



# Alternative Summer Annual Legumes

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# Background Information

- Growing demand for forage in the region
- Summer annual forage grasses common in the region (forage sorghum, sorghum-sudan, etc.)
- High yielding, but low protein
- Growing & lactating cattle require high quality forage
- Alfalfa requires irrigation (<24" rainfall)
- Limited knowledge about potential summer annual forage legume capabilities in the region

# Objective

- Determine the yield potential, forage nutritive value, and water-use efficiency of six warm-season annual forage species (four legume species and two grass species)

# Hypotheses

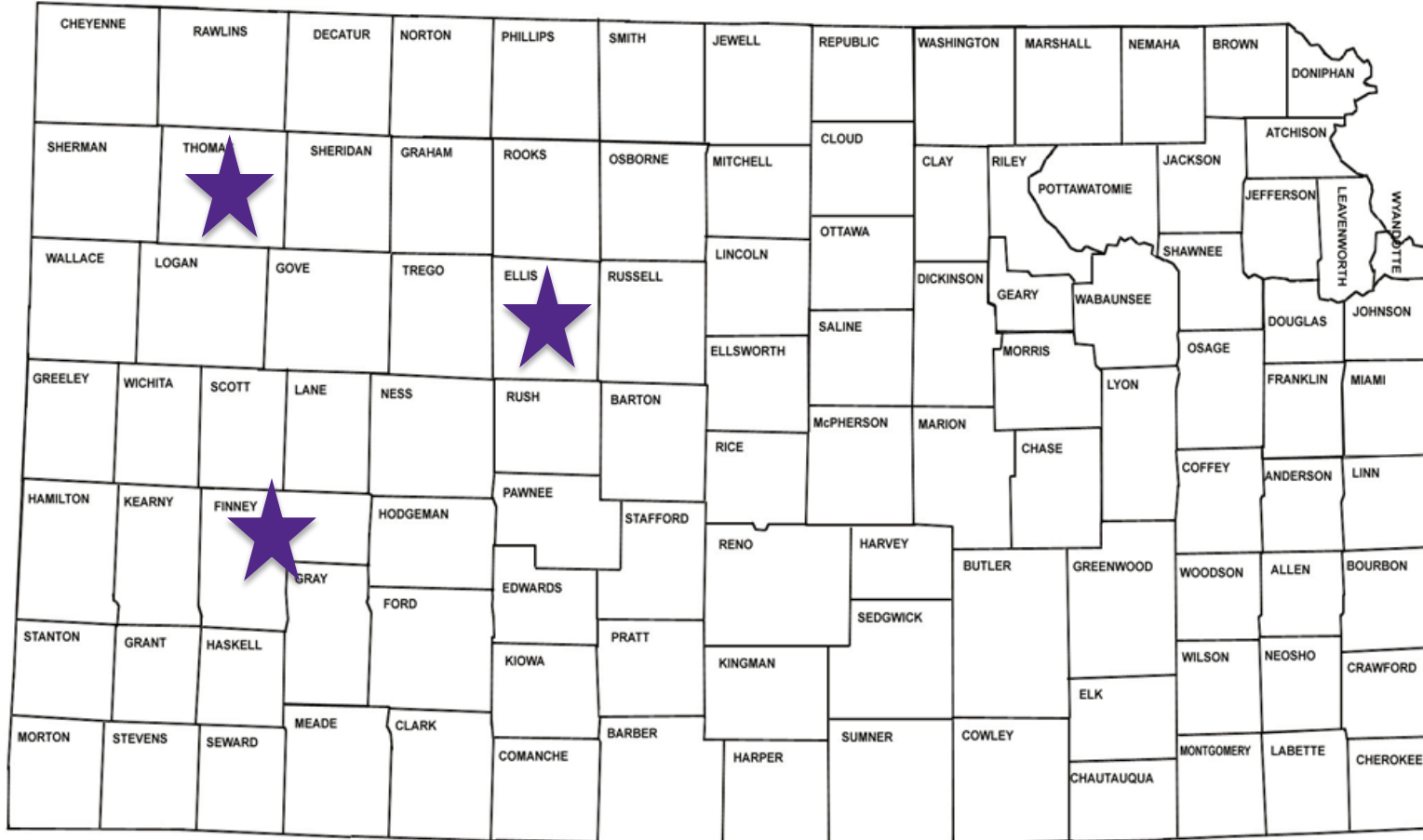
## Hypothesis #1

Grass species will produce more forage yield and better water productivity than legumes but have lower crude protein and higher fiber content than legumes

