

Optimizing Sorghum as a Versatile Forage Crop: Insights from a Multi-Year California Study

by

Kaweesi Tadeo (PhD)

Background

- The California dairy industry, a significant economic driver generating over \$57.7 billion annually in recent years
- Faces challenges in securing a sustainable and cost-effective feed supply due to rising costs and competition for water resources.
- Sorghum, a versatile C4 grass with increasing prominence, due to its exceptional adaptability, drought tolerance, and diverse applications



Study Overview

- **Objective:** Evaluate the performance and stability of 59 sorghum hybrids across diverse environments in California over five years (2019–2023)
- **Focus:** biomass yield, forage quality traits, and biofuel-relevant chemical composition.
- **Locations:** the University of California, Division of Agriculture and Natural Resources - Kearney AREC, Parlier (KARE), WestSide AREC, Five Points (WSREC), and the University of California Davis, (Davis).



Evaluation of sorghum hybrids

- Sorghum hybrids comprising (i) traditional forage sorghum (non-bmr), (ii) brown midrib (bmr) sorghum, (iii) photoperiod-sensitive (PS) sorghum, and (iv) photoperiod sensitive bmr (PS bmr) sorghum.
- Traits evaluated: Biomass yield, crude protein, height, ash, starch, ADF, NDF, NDFD30, WSC sugar, ESC sugar
- Quality parameters: Relative forage quality (RFQ) and Milk/ton
- RFQ was calculated from total digestible nutrients and digestible dry matter (combines the digestibility and intake potential of the feed)
- Milk/ton 2013 was used to rank samples for different sorghum hybrids, showing the potential milk yield per ton of forage dry matter (lb/ton).

Characterization of different sorghum hybrids

- A **RFQ of 100** was considered the average score across multiple types of forage to generate a relative index value and was represented as a **fully mature alfalfa hay**.
- Based on the RFQ score, the feed quality for a sorghum hybrid was graded either as **utility** (<90), **standard** (91–110), **select** (111–140), **choice** (141–160), **prime** (161–185), and **supreme grade** (>185).
- Each sorghum hybrid milk/ton score could then be compared to the average **alfalfa-grass milk** yield of 3000 lb/ton

Table 1: Categorization of sorghum based on relative feed quality score

RFQ Score	Grade**	No of sorghum hybrids
>185	Supreme	0
160-180	Prime	0
140-159	Choice	2 (UCSG08, UCSG51)
110-139	Select	35
90-109	Standard	21
<90	Utility	1

Grade** -- **Supreme** and **Prime** denotes exceptionally nutritious, highly palatable formulated to meet or exceed nutritional requirements for the intended animals

Choice grade feed of **good quality, with nutritional value that meets all necessary** nutritional standards for the animals it is intended for

Select grade - **acceptable quality, meeting basic nutritional requirements** providing adequate nutrition for animals

Standard grade feed - meets **minimum nutritional requirements**, suitable for basic maintenance but may not be optimal for high-performance animals

Utility grade feed **would be of lower quality**, that meets **very basic** nutritional needs but may not be ideal for promoting optimal growth or production.

