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Initial Evaluation of the Merit of Guar as a Dairy Forage Replacement Crop during Drought-Induced Water Restrictions

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Abstract: Dairy is the largest sector of the agricultural industry in New Mexico, but the sector's need for high quality forage in the face of ongoing drought and climate change causes concern. The economic merit of using guar to replace alfalfa under imposed constraints in irrigation water availability is evaluated. Nutritional quality of guar (*Cyamopsis tetragonoloba* L.) grown at the NMSU Agricultural Science Center at Clovis was estimated using Near Infrared Spectroscopy (NIRS) analysis. Results show that 45.6 percent of analyzed samples were comparable to Supreme or Premium alfalfa (*Medicago sativa*) hay using Relative Feed Value index, and 23.7% met this criteria using crude protein. While alfalfa uses 4.4 acre-feet of water (approximately 5400 cubic meters) per season, the guar sampled used 5 inches (500 cubic meters) of applied irrigation. Microsoft Excel Version 2404 LP Solver was used to identify an optimum crop mix of alfalfa and guar under different levels of irrigation water constraints. With increasing levels in modeled irrigation restrictions, the use of guar increased the potential forage production by 3% under a 0.4 acre-foot restriction up to almost 59% under a 1.5 acre-feet irrigation water limit. Our results merit additional research, including forage trials to determine the impact of guar forage on milk production and further agronomic research into growing guar to maximize forage yield.



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1. Introduction

In 2020, New Mexico was the ninth largest milk-producing state, providing approximately 8.17 billion pounds of milk [1]. Dairy is the most important agricultural industry in the State of New Mexico, contributing 43.4 percent of the total New Mexico agricultural commodity cash receipts [2]. The dairy industry relies on the state's major crop, alfalfa hay. In 2023, an estimated 155,000 acres of alfalfa were harvested [1]. But the industry's dependence on high quality forage production is a widely recognized concern [3]. Twenty-five years ago, a survey of dairy farmers found that 26.5% of respondents viewed water shortages and reduced irrigation for forage production as problems facing the industry [4].

Unfortunately, for the last two decades, the state has faced a severe drought. The Elephant Butte Reservoir (Rio Grande's southern water reservoir) was at 12.6 percent capacity in April 2022 [5]. On the eastern side of the state, the Ogallala aquifer is the main source of irrigation. It is estimated that 60 percent of the aquifer will be depleted in the next 50 years [6]. The 50-year water plan report published by the New Mexico Bureau of Geology and Mineral Resources and Interstate Streams Commission predicts that the state will have a pronounced warming trend, potentially causing decades of drought [7]. Accordingly, considering strategies for responding to the water issues in the state is essential. A number of states in the Southwest are considering various options to encourage the fallowing of agricultural lands as a response to water scarcity [8]. This paper evaluates the economic

merit of growing guar (*Cyamopsis tetragonoloba* L.) as an alternative forage replacement crop during drought-induced water restrictions, especially in relation to the needs of the dairy industry.

Guar is a summer annual legume with drought tolerant characteristics and low water requirements. It has been cultivated in India and Pakistan from ancient times. Guar cultivars can be adapted to arid and semiarid climates, and to high temperatures and dry conditions [9]. Nationally, guar production changed from 5 million pounds of US production in 1997 to over 10.4 million pounds in 2017. Oklahoma and Texas are the only states included in the NASS Quickstats database for guar production [1]. Interest in guar as a commercial crop in the Southwestern U.S. was supported by the Sustainable Bioeconomy for Arid Regions (SBAR) center, which researched agronomic and techno-economic issues related to guar expansion (see www.sbar.arizona.edu, accessed on 19 May 2024 for additional information)). Adoption of this crop as a sustainable alternative has suffered setbacks, with the only domestic guar processor filing for Chapter 11 Bankruptcy in April 2014 [10]. The plant was acquired by Guar Resources, but according to the company website, guar gum production is temporarily on hold [11].