## Hypothesis #2

Annual legume species performance will vary, and certain species will be identified as potential alternative crops for the semi-arid Great Plains

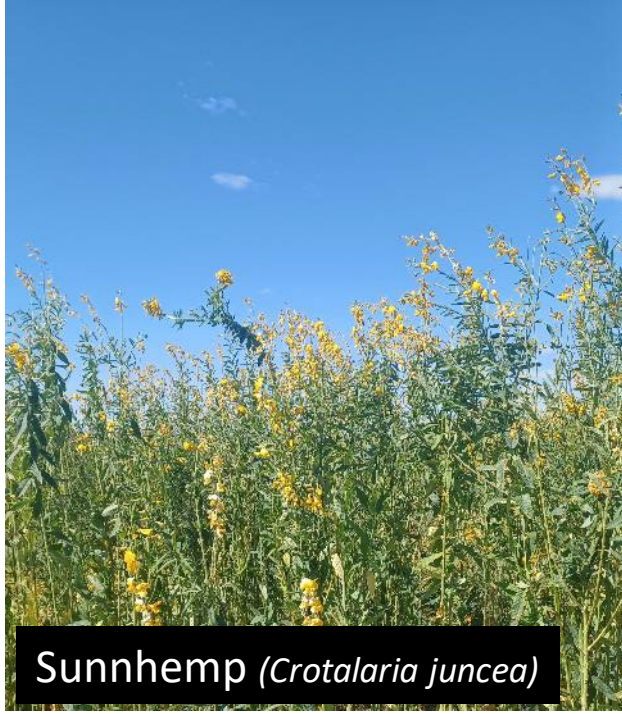
# Materials and Methods



- Garden City
  - ❖ Irrigated
- Colby
  - ❖ Dryland
- Hays
  - ❖ Dryland



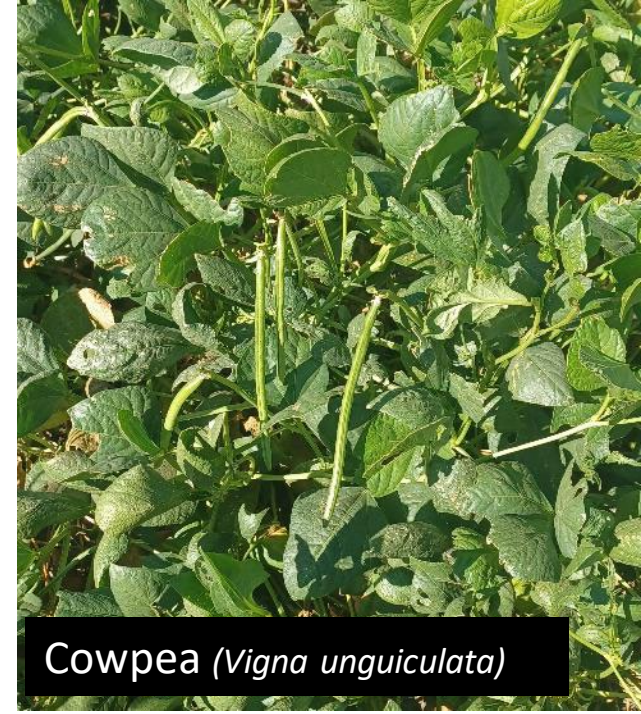
Forage Soybean (*Glycine max*)



Sunnhemp (*Crotalaria juncea*)



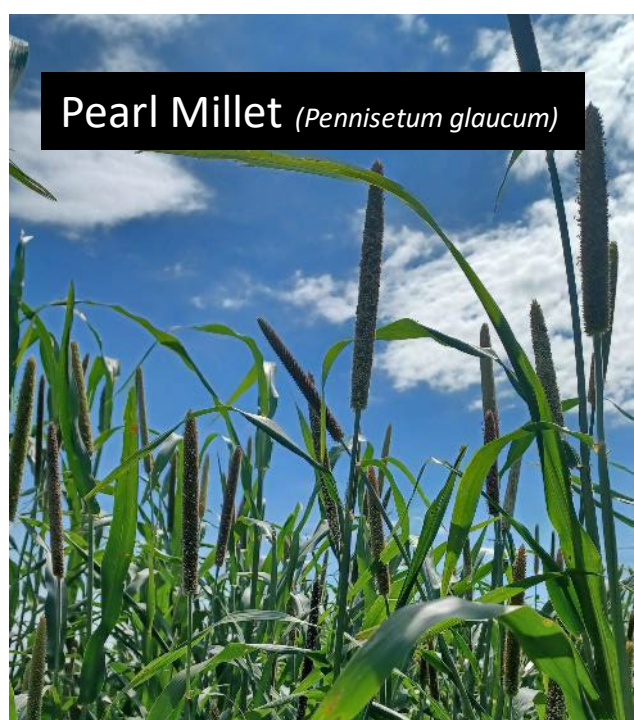
Lablab (*Lablab purpureus*)