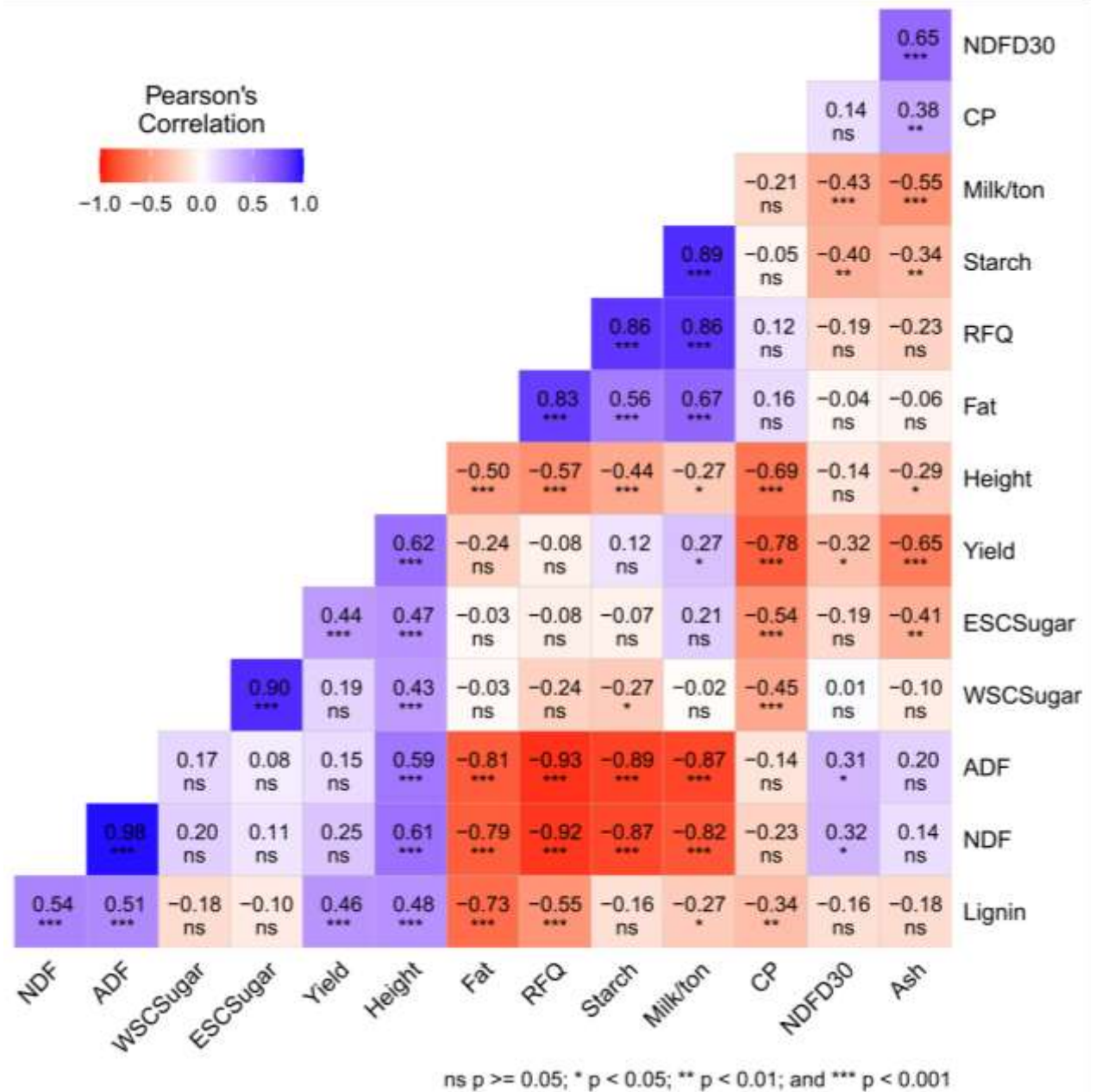
Table 2: Predicted genotypic mean of yield and compositional qualities of 59 sorghum genotypes evaluated in three locations in California