The white powder extracted from guar beans, commonly called guar gum, has functional properties as a stabilizer, emulsifier, and thickener in food; pharmaceutical; textile; paint; paper; explosive; and cosmetics industries [12]. Planting guar increased in the 2010's in New Mexico and West Texas in conjunction with the increase in hydraulic fracturing in the oil industry. Guar gum is used to increase the viscosity of injected fluids to make oil recovery more efficient [13].

Guar as a Potential Forage

Since the name “guar” means “cow food” in Hindi [14], there has been interest in using the byproducts of guar gum production as an animal feed, especially when large quantities of guar gum were utilized in the oil and gas industry. An Iranian study found that 4 percent of soybean (*Glycine max*) meal could be replaced with guar meal in lactating Holstein cows without any negative effect on performance [15]. Another study, also on lactating Holstein cattle, demonstrated that guar meal could effectively replace cottonseed (*Gossypium hirsutum*) meal, but they noted issues with palatability when more than five percent guar meal was fed. The authors also noted that dairy cows and heifers acclimated to taste and odor after a few days, even with rations containing 10–15% guar meal (Salehpour, Qazvinian, and Cadavez, 2012 [16]); and Olfaz, Kilic, and Yavrucu, 2019 [17] attempted to address palatability issues caused by the presence of hydrocyanic acid in young guar beans by mixing them with other grains, molasses, or molasses + ecomass (Ecomass is a feed additive containing 48% CP and 94% dry matter in dark brown powder form, containing powdered fermentation-derived proteins and complementary carbohydrates (bran and corn gluten)) and ensiling the product. The analysis of palatability relied on the measurement of the tannin content of post-fermentation feed [17]. Other studies have incorporated animal performance results, and found success in improving performance [18–20]. However, these were primarily focused on improving the diets of small ruminants in situations of protein deficiency.

This study represents a switch in focus to provide an initial look at the potential for using guar as a drought-tolerant forage replacement for alfalfa, specifically under the assumption that many dairy forage producers may face mandated reductions in irrigation. Unlike earlier dairy studies, this study is a change from attempting to use guar meal produced as a by-product in the extraction of guar gum. Instead, this study evaluates the nutritional composition of the vegetative biomass, and proposes the utilization of guar as a forage. This study recognizes the attractiveness of alfalfa as a forage for high-producing dairy cattle of the Southwest, but hypothesizes that the low water requirements of guar may make the plant a feasible option when faced with irrigation restrictions.

2. Methods and Data

The reader should recognize this as a preliminary study, not as the definitive research on guar as a potential feed. This work contains no animal trials. This work is based on the best available estimates, in some cases this relies on extrapolations from research trials originally focused on seed production in a study on the potential of guar for development of bioeconomies.

Understanding that the data was obtained from prior research evaluating the commercial production of guar gum informs some of the methodology. The guar varieties selected, the seeding rates, and all other aspects of the guar trials were not designed with forage production in mind. However, the underlying objective of the original research was focused on the search for sustainable cropping options to support rural economies increasingly challenged by drought. To this end, this study analyzed biomass collected in guar-gum trials and analyzed it for forage potential. The results here rely on estimates from a number of different research projects as a source of reasonable parameter estimates. As noted below, the majority of guar samples and research projects were from Agricultural Science Centers near Clovis, NM and Tucumcari, NM, both areas where a large percent of forage production is used to support New Mexico dairies.

2.1. Nutritional Analysis

Nutritional analysis was conducted on 292 samples of guar by Ward Laboratories, Inc. (Kearney, NE, USA) using near-infrared reflectance spectroscopy (NIRS) analysis to estimate forage quality. The samples for the NIRS analysis were taken from a guar fertility management experiment with different irrigation treatments, and 292 samples were analyzed [6]. The study evaluated two irrigation treatments: 5 inches of irrigation applied pre-planting, and 5 inches of irrigation applied in-season over a 3-month period. Four fertilization protocols were used: 0 pounds/acre, 20 pounds/acre (22.4 kg/ha), 40 pounds/acre (44.8 kg/ha), and 60 pounds/acre (67.2 kg/ha) of “RapidUp” 20:20:20 NPK fertilizer. Three cultivars, Monument, Kinman and Judd66, were included. The guar samples were primarily grown in the Agricultural Science Center in Clovis, New Mexico (288 samples from this location), with an additional four samples contributed from Leyendecker Agricultural Science Center in Las Cruces, NM, USA.