Cowpea (*Vigna unguiculata*)



BMR Forage Sorghum  
(*Sorghum bicolor*)



Pearl Millet (*Pennisetum glaucum*)

## Materials and Methods

- In Garden City, each species harvested multiple times
- In Colby and Hays, crops were harvested at end of growing season
- Grasses – Boot, Anthesis, Soft Dough, and Kernel Hard
- Forage Soybean and Cowpea – Begin Flowering, Beginning Pod Formation, Beginning Seed Fill, and Beginning Maturity
- Sunnhemp – Beginning Flowering and End of Season (never formed pods)
- Lablab – End of Season (never entered reproductive stage)

# Materials and Methods

- At beginning of season soil water content was measured
- Soil water content was measured again at each harvest
- Harvest done by hand (could account for higher yields compared to machine harvest)

# Areas of Analysis

- Yield x Location
- Water Use x Location
- Water Use Efficiency (WUE) x Location
- Yield x Cutting Stage
- Water Use x Cutting Stage
- Water Use Efficiency (WUE) x Cutting Stage





# Yield x Location

## *Type III Test of Fixed Effects for Yield Across All Locations*

Test of Fixed Effects	P>F
Species	<.0001
Year	0.1117
Location	<.0001
Species x Year	0.2467
Species x Location	<.0001
Year x Location	0.0007
Species x Year x Location	0.0002

