Comparing yield, nutritional quality, water and nitrogen use efficiencies of deficit drip and flood irrigated sorghum (*Sorghum bicolor*) and corn (*Zea mays*) subjected to different nitrogen rates

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8th GLOBAL NITROGEN CONFERENCE
30. MAY – 3. JUNE 2021 | BERLIN, GERMANY

Introduction

- Historic droughts and unprecedented water allocations in the Central Valley of California have inspired a renewed interest in forage sorghum as an alternative silage crop.
- In 2017, California reported 345,000 harvested acres of corn for silage, and only an estimated 60,000 acres of sorghum (USDA, 2017). Corn is usually favored because of its higher nutrient digestibility; however, numerous studies have shown that sorghum can replace other feed grains in rations. In addition, sorghum is more drought-tolerant, less susceptible to water stress, and boasts a higher tolerance to salinity than corn.
- Recent studies have evaluated sorghum's response to different irrigation rates based on cultivar. (Hutmacher, 2016). However, to date, no studies have reported on sorghum response to both variable irrigation and nitrogen fertilizer rates.

Objectives

Thus, the objectives of this study were to evaluate the yield and nutritive performance of sorghum subjected to different irrigation and fertility regimes and compare these results to those obtained with silage corn that has traditionally been supplied as forage for the dairy industry.

Materials & Methods

Study Description:

- Location: California State University Fresno, Campus farm.
- Soil: Sandy loam with pH of 6.7 – 7.
- Crops: Silage corn (*Zea mays L.*) and Silage sorghum (*Sorghum bicolor (L.) Moench*).

Experimental Design:

- Split-Split plot design with Crop as the main factor, Fertilizer rate as the sub-factor and Irrigation as the sub-sub factor.
  - ✓ 2 crops: Corn and sorghum
  - ✓ 4 fertilizer rates: 0, 75, 150, and 225 lbs N/acre (UAN-32).
  - ✓ 3 irrigation treatments: Surface drip (at 100% and 70% of ET_c) and Flood (at 100% of ET_c).
- Each treatment was replicated four times resulting in 48 subplots for each crop type (Fig. 1).

Fig. 1: Field experimental design

Irrigation and Fertilizer Applications:

•Irrigation was scheduled using ET_o values obtained from a proximate CIMIS station (#80 Fresno State) and crop coefficients computed based on published FAO-56 values (Allen et al., 1998).

•Nitrogen fertilization was split into 3 applications. UAN-32 was injected into irrigation lines.

Data measurements and analyses:

•Crop height, leaf counts, and chlorophyll content (SPAD meter readings) taken bi-monthly during growing season.

•Pre and post-season soil nitrate concentrations at three depths (12, 24, and 36").

•Fresh weight (total yield in tons/ac), dry matter percent, and comprehensive forage nutrient analysis.

•NUE and WUE calculated as yield per lbs N/ac and irrigation applied in mm, respectively.

•Statistical analyses were conducted using SPSS at 0.05 significance level.

Fig. 2: Planting (top left), mechanical and hand harvesting, and aerial view of experimental field (bottom right)

Results

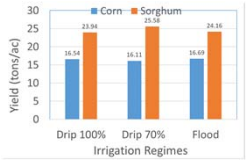

Fig. 3: Yields as a function of irrigation

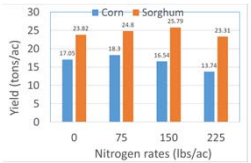

Fig. 4: Yields as a function of nitrogen rates

Table 1: Statistical significance values for effects of fertilizer, irrigation, and their interaction on yields (α = 0.05)

Crop	Fertilizer (F)	Irrigation (I)	F x I
Corn	0.057	0.063	0.048
Sorghum	0.593	0.533	0.951

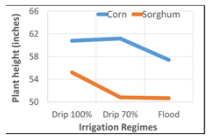

Fig. 5: Average crop heights based on irrigation regimes

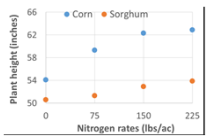

Fig. 6: Average crop heights based on nitrogen rates

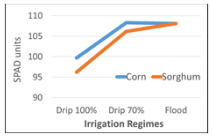

Fig. 7: Chlorophyll content based on irrigation regimes

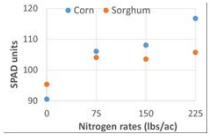

Fig. 8: Chlorophyll content based on nitrogen rates

Table 2: Yield, water applied, and water use efficiency for corn and sorghum

	Corn			Sorghum		
	Yield (tons/ac)	Water Applied (mm)	WUE (tons/ac/mm)	Yield (tons/ac)	Water Applied (mm)	WUE (tons/ac/mm)
Drip 100%	16.54	520.95	0.0317	25.97	685.67	0.0349
Drip 70%	16.11	372.43	0.043	22.48	500.38	0.051
Flood	16.69	518.9	0.0321	24.85	701.87	0.0344

Table 3: Nitrogen use efficiency for corn and sorghum

	Corn		Sorghum	
N rate per acre	Yield (tons/ac)	NUE (tons/ac/mm)	Yield (tons/ac)	NUE (tons/ac/mm)
75 lbs N	18.29	0.244	24.79	0.33
150 lbs N	16.54	0.11	25.79	0.17
225 lbs N	13.74	0.061	23.31	0.103

Discussion & Future Work

- Results showed that crop and irrigation treatments had an effect on yield and water use efficiency (WUE) (Figs 3, 4). The sorghum had significantly higher yields than corn for the treatments at $p = 0.05$ (Tables 1, 2) even though the crop height was lower than corn (Figs 5, 6).
- The 100% ET drip and 100% ET flood treatments had similar yields of 25.9 t ac^{-1} and 24.16 t ac^{-1} for sorghum respectively. The 70% drip irrigation saw reduction in sorghum yield at 22.4 t ac^{-1}.
- Irrigation, however , did not significantly affect corn yield, with an average yield of 16.4 t ac^{-1}.
- The sorghum crop had an approximate 20% increase in WUE compared to corn when irrigated with drip at 100% ET. Furthermore, the deficit irrigated (70% ET) treatments had significantly higher water use efficiency compared to the fully irrigated treatments (100% ET) for both corn and sorghum.
- Chlorophyll contents were similar for both crops (Figs 7, 8). The N treatments had a significant effect on corn yields at $p=0.057$; however, no significant difference was observed for sorghum (Table 3). NUE was highest when the crops were fertilized at the lower N rate of 75 lbs N ac^{-1}. Sorghum exhibited greater NUE than corn for all N levels.
- These results suggest that sorghum could outperform corn in terms of yield and efficiency. Additionally, drip irrigated sorghum could produce yields that are equal to the industry standard of furrow irrigated forage crops. Deficit irrigating both crops with drip at 70% could also optimize water use efficiency. Nutritional analyses showed that forage corn had higher proteins and lower fiber contents than sorghum.

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ACKNOWLEDGMENTS: Funding for this project was provided by the California State University Agricultural Research Institute with matching funds from the Department of Water Resources, Malley Farms Inc. The authors acknowledge the help of the CSUF Grad Lab Research Group and many individuals involved in this project including V. Salena and N. Toribio. Special thanks to Jeff Dahlberg and UC KARE for lending the forage harvester.