	55.4	108	Utility
Threepeat	207^{a}	36.4^{abc}	3.6^{cde}	10.0^{bc}	10.4^{de}	32.4	52.8	114	Utility
Xtragraze BMR-6	198^{ab}	30.4^{d}	4.3^{abcd}	13.9^{ab}	12.2^{abcd}	34.5	57.5	101	Utility
Mean	**160**	**34.2**	**4.1**	**12.1**	**11.7**	**32.3**	**55.5**	**108**	Utility
SEM	12	2.1	0.5	1.7	1.5	1.8	2.2	7	
P-value	**<0.001**	**0.017**	**0.011**	**0.042**	**0.010**	**0.128**	**0.372**	**0.322**	

[†]Estimated silage based on DM (dry matter) of each variety.
[‡]Estimated silage based on sorghum-sudangrass varieties at the typical 65% moisture (DM = 35%).
[¶]ADF; acid detergent fiber.
[§]NDF; neutral detergent fiber.
[ǁ]RFV; relative feed value.
[ǂ]Means followed by the same lowercase letter superscripts within columns are not different $P > 0.05$.

Plant height

Forage sorghum plant height differs among varieties ($P < 0.001$). The varieties Threepeat, Xtragraze, Sweet six, ForageKing, Grazex and Super Sugar were among the tallest. In addition, varieties SOR19040, Silo-Pro and DwarfKing were among the shortest. In this evaluation, plant height ranged from 93 to 207 cm (Table 2) and does not appear to be affected by the shortened irrigation season, based on the typical plant height of each variety.

Dry matter (DM) content

Forage DM content was affected by variety ($P = 0.017$). Sorghum-sudangrass varieties Grazex, ForageKing, Threepeat and DwarfKing were ranked among the greatest in DM content (Table 2). The variety Xtragraze had lower DM content than Grazex, ForageKing, Threepeat and DwarfKing (Table 2). Across all varieties, the average DM content was 34.2% ± 2.1 (Table 2).

Forage sorghum biomass

Sorghum-sudangrass biomass was influenced by variety ($P = 0.011$). The variety Super Sugar produced greater biomass than DwarfKing, SOR19011, Grazex, Sweet Six, PhotoKing, Threepeat, ForageKing and SOR19040 (Table 2). The varieties Super Sugar, SilageKing, CW 7700, Xtragraze and Silo-Pro were ranked among the greatest in biomass production. No variety distinctly ranked lowest or greatest in biomass production. However, the variety SOR19040 ranked among the lowest in biomass production (Table 2). The biomass yield values ranged from 2.7 to 5.4 tons/acre, with an average yield of 4.1 tons/acre (± 0.5 tons/acre) across all varieties (Table 2). Differences in biomass yield among the varieties evaluated could have been due to their varying tolerance for water deficit, since only a trend existed for a positive relationship between plant height and biomass in this study ($P = 0.097$; $r = 0.233$). This forage sorghum evaluation dealt with an unexpected shortened irrigation season but produced similar biomass to those reported for sorghum × sudangrass photosensitive, sorghum × sudangrass BMR, forage sorghum, and forage sorghum BMR cultivars in a study conducted in Kingsville, Texas, under rainfed practice (McCuistion et al., 2017).

Silage production

Silage production based on the dry matter content of each sample was altered by variety ($P = 0.042$). Silage production of the varieties SilageKing and Super Sugar was greater than varieties Threepeat, Grazex, ForageKing and SOR19040 (Table 2). Both CW 7700 and Xtragraze produced greater silage than ForageKing and SOR19040 (Table 2). Silage production based on sample dry matter ranged from 8.7 to 15.7 tons/acre, with an average of 12.1 tons/acre (±1.7) across all varieties (Table 2). Silage production was also computed based on the standard 65% moisture content (that is, 35% DM) of forage sorghums. Again, variety influenced silage production ($P = 0.010$; Table 2). The variety Super Sugar produced a greater quantity of silage than DwarfKing, Grazex, S19011, Sweet Six, PhotoKing, Threepeat, ForageKing and SOR19040 (Table 2). The varieties Super Sugar, SilageKing, CW 7700, Xtragraze and Silo-Pro ranked among the greatest in silage production (Table 2). Again, no single variety was distinctly superior or inferior in silage production based on the standard 65% moisture. However, SOR19040 ranked among the lowest (Table 2). For the 65% moisture, silage production ranged from 7.8 to 15.4 tons/acre (± 1.5), with an average of 11.7 tons/acre across all varieties (Table 2). At 65% moisture content, silage yield in this study was mostly lower than the ranges of 12.7 to 28.6 tons/acre and 11.7 to 22.4 tons/acre, with averages of 18.7 and 16.3 tons/acre reported from the 2017 and 2019 forage sorghums varietal evaluations, respectively, in California (Dahlberg et al., 2017; 2019).

Acid (ADF) and neutral detergent fiber (NDF) content

Neither ADF nor NDF contents were different among varieties ($P > 0.05$). The ADF content ranged from 27.1 to 36.6% among varieties, with a mean of 32.3% ± 1.8 (Table 2). For NDF content, varieties ranged from 51.5 to 58.9%, with a mean of 55.5% ± 2.2 (Table 2). Relative feed value and quality designation were similar among all sorghum-sudangrass varieties in this evaluation (Table 2). Both the ADF and NDF contents from the varieties of sorghum evaluated in this study were similar to the pre-ensiled ADF and NDF contents reported by McCuistion et al. (2017). Except for Grazex BMR, all other sorghum varieties were ranked above the average RFV score of 100 (Dahlberg et al., 2017).

Summary

Even for a drought-tolerant crop such as forage sorghum, the yield will be negatively impacted by severe water shortages. However, based on the biomass yield and estimated silage production under a shortened irrigation season, forage sorghums will be a valuable crop to integrate into the annual crop production cycle in Nevada. Given that the RFV was similar among all varieties, a selection from this pool of sorghum-sudangrass varieties evaluated can be based on biomass and silage production, coupled with harvest objective (single- or multi-cut, or grazing), seed price and availability, and pest and disease resistance.

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