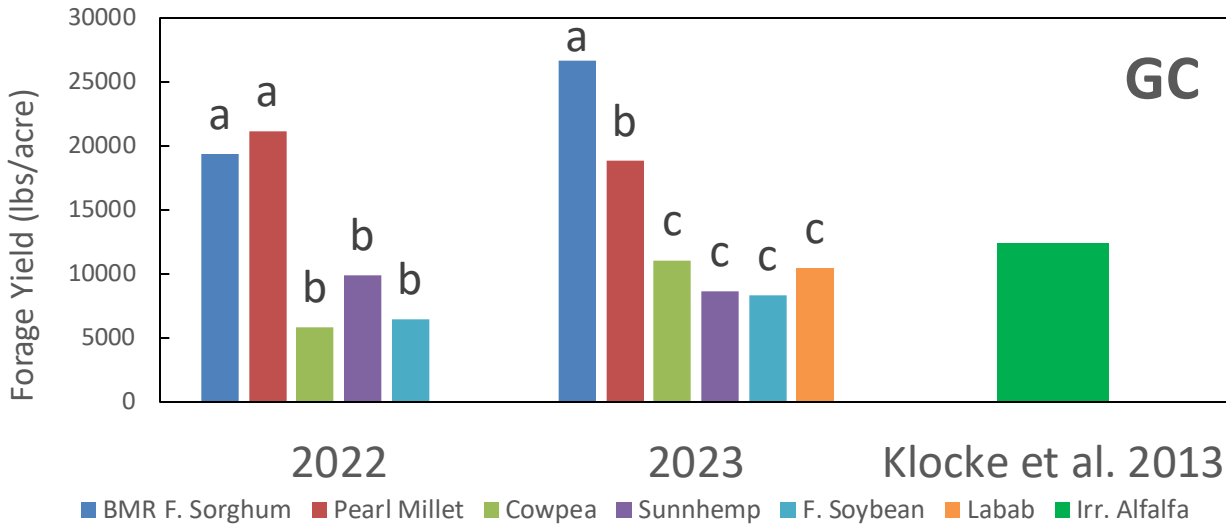
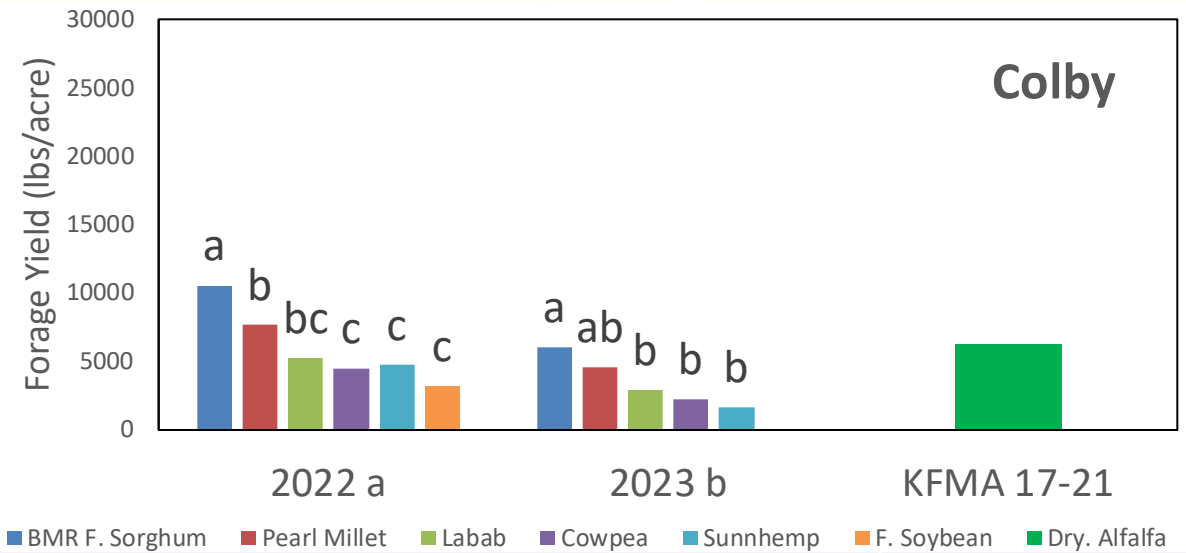
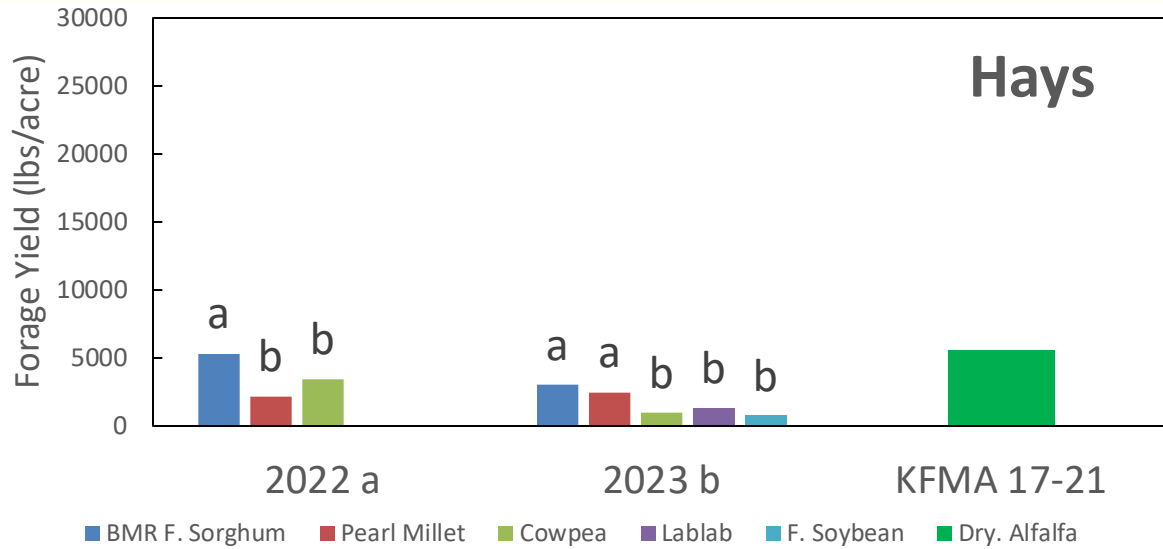
## *Type III Test of Fixed Effects for Yield Across Dryland Locations*

Test of Fixed Effects	P>F
Species	<.0001
Year	<.0001
Location	0.0011
Species x Year	0.0621
Species x Location	0.0007
Year x Location	0.0037
Species x Year x Location	0.0483

