Sunn hemp as an alternative forage in the Texas High Plains Region

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Key words: sorghum; water use efficiency, semi-arid climate

Abstract
Forage production in the Texas High Plains, a semi-arid region, is critical to sustain the local cattle industry. However, the main source of water for irrigation is the highly depleted Ogallala Aquifer, making forage crop water productivity (CWP) of high importance. In this one-year study, three types of forages were cultivated under deficit irrigation treatments of 80% and 50% of full crop water use. The forages were: a non-brown midrib forage sorghum; a legume, sunn hemp; and a sorghum/sunn hemp mix. The experiment was conducted in Bushland, Texas in 2019. Treatment plots were arranged in a split plot design with four replications under a 6-span variable rate irrigation center pivot sprinkler. Above ground biomass samples were taken by hand from a 1 m^2 quadrat in each of the 24 plots on Jul 23, Aug 6 for forage analysis, and on Aug 19 to assess biomass yield and CWP. Crude protein was significantly higher at the first and second cuttings in the sunn hemp monocrop, but not significantly different between irrigation levels. The final biomass yields and CWP were similar between the sorghum (23.6 Mg ha^{-1}) and sorghum/sunn hemp (25.1 Mg ha^{-1}) forages, irrespective of irrigation level. The sunn hemp monocrop produced significantly lower biomass (9.75 Mg ha^{-1}), which reduced CWP.

Introduction
The Texas High Plains region serves a vital role in support of cattle feed production. However, water resources for crop production are declining due to the non-replenishing Ogallala Aquifer. Sorghum (*Sorghum bicolor* (L.) Moench) is a source of cattle feed in the Texas High Plains region and is relatively drought tolerant (Rooney et al. 2007), but it has a low crude protein (CP) level of approximately 7.5% of dry matter (DM). It is possible that the integration of warm-season legumes in pastures consumed by beef and dairy cattle can increase forage quality (Mansoer et al. 1997; Lepcha and Naumann 2021). Sunn hemp (*Crotalaria juncea* L.) as a grazed forage was found to contain a relatively high percent of CP (> 15%) and a low percentage of fiber (Katiyar and Ranjhan (1969); Lepcha et al. 2019). Although sunn hemp has been grown successfully in subhumid and humid climates (Lales and Mabbayad 1983; Rotar and Joy 1983), it is not known if sunn hemp will thrive in a semi-arid region or increase the nutritive value of a sorghum/sunn hemp mixed forage.

The objectives of this research were to investigate the effects of forage type and irrigation level on forage quality parameters- percent dry matter (%DM), crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), ash and fat from early forage cuttings of sorghum, sunn hemp and a sorghum/sunn hemp mix, and to assess biomass yields and CWP of the forages at final harvest.

Methods
The experiment was conducted in 2019 at the Conservation and Production Research Laboratory (CPRL) in Bushland, Texas, USA (35˚11′N, 102˚06′W, 1174 m above mean sea level). Soil type is Pullman clay loam soil (fine, mixed, superactive, thermic Torrertic Paleustoll) (USDA-NRCS, 2017). Plots were arranged in a split plot design under a 6-span variable rate irrigation center pivot system. Forage type was the main plot factor and irrigation level was the sub-plot factor. Soil samples from each of the 24 treatment plots were analyzed to determine fertilizer rate of N and P to reach sorghum forage target yields of 44,000 kg ha^{-1}. The three types of forages were: 1) forage sorghum, cv. Nutrichoice II, Channel (safened with Concep III), designated (S), with a seeding rate of 5.93 kg ha^{-1}; 2) sunn hemp [*Crotalaria juncea* L.], designated (H), with a seeding rate of 28.1 kg ha^{-1}; and 3) a mixture of the sorghum/sunn hemp forages, designated (SH), with seeding rates of 6.74 kg ha^{-1} of S and 21.3 kg ha^{-1} of H. The S forage was planted in rows spaced 0.76 m apart, and the SH and H forages were drilled in rows spaced 0.25 m apart. All forages were planted on June 12 and grown using agronomic practices similar to those within the region (Table 1). The forages were irrigated

throughout the growing season under mild (I_{80}) and moderate (I_{50}) deficit irrigation treatment levels (where 80% and 50% represent percent replenishment of soil water depletion to field capacity) based on weekly neutron probe readings. Biomass samples for forage analysis were taken on Jul 23 and Aug 6 using a 1 m^2 quadrat. Final harvest samples to evaluate biomass yields, and crop water use efficiency were taken on Aug 19, 2019.

Statistical analysis was by ANOVA, and mean multiple comparisons were made with the Least Significant Difference Student's t-test (JMP 16.0.0, SAS Institute Inc., Cary, N.C.).

Table 1. Agronomic practices for the 2019 alternative forage study, Bushland, Texas.

Pre-plant soil sampling	Mar 18 – Mar 19
Fertilizer Application	Mar 25: 140 kg-N ha^{-1} and 56 kg-P ha^{-1} applied by knife rig
Planting Date	Jun 12: all forages
Herbicide	Brawl pre-emergent applied to S treatment plots, rate = 4.7 L ha^{-1} on Jun 13
Pesticides	Yuma 4 E applied for thrips through sprinkler system on Jun 28
	Tundra applied to control black blister beetles through sprinkler on Jul 17

Figure 1. Baled sunn hemp from the 2019 alternative forage study at Bushland, Texas.