The results were used to evaluate the nutritional comparability of guar to alfalfa. In this analysis, guar and alfalfa were compared based on sample levels of CP, and on index values for RFV and RFQ. These were used based on their importance for forage selection and valuation [21].

2.2. Estimated Water Usage

To reiterate, this study intends to explore the merit of continued research into guar as a potential alternative to fallowing land as a response to water restrictions. As such, available data were used to provide early parameter estimates. Please note that the water use estimates are from different years. Still, these estimates from New Mexico Agricultural Science Centers provide sufficient data for reasonably reliable estimates of expected water use in these two crops. Alfalfa water use was determined from observations at Tucumcari, Clovis, and Artesia Agricultural Science Centers. Annual water usage for alfalfa is based on unpublished data from 2014 and 2015 from New Mexico State University’s Agricultural Science Centers at Tucumcari, NM, and Artesia, NM. Guar water usage estimates are based on amounts of applied water from the treatments described above.

2.3. Yield Estimates

Alfalfa, with multiple cuttings per year, has much higher yields than guar. For this study, the average yields based on the same data from the New Mexico Agricultural Science Centers mentioned above were 6.99 Tons/Acre, or 15.67 MgHa^{−1} from 2021.

Guar yield was estimated from biomass data taken from [6], a separate research trial. DAP and NPK signify the days after planting on 7 June 2021 and 20-20-20 fertilizer (nitrogen

(N), phosphorus (P), and potassium (K), each at 20% of the formulation) applied in lb/ac at the preceding values, respectively. The maximum yield of 2.6 tons/acre (5832 kg/ha) achieved from 20 kg/ha of NPK and in-season irrigation with 5 inches of applied irrigation was used as the estimate of guar yield.

The yield of guar is highly variable, but it is important to remember that the plots were originally planted to measure differences in seed production and not for a total biomass production objective. Because of this, we used the highest guar yield of 2.59 tons/acre or 5.83 MgHa⁻¹. It is plausible that guar, when planted for forage production, will yield greater quantities of biomass. Accordingly, the model provides a very conservative estimate of the potential for using guar as an alternative to fallowing portions of a farm as a drought-response, and this potential increases with increased yields. Because the best biomass measurements come from earlier studies focused on seed production, this study can likely be viewed as a lower-bound estimate of the potential use of guar as a drought response.

2.4. Costs of Production and Forage Price Estimates

Costs of production for both guar and alfalfa are estimated based on the Breakeven for New Crop Options Model (BENCO) developed under the Sustainable Bioeconomies for Arid Regions grant (This model, developed under the SBAR grant, is designed to allow farmers to consider the adoption of new crops in response to climate change. The model can be customized for any new crop under consideration, but includes guar because of the central focus of guar as a potential commercial crop) [22]. Alfalfa costs are based on single-year costs and revenue for established stands. Alfalfa prices were based on US Department of Agriculture—National Agriculture Statistics Service estimates of monthly prices received in New Mexico measured in USD/ton, with a USD 270 average for 2022 [1]. Guar has never been sold as a forage in this country, so no market data exists. The price of guar forage was based on US Department of Agriculture National Agriculture Statistics Service estimates of monthly prices received in New Mexico; estimates for “Other hay, excluding alfalfa” for New Mexico in 2022 averaged USD 224/ton [1]. Because of uncertainty in the valuation, additional comparisons were made based on total levels of CP and RFV, and this did not change optimal crop mixes.

2.5. Forage Quality

Forage quality has several types of measurements depending on the desired analysis. Feed protein content, measured as Crude Protein (CP), is commonly used as an indicator of forage value [23], although there has been a shift in the past three decades to balancing diets for Rumen Degradable Protein and Rumen Undegradable Protein fractions [24]. The RFV (Relative Feed Value) index combines digestibility and intake to allow for the comparison of forages on the basis of energy. The index compares forages to alfalfa, with full-bloom alfalfa used as a 100 on the RFV index [25].