## *Type III Test of Fixed Effects for Yield in Garden City*

Test of Fixed Effects	P>F
Species	<.0001
Year	0.0781
Species x Year	0.0288

# Yield x Location



Location		2022	2023
<b>Colby</b>	Growing Season Length (days)	91	71
	Stored + In-Season Water (in.)	9.59	8.58
<b>Hays</b>	Growing Season Length (days)	111	Grasses: 103 Legumes: 74
	Stored + In-Season Water (in.)	13.60	Grasses: 11.41 Legumes: 8.35
<b>GC</b>	Growing Season Length (days)	Grasses: 111 Legumes: 116	Grasses: 107 Legumes: 133
	Stored + In-Season Water (in.)	Grasses: 22.36	Grasses: 23.66
		Legumes: 22.36	Legumes: 25.5



# Water Use x Location

## *Type III Test of Fixed Effects for Water Use Across All Locations*

Test of Fixed Effects	P>F
Species	0.0187
Year	0.4949
Location	<.0001
Species x Year	0.0003
Species x Location	0.0003
Year x Location	0.0004
Species x Year x Location	0.0004

## *Type III Test of Fixed Effects for Water Use Across Dryland Locations*

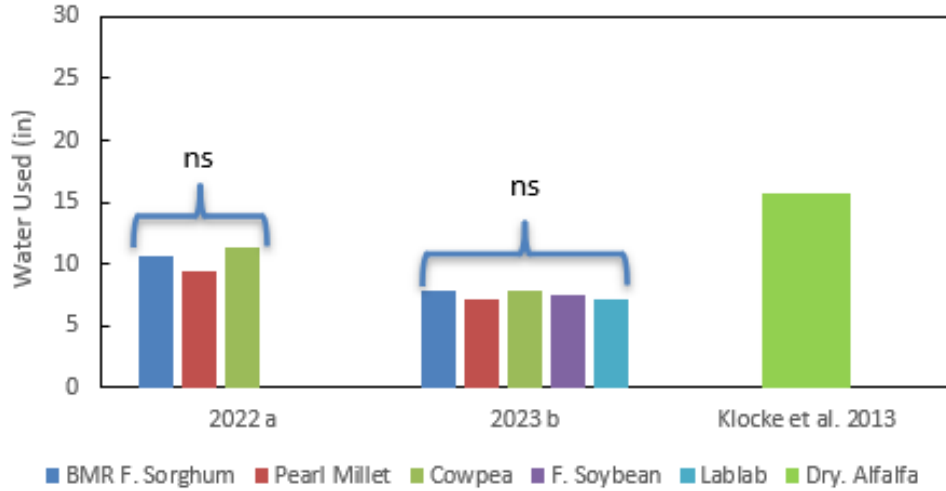
Test of Fixed Effects	P>F
Species	0.0034
Year	0.0006
Location	0.0151
Species x Year	0.6502
Species x Location	0.0435
Year x Location	0.6425
Species x Year x Location	0.6957

## *Type III Test of Fixed Effects for Water Use in Garden City*

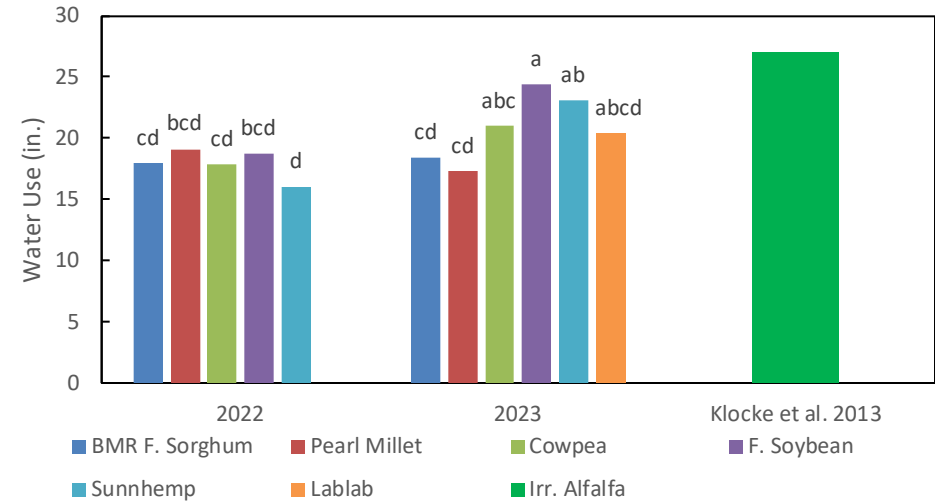
Test of Fixed Effects	P>F
Species	0.01
Year	0.0028
Species x Year	0.0004