Results and Discussion

Forage analysis

Data was analysed separately by sampling date. For both sampling dates, forage type had a significant effect on % CP, ADF, NDF, ash and fat (Table 2). In the type H forages, CP was consistently greater compared with type S and SH forages. These results were similar to findings by Mosqueda (2022). ADF and NDF were always numerically lower in the H forages with values similar to those reported by Eberle and Shortnacy (2021), while ash and fat were numerically greater in the H forages.

For the Jul 23 sampling date, irrigation level did not influence any of the nutritional parameters. However, irrigation level and the interaction of forage type X irrigation level significantly influenced %DM for the Aug 6 sampling date.

Table 2. Forage analysis- precent dry matter (DM), crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), ash and fat- results from the first (Jul 23) and second (Aug 6) biomass sampling dates in 2019 for the different types of forages- sorghum (S), sunn hemp (H), and the sorghum-sunn hemp (SH) mix.

Nutrient	% DM	CP (%)	ADF (%)	NDF (%)	Ash (%)	Fat (%)
Sample Date: Jul 23, 2019						
Forage Type	NS‡	***	*	**	*	**
Irrigation Level	NS	NS	NS	NS	NS	NS
Forage Type X Irrigation Level	NS	NS	NS	NS	NS	NS
Forage Type X Irrigation Level - I_{80}						
Sorghum (S)	85.7a‡‡	13.6b	46.9a	63.5a	11.2ab	1.5b
Sunn hemp (H)	88.6a	27.6a	33.8ab	38.1c	12.33a b	2.7a
Sorghum/sunn hemp mix (SH)	90.8a	15.0b	37.3ab	53.8ab	10.03b	2.2ab
Forage Type X Irrigation Level - I_{50}						
Sorghum (S)	90.0a	13.6b	40.8ab	56.8a	10.1b	2.0ab
Sunn hemp (H)	89.5a	28.7a	27.5b	30.6c	12.8a	3.0a
Sorghum/sunn hemp mix (SH)	91.1a	16.0b	38.6ab	51.3ab	10.5ab	2.0ab
Sample Date: Aug 6, 2019						
Forage Type	NS	***	*	*	**	*
Irrigation Level	**	NS	NS	NS	NS	NS
Forage Type X Irrigation Level	**	NS	NS	NS	NS	NS
Forage Type X Irrigation Level - I_{80}						
Sorghum (S)	92.0a	10.2b	42.0a	59.1ab	8.6b	2.0ab
Sunn hemp (H)	89.7c	25.6a	32.9b	42.5c	12.9a	2.5a
Sorghum/sunn hemp mix (SH)	90.4bc	14.5b	43.0a	60.7a	9.6b	1.9ab
Forage Type X Irrigation Level - I_{50}						
Sorghum (S)	90.4bc	11.6b	43.3a	64.1a	9.8b	1.8b
Sunn hemp (H)	90.2bc	25.0a	35.5ab	46.4bc	11.9a	2.4ab
Sorghum/sunn hemp mix (SH)	91.2ab	12.5b	44.7a	60.8a	9.6b	1.8b

‡NS- not significant at $p < 0.05$

‡‡Means followed by the same letter for each column and sampling date are not significantly different.

*$p < 0.05$

**$p < 0.001$

*** $p < 0.0001$

Biomass yields and crop water productivity

Mean biomass yields for the H forages in this study were nearly 11 Mg ha^{-1} and 9 Mg ha^{-1} for the I_{80} and I_{50} treatments, respectively. These values were at the lower end of the range of biomass yields for sunn hemp grown in more humid regions of Alabama, Georgia and Florida (Schomberg et al. 2007). The SH forage at the I_{80} level required more irrigation than all other forages X irrigation level except for the H-I_{80} forage. Grouping forages by type and comparing yield and CWP between irrigation levels, demonstrated that irrigation level did not influence crop response. This is not surprising with sorghum, which has been characterized as a drought tolerant crop (Krieg 1988). However, there are no known studies that have addressed drought tolerance in sunn hemp. Above-ground biomass yields were significantly greater for the S and SH forages irrespective of irrigation level as compared with the H forages. The smaller biomass yields produced by the H monocrop forages significantly reduced CWP values.

Table 3. Mean final biomass yield, irrigation amounts, seasonal crop water use (ET_c), and crop water productivity (CWP) for forage type by irrigation level treatments, sampled on Aug 19, 2019, at Bushland, Texas.

Forage Type	Yield (Mg ha^{-1})	Irrigation (mm)	Seasonal ET_c (mm)	CWP (kg m^{-3})
Sunn hemp (H) -I_{80}	10.9b[ǂ]	412ab	696ab	2.03b
Sunn hemp (H) -I_{50}	8.6b	265b	573c	2.11b
Sorghum (S) -I_{80}	23.7a	383b	692bc	5.41a
Sorghum (S) -I_{50}	23.5a	263b	600c	5.17a
Sorghum/sunn hemp mix (SH) - I_{80}	21.3a	499a	764a	4.83a
Sorghum/sunn hemp mix (SH) -I_{50}	23.5a	402b	700ab	4.24a

[ǂ]Means followed by the same letter for each column and sampling date are not significantly different.

Conclusions and/or Implications

Sunn hemp performed well under moderate deficit irrigation in a semi-arid region and could be considered as a drought tolerant nutritive forage in early growth. However, when intercropped with sorghum, sunn hemp did not significantly improve forage nutritional parameters, and when grown as a monocrop, sunn hemp produced biomass yields that were less than 50% of forages containing sorghum.

Acknowledgements

This work was funded by the Ogallala Aquifer Program, a consortium between USDA-Agricultural Research Service, Kansas State University, Texas AgriLife Extension Service & Research, Texas Tech University, and West Texas A&M University.

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