The RFV calculation is essentially a measurement of digestibility.

$$\text{RFV} = (\text{Dry matter intake as a percentage of bodyweight}) \times (\text{Digestible dry matter as a percentage of bodyweight}) \div 1.29$$

More specifically, RFV calculations rely on acid detergent fiber (ADF) and neutral detergent fiber (NDF) measurements so that digestible dry matter = $(88.9 - (0.779 \times \% \text{ADF}))$ and dry matter intake = $(120 \div \% \text{NDF})$.

In contrast, RFQ (Relative Forage Quality) is considered to be a new measure with some advantages over RFV. The RFQ index is based on the summative energy equation (used in the new Dairy NRC [26]) to estimate the digestibility of nutrients contributing to energy and dry-matter intake based on digestible NDF (Neutral Detergent Fiber) and NDFD (NDF Digestibility) [21]. The primary difference is that Total Digestible Nutrients (TDN) is used instead of digestible dry matter, as in the RFV calculation.

$$\text{RFQ} = (\text{Dry matter intake as a percent of body weight}) \times (\text{Total Digestible Nutrients as a percent of bodyweight}).$$

For a legume, the TDN is calculated as such:

$$\text{TDN} = (\text{Non fibrous carbohydrates} \times 0.98) + (\text{Crude protein} \times 0.93) + (\text{Fatty acids} \times 0.97 \times 2.25) + [\text{Nitrogen free NDF} \times \text{NDFD}/1000] - 7.$$

The Dry matter intake for legumes is calculated as:

$$\text{DMI} = 120/\text{NDF} + (\text{NDFD} - 45) \times 0.374/1350 \times 100$$

Both RFV and RFQ are widely used to evaluate hay.

Linear Programming (LP) models, and their wide availability, provide a simple tool for farmers facing increasingly difficult resource constraints. Arguably, the most pressing constraint for New Mexico farmers is the increased risk of irrigation water limitations [27]. The model created here utilizes Excel Solver LP (Microsoft 365, Redmond, WA, USA, 2023), which allows farmers to replicate the analysis provided here and easily customize the model for individual farms.

The LP Model has three decision variables: the amount of land to devote to alfalfa, guar, or fallow, with subscripts a , g , and f , representing alfalfa, guar, and fallow, respectively.

The objective function seeks to maximize the gross margin of forage produced on a farm consisting of L available acres. Here, F_V represents the value of the total forage produced. Total forage production is calculated by multiplying the acres devoted to each crop by the estimated yield of each crop. Then, the total forage produced is multiplied by the gross margin for each type of forage.

$$\text{Objective} = \text{Max } F_V = \sum_{i=1}^3 L_i Y_i M_i$$

Subject to:

$$L_a + L_g + L_f = L_{\text{total}}$$

$$L_i \geq 0$$

$$W_i = C_i L_i$$

$$W_a + W_g + W_f \geq W_{\text{total}}$$

For simplicity of interpretation, 100 acres were used as the total farm size in production.

3. Results

Table 1 shows the percentages of the guar samples analyzed. The crude protein analysis was the nutritional component that guar fared the worst in, with 40.1 percent of samples below 16.0, or utility hay classification [28]. The estimates for RFV and RFQ of guar biomass look promising. For RFV, 45.6% percent of samples would meet Supreme or Premium designation, and for RFQ, 97.9% percent of samples met the criteria for Premium alfalfa hay.

Table 2 shows a marked improvement in nutritional composition for the earliest planting date. There were 96 samples taken from 9 August 2021, another 96 from 30 August 2021, and 100 samples harvested on 22 September 2021. One Way ANOVA showed that differences in the mean are significant among harvest dates at the $\alpha = 0.05$ level.