# End of Season Water Use x Location

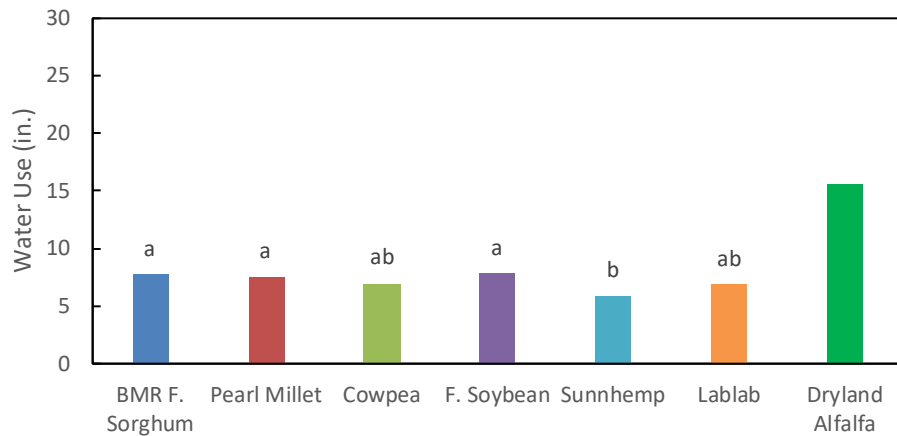
Water Use by Year and Species in Hays



Water Use by Year and Species in GC



Water Use by Species Across Years in Colby



Type III Test of Fixed Effects for Water Use at Hays and Colby

Test of Fixed Effects	P>F	
	Hays	Colby
Species	0.1725	0.0018
Year	0.0339	0.002
Species x Year	0.44	0.851



# WUE x Location

*Type III Test of Fixed Effects for WUE Across All Locations*

Test of Fixed Effects	P>F
Species	<.0001
Year	0.0282
Location	<.0001
Species x Year	0.1114
Species x Location	<.0001
Year x Location	0.0085
Species x Year x Location	<b>0.0061</b>

*Type III Test of Fixed Effects for WUE Across Dryland Locations*

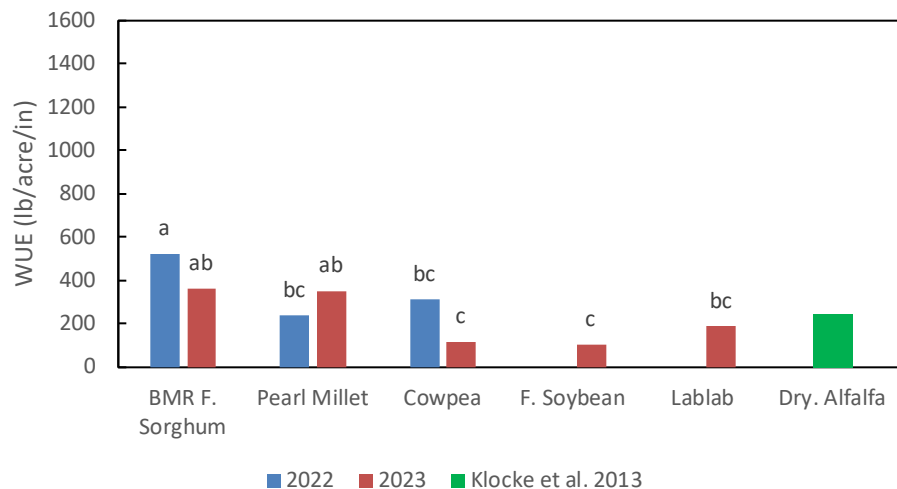
Test of Fixed Effects	P>F
Species	<.0001
Year	0.0095
Location	<.0001
Species x Year	0.1310
Species x Location	<b>0.0124</b>
Year x Location	0.3096
Species x Year x Location	0.4360