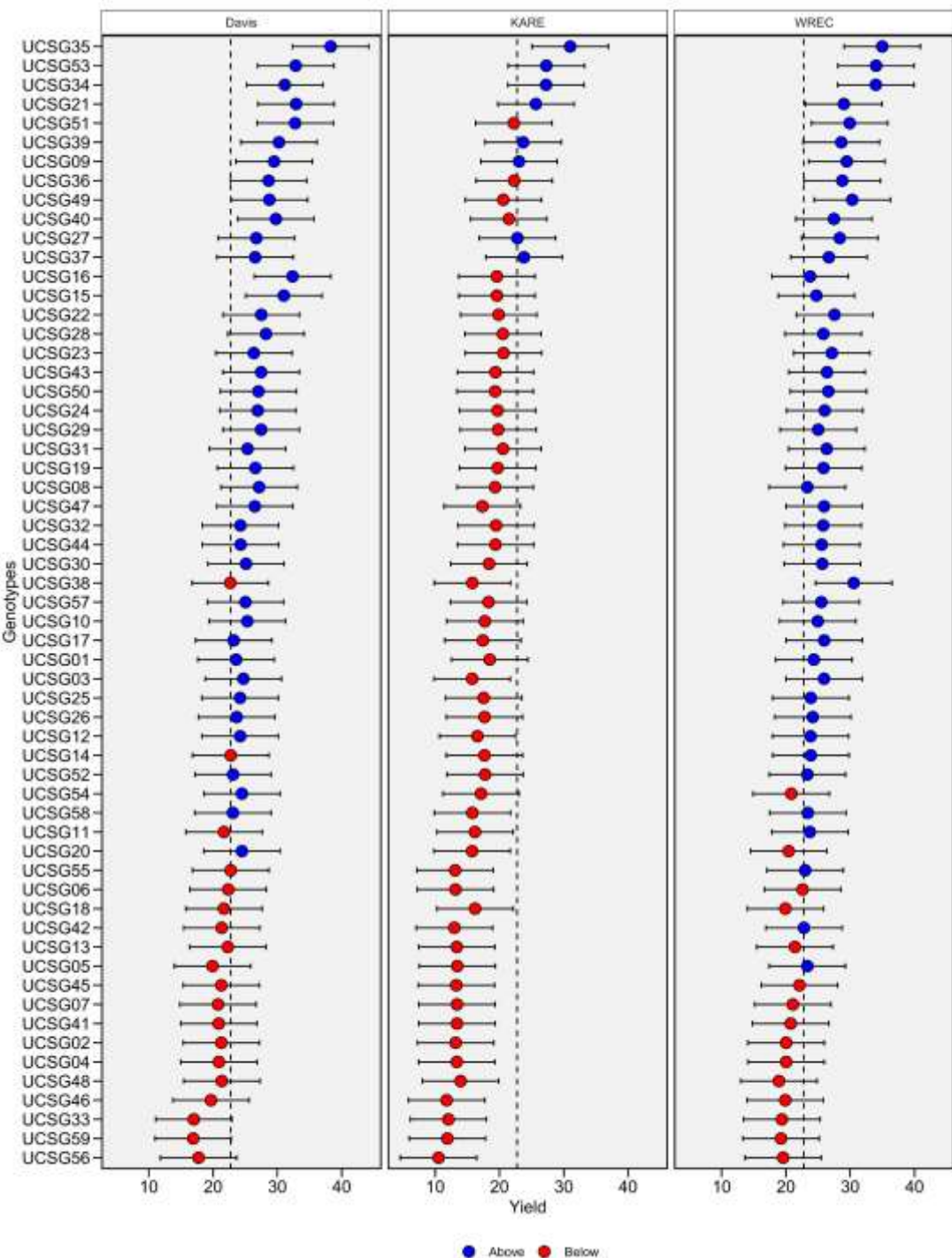
Genotype	Yield	CP [§]	NDF30 ^{§§}	Starch	WSC Sugar	RFQ ^{§§§}	Milk/Ton
UCSG35	75.10	6.99	49.82	6.26	9.74	95.63	2608.80
UCSG53	68.37	6.90	50.10	4.23	8.84	92.39	2537.02
UCSG34	67.21	7.14	49.55	6.77	9.24	98.28	2587.77
UCSG21	64.00	7.42	52.33	5.77	8.10	90.66	2460.20
UCSG51	62.25	8.36	45.92	27.24	2.24	146.26	3119.35
UCSG39	60.66	7.57	50.69	9.15	9.02	102.14	2628.38
UCSG09	60.32	7.89	50.80	16.42	7.29	118.90	2806.50
UCSG36	58.78	8.03	54.57	4.76	8.24	105.16	2467.82
UCSG49	58.78	7.68	48.81	10.46	9.62	101.24	2629.32
UCSG40	58.13	7.72	53.33	12.39	9.14	115.36	2868.67
UCSG27	57.59	7.42	48.38	11.89	11.09	111.48	2761.56
UCSG37	57.12	7.47	51.63	3.40	8.09	91.75	2396.33
UCSG16	56.16	8.09	47.53	18.35	7.79	123.15	2882.14
UCSG15	55.91	8.01	47.19	18.40	7.60	119.26	2892.71
UCSG22	55.59	7.84	48.88	12.23	8.82	105.82	2613.97
UCSG28	55.42	7.79	47.90	19.46	11.18	126.96	3027.72
UCSG23	55.08	8.17	52.92	18.87	9.18	128.80	2840.29
UCSG43	54.52	8.22	49.68	20.62	7.86	126.00	2888.93