Unfortunately, earlier harvest would likely have predictable decreases in yield (replicated in Table 3 from [6]). Table 3 shows the averages of above-ground biomass of two irrigation treatments, along with four fertilization treatments and two different cultivars. No yield data were collected that were associated with the guar nutritional sample data. The biomass yields in this study show that the greatest yields, in general, occur approximately 107 days after planting (Table 3). The yield used in estimating optimal crop mixes were based on averages from interactions between the different treatments.

Table 1. Percent of guar samples collected in 2022 at Clovis, NM, USA, fitting in each hay quality category. The first three columns provide the USDA Guidelines for hay quality designations, and the last three columns indicate the percent of the guar samples fitting each quality designation.

USDA Hay Quality Designation Guidelines						
	USDA Guides			Guar Samples		
	Crude Protein (CP)	Relative Feed Value (RFV)	Relative Feed Quality (RFQ)	Crude Protein (CP)	Relative Feed Value (RFV)	Relative Feed Quality (RFQ)
Supreme	>22	>185	--	11.0%	37.0%	--
Premium	20–22	170–185	≥140	12.7%	8.6%	97.9%
Good	18–20	150–170	110–139	16.1%	13.4%	1.4%
Fair	16–18	130–150	90–109	20.2%	22.9%	0.7%
Utility	<16	<130	<90	40.1%	18.2%	0.0%

Note: USDA guidelines taken from [28]. RFQ values taken from [29]. CP, RFV, and RFQ signify crude protein, relative feed value, and relative forage quality, respectively.

Table 2. Average guar sample values by date of harvest at Clovis, NM, USA in 2022. Guar was planted on 7 June 2022.

Harvest Date	Crude Protein (CP)	Relative Feed Value (RFV)	Relative Feed Quality (RFQ)
9 August 2021	21.1	228.0	180.4
30 August 2021	16.1	163.2	173.6
22 September 2021	14.5	128.6	164.3

Notes: The means of each planting date are statistically different for each category at $\alpha = 0.05$. CP, RFV, and RFQ signify crude protein, relative feed value, and relative forage quality, respectively.

Table 3. Above-ground guar biomass grown in 2021 with different treatments applied at Clovis, NM, USA.

Days after Planting	Biomass					Average
	44 DAP	63 DAP	84 DAP	107 DAP	140 DAP	Total
Treatments	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)
Irrigation						
Pre-Irrigation (PI)	328	3766	4002	4443	4226	3353
In season (NPI)	379	3823	5485	5918	5511	4223
Fertilization						
0 NPK	339	3522	4564	4605	4474	3501
20 NPK	303	3510	4715	5262	5015	3761
40 NPK	346	4262	4819	5361	4879	3933
60 NPK	424	3883	4876	5493	5106	3956
Cultivar						
Kinman	347	3939	4873	5373	4943	3895
Judd 66	360	3650	4615	4988	4794	3681

Notes: Biomass data taken from a separate research trial [6]. DAP and NPK signify days after planting 7 June 2021 and 20-20-20 fertilizer (nitrogen (N), phosphorus (P), and potassium (K), each at 20% of the formulation) applied in lb/ac at the preceding values, respectively.

To consider the potential of this drought-resistant crop playing a role in the arid-land dairies' response to irrigation water limitations, linear programming was used to evaluate the crop mix between alfalfa, guar, and simply fallowing land with no water applied. Fallowing was never included as part of an optimal solution, an equally promising result that guar might provide an option for improving forage production in drought, while also providing some soil protection and ground cover benefits not measured here. The results are shown in Table 4. The yield advantages of alfalfa make it a better choice whenever enough water is available. In eastern New Mexico, ranging from Tucumcari to Artesia,

this requires approximately 4.4 acre-feet of applied water. Consider the case of a mild restriction that drops available irrigation to 4.0 acre-feet to the 100-acre farm in the scenario. Under the restriction, a maximum of 90.9 acres of alfalfa could be grown. By sacrificing less than an acre of alfalfa, the remaining 10 acres could be planted to guar. This is a loss of almost 6.4 tons of alfalfa, or a lost value of USD 1715 using the USD 270 for premium hay, or USD 1214 using the gross margin estimate. Instead, the 10 acres of guar yields 26 tons with a gross margin of USD 4804. The protein is likely lower, but if the reader considers the RFV or RFQ, the energy and digestibility of guar may still make this a useful alternative for drought conditions. Additionally, all of the farmable acreage is planted to a nitrogen-fixing legume.

Table 4. Optimal crop mixes for 100 acre farm under increasingly constrained water availability in the US Southwest.

Acres\Water Ac-Ft	4.4	4.0	3.5	3.0	2.5	2.0	1.5	1.0
Fallow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alfalfa	100.0	90.0	77.4	64.9	52.3	39.7	27.2	14.6
Guar	0.0	10.0	22.6	35.1	47.7	60.3	72.8	85.4
Forage Produced Avg Tons/Ac	7.0	6.5	6.0	5.4	4.9	4.3	3.8	3.2

Under the extreme scenario of 1 acre-foot of water, guar would constitute 85.4 percent of forage produced. When faced with a two-crop choice, that is a much greater percentage than would likely be fed. The lower yield of guar results in a decrease in forage production of more than 54 percent, so additional forage would almost assuredly be imported to the farm.

Figure 1 demonstrates the relative contribution of total forage produced and the percentage of water devoted to each crop under water constraints. The image reinforces the a priori expectations that guar would be planted in response to extreme water restrictions.

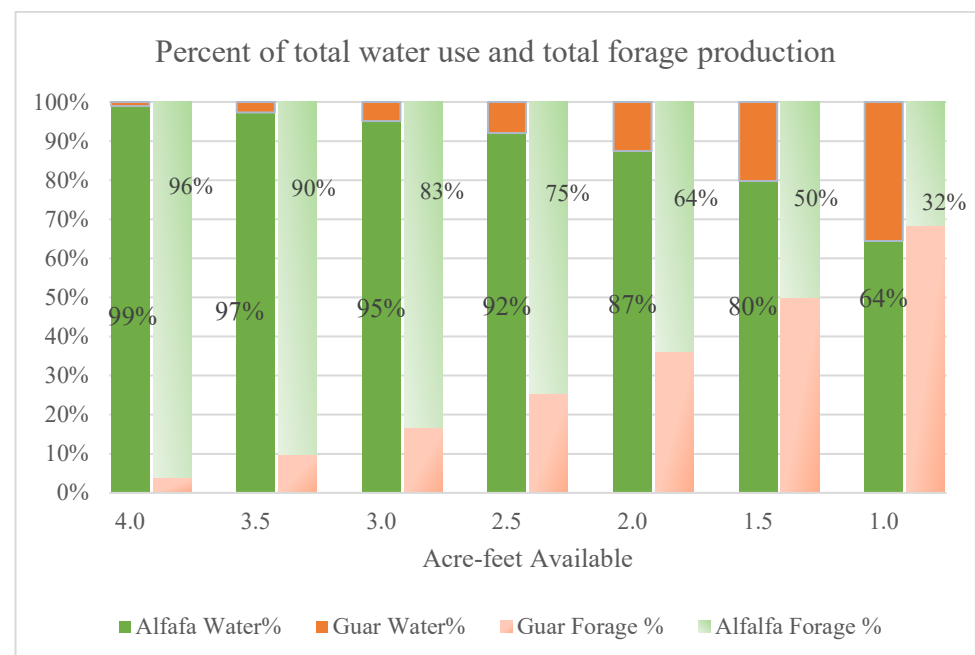


Figure 1. Percent of total water use and total forage production under decreasing water availability. Alfalfa is shown in green, guar is shown in orange; water use is shown in darker shades, forage production is shown in lighter shades. Labels indicate the percentage of water used by alfalfa and the percent of total forage contributed by alfalfa.