Evaluated sorghum hybrids varied ranging -- **2123.89 and 3119.35 lb/ton** -- Hybrids **UCSG51, UCSG28 & UCSG08** performed better than **alfalfa-grass** milk yield of 3000 lb/ton

Correlation Between Compositional and Yield Traits Among Different Sorghum Genotypes

- Fat, starch, and relative feed quality (RFQ) were highly correlated with milk/ton
- Implication – Increase fat and starch – through breeding or mechanization (starch)
- Biomass yield positively correlated with height, structural fiber, and lignin,
- Yet structural fiber and lignin were negatively correlated to forage quality traits (RFQ & Milk/ton)
- Implication –High biomass has a quality penalty associated with high fiber content ---ideal for biofuel but not forage



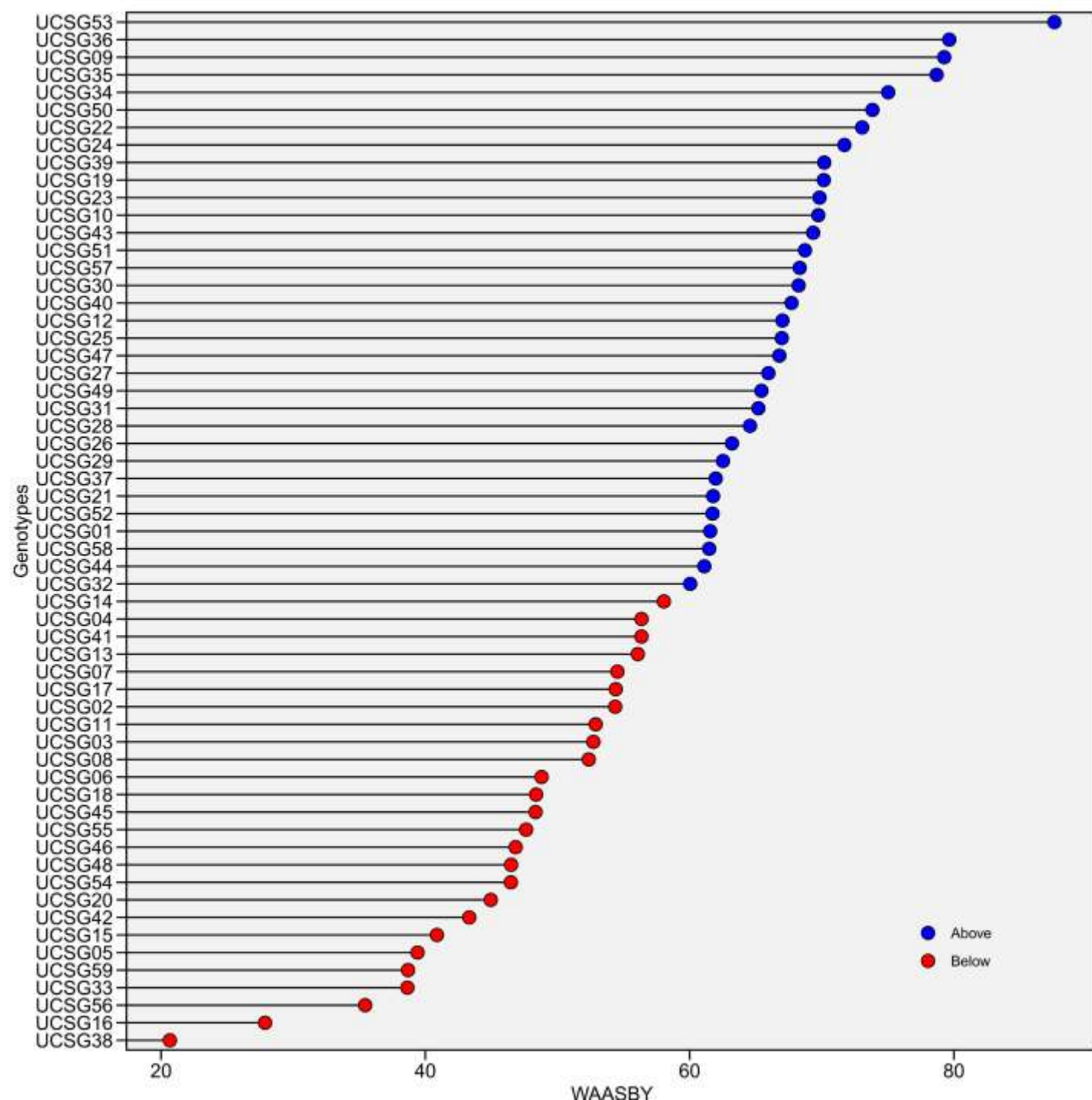


Performance in the three locations

- Plant responses across the three environments showed high variation, with sorghum hybrids at KARE having comparatively lower yields
- The sandy loam soil at the KARE site has much lower soil water-holding capacity than soils at the other two sites.

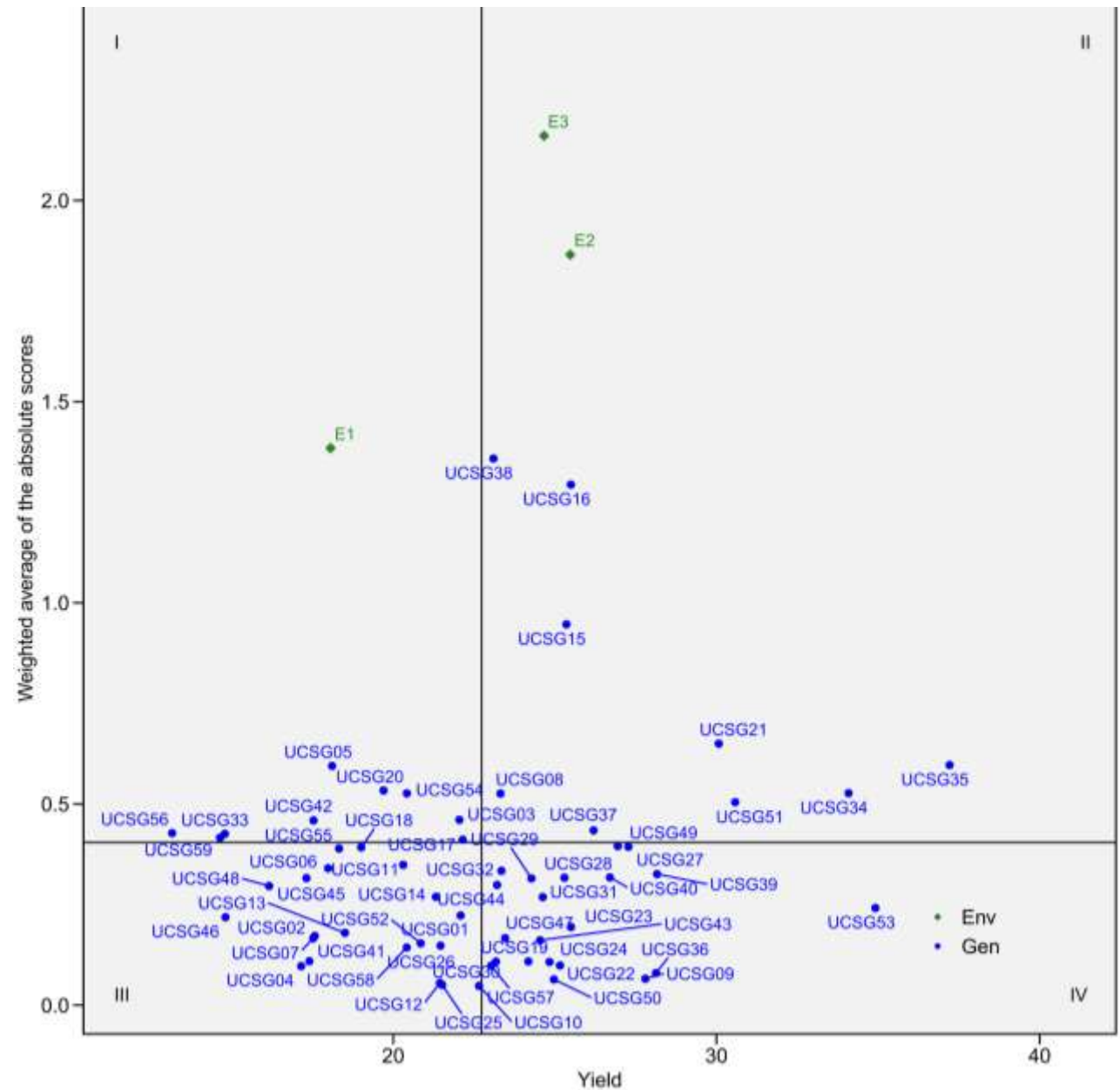
Mean Performance and Stability of Sorghum Hybrids in Different Environments in California