4. Discussion

The results here are presented based on the forage quality analysis, but seem promising enough to justify progression to animal trials. Peter Robinson, dairy extension specialist at University of California-Davis, notes that the expense of alfalfa has resulted in alfalfa losing ration-share to other forages for the past two decades, but he also noted that alfalfa hay has values beyond those traditionally used in ration formulation, including alfalfa's ability to stimulate cud chewing due to its cation exchange capacity [30]. Aside from the uncaptured benefits of alfalfa in dairy rations, the nutritional analysis might be missing potential, but yet unknown, negative aspects of guar as a forage. As noted earlier, most of the feed trials of guar have been in impoverished areas in small ruminants where guar was utilized to improve low production animals. According to USDA NASS data for 2021, in New Mexico, dairy cows produce 24,541 pounds of milk per head/year, compared to a national average of 23,948 [1]. While the previous literature has shown that guar meal use has not limited production by Holstein cattle, the effect of forage needs to be evaluated. A major concern is related to palatability issues potentially decreasing intake [16,17]. Other concerns, such as the potential for animal bloat or other types of digestive upset, require animal feed trials, but should not be interpreted as resolved through this Excel-based analysis or the nutritional analysis conducted.

In addition to feed-trials, the positive findings justify further investigation, including analysis in more sophisticated linear programming software like GAMS (GAMS Development Corp -GAMS is a registered trademark of GAMS Software GmbH in the European Union, 2023). This would allow for greater flexibility, including options to reduce irrigation on alfalfa and accept lower yields. The current model only presents corner solutions for set levels of water. Quadratic production functions would allow farmers to choose to irrigate conventional crops at suboptimal levels for lower yield.

Here, guar was compared to alfalfa because of its importance in dairy rations and because the guar nutritional analysis was high enough in protein and RFV to be comparable to alfalfa. Additionally, the high water use in alfalfa makes it a likely target for replacement under water constraints. An obvious area for further work is to compare guar to other forages. Other forages commonly fed to dairy cattle are corn (*Zea mays*) silage [31] and sorghum (*Sorghum bicolor* and *S. bicolor* × *S. sudanese*) silage [32], each dependent on irrigation when grown in the western U.S.

There are some issues with the comparison. First, the comparison is between guar, an annual plant, and alfalfa, a perennial plant. We compared the full water usage of alfalfa, but did not account for the plant's ability to go dormant during low water periods. Still, the results hold because alfalfa production is also negated during these periods.

The majority of research on yield in guar has been focused on seed pods, with much less focus on total biomass production. However, work done by Adams et al. (2020) compared the growth stages of Kinman, Monument, and Lewis varieties. This work includes comparisons of biomass [33]. This follows work characterizing 68 guar genotypes; of these, 17 non-branching genotypes were selected, of which 4 were focused on for seed production [34]. If guar is found to have merit as a drought-tolerant forage, it likely warrants revisiting the selection of varieties to select specifically for greater forage production. In addition to evaluating other varieties based on growth structure and resultant biomass production, there are also environmental factors that may affect the nutritive value, including pedoclimatic conditions.

In New Mexico, dairy production has shifted northward in the state, with the percentage of milk production produced in the southern portion of the state declining through the past decade (based on changes in permitted cattle by location). While guar is known for its heat tolerance, the viability of guar as a dairy forage may be related to its ability to tolerate cooler temperatures, and thus its ability to be grown in the southern High Plains region of the U.S. [35]. This is another area justifying further research. However, consideration of guar as a potential forage option could result in research trials including additional

information on biomass yield, which would improve the ability to model the tradeoff between traditional forages and guar.

Other options for research include varying the planting structure of guar. The samples and yield data came from trials that were originally intended to evaluate seed production. Planting in narrower rows compared to the 30 inches (60 cm) used by Sidhu et al. may increase yield through more efficient resource utilization [6].

5. Conclusions

It is important to note that the study parameters were all pulled from data gathered in the Agricultural Science Centers in New Mexico. The results may not be generalizable for other regions. Still, the results have promise, and merit additional research. The benefits of guar arise primarily from extremely low water use, especially when compared to the greater water requirements of other high-quality forages that support the dairy industry in arid and semiarid regions, such as the US Southwest.

This paper should not be interpreted as concluding that guar is a viable dairy forage, only that it merits further consideration, including animal trials. While further research is needed, the potential of a drought-tolerant forage with low fertilizer needs is worth exploring for dairy farmers in the arid Southwest.

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