- Stability of the sorghum hybrids in different environments across multiple years was assessed using a superior index of weighted average absolute scores from BLUP for yield (WAASBY)
- The five most productive and stable sorghum hybrids in all locations and across the time of evaluation were UCSG53, UCSG36, UCSG09, UCSG35 and UCSG34.



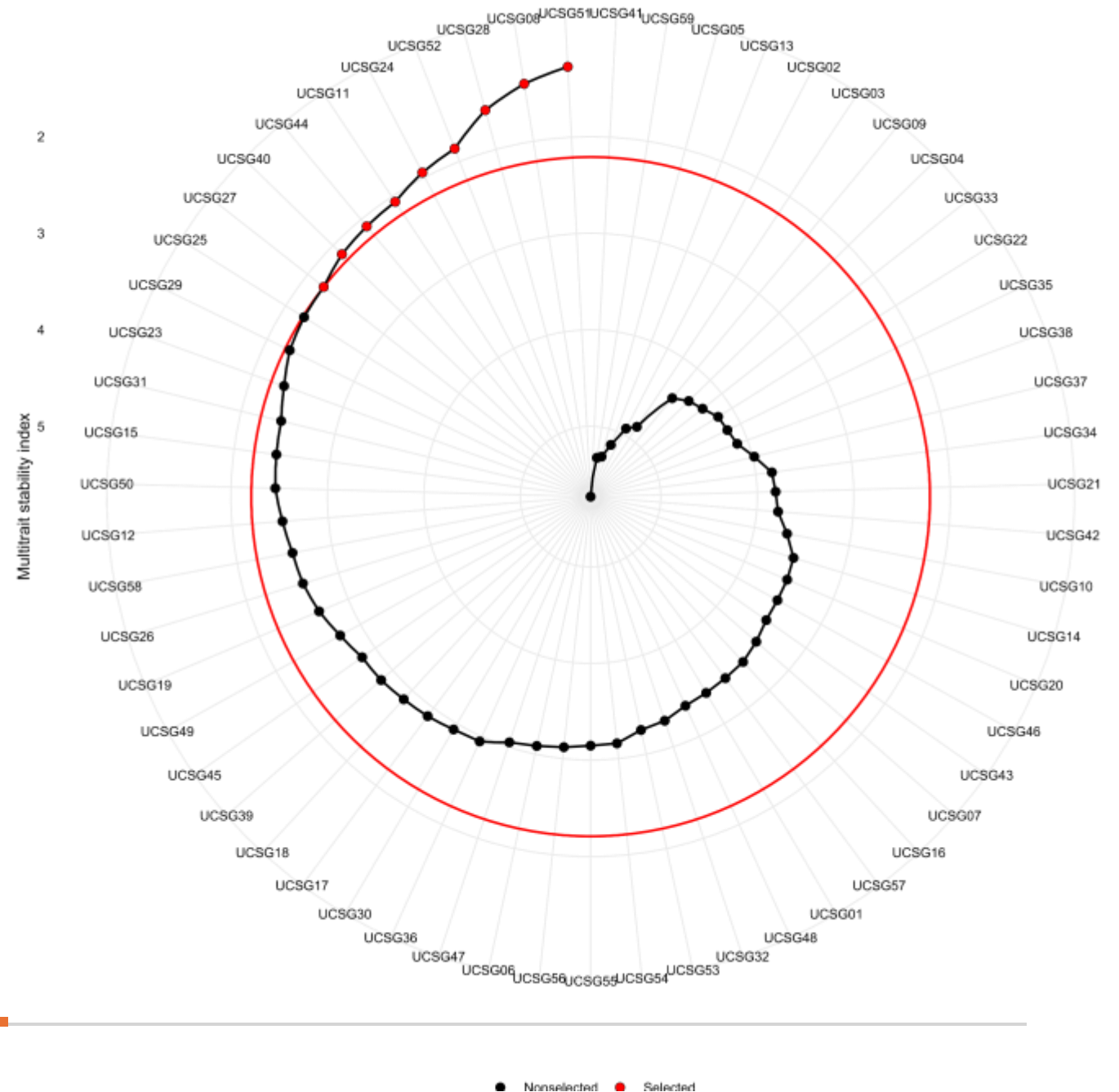
Multi-Trait Selection - four groups (groups I–IV)

- Group I had sorghum hybrids that were both not productive and not stable
- Group II had hybrids that were highly productive but not stable
- Group III had hybrids that were highly stable but not productive
- Group IV had hybrids that were highly stable and productive



Multi-Trait Selection for High-Quality Forage and Biofuel Production

- Multi-trait stability index was used to identify the stable genotypes combining good quality traits (RFQ and milk/ton for feed and high carbohydrate content for biofuel production)
- Radar plot showing the best sorghum hybrids selected for forage based on Yield, Milk, and RFQ using multi-trait stability index



- For biofuel production, the sorghum hybrids with high biomass yield also had high structural carbohydrates such as fiber (lignin and NDF)
- Therefore, stable hybrids combining biomass yield, starch, and high NDF content were selected for both first-and second-generation biofuel production
- Three sorghum hybrids (UCSG51, UCSG08, UCSG27) exhibiting desirable traits for both forage and biofuel production

Breeding implications

Breeders focusing on the development of high-quality forage for dairy production should

- i. Prioritize genotypes with high fat and starch levels to enhance the overall feed quality and milk production potential of sorghum forage
- ii. Target genotypes with reduced structural carbohydrates (ADF, NDF, and lignin) to improve digestibility and nutrient utilization by dairy cows.
- iii. Ability to explore “compromise traits” for selection of dual-purpose sorghum hybrids – such as 1) optimizing the cellulose to hemicellulose ratio, 2) balancing starch and stem sugar content etc can enhance both livestock digestibility and biofuel conversion efficiency
- iv. Develop separate breeding schemes for forage and biofuel sorghums.

Key Findings for California Dairy Farmers

Optimal Sorghum Hybrids for High-Quality Forage

- Nine sorghum hybrids identified with high biomass yield, relative feed quality (RFQ), and milk production potential
- Top performers: UCSG51, UCSG08, UCSG28

Balancing Yield and Quality

- High fat and starch content positively correlated with milk/ton
- Lower fiber content (ADF, NDF) associated with better feed quality
- Consider these traits when selecting sorghum varieties for dairy feed





Multipurpose Sorghum Options

- Three hybrids (UCSG51, UCSG08, UCSG27) suitable for both high-quality feed and biofuel production
- Provides flexibility for farmers to diversify income streams or adjust crop use based on market demands

Acknowledgement

Article

Optimizing Sorghum for California: A Multi-Location Evaluation of Biomass Yield, Feed Quality, and Biofuel Feedstock Potential

Jackie Atim ^{1,*} , Tadeo Kaweesi ¹ , Robert B. Hutmacher ^{2,3}, Daniel H. Putnam ³, Julie Pedraza ¹, Christopher M. de Ben ³, Tarilee Schramm ¹, Jorge Angeles ¹, Nicholas E. Clark ¹  and Jeffery A. Dahlberg ¹ 

Seed companies: Scott Seeds, Dyna-Dro Seeds, S&W Seeds, Zinma Seeds, Sorghum Partners, Moj Seeds, Grayland ward Seed, Croplan, Richardson Seeds, Advanta-Alta and Supra International