*Type III Test of Fixed Effects for WUE in GC*

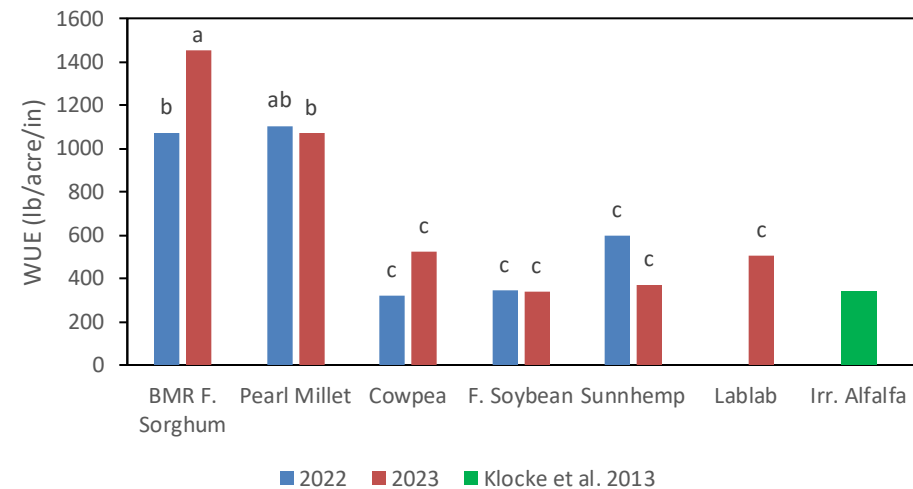
Test of Fixed Effects	P>F
Species	<.0001
Year	0.2373
Species x Year	<b>0.0061</b>

# WUE x Location

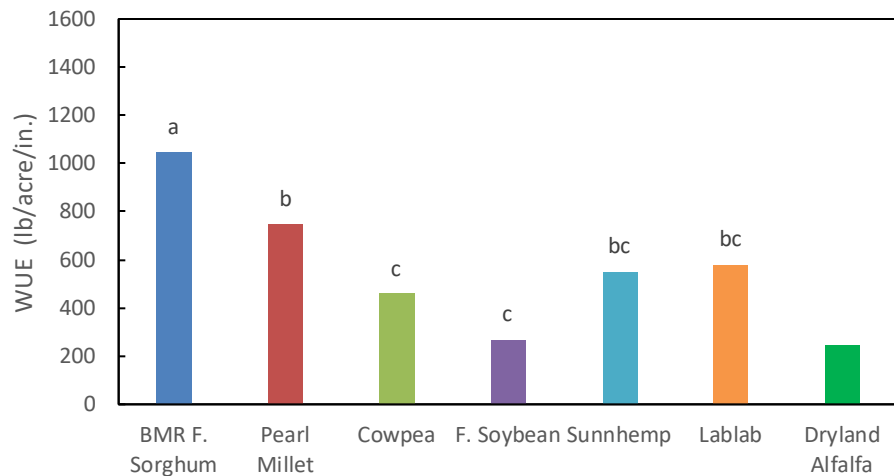
### WUE by Year and Species in Hays



### WUE by Year and Species in GC



### Water Use by Species Across Years in Colby



### Type III Test of Fixed Effects for WUE at Hays and Colby

Test of Fixed Effects	P>F	
	Hays	Colby
Species	0.0002	<.0001
Year	0.2149	0.0289
Species x Year	0.0018	0.5765



## Garden City

# Cutting Stage Impact on Yield, Water Use, and WUE

### *Type III Test of Fixed Effects for Yield Across All Cuttings*

Test of Fixed Effects	P>F
Species	<.0001
Year	0.0115
Cut	<.0001
Species x Year	0.0049
Species x Cut	<.0001
Year x Cut	0.251
Species x Year x Cut	<b>0.0053</b>

### *Type III Test of Fixed Effects for Water Use Across All Cuttings*

Test of Fixed Effects	P>F
Species	<.0001
Year	0.0002
Cut	<.0001
Species x Year	<.0001
Species x Cut	<.0001
Year x Cut	0.0003
Species x Year x Cut	<b>0.0233</b>

### *Type III Test of Fixed Effects for WUE All Cuttings*

Test of Fixed Effects	P>F
Species	<.0001
Year	0.6015
Cut	0.0001
Species x Year	0.0043
Species x Cut	<.0001
Year x Cut	0.0727
Species x Year x Cut	<b>0.0012</b>

# BMR Forage Sorghum

## Type III Test of Fixed Effects for BMR FS Yield

Test of Fixed Effects	P>F
Year	0.4048
Cut	<.0001
Year x Cut	0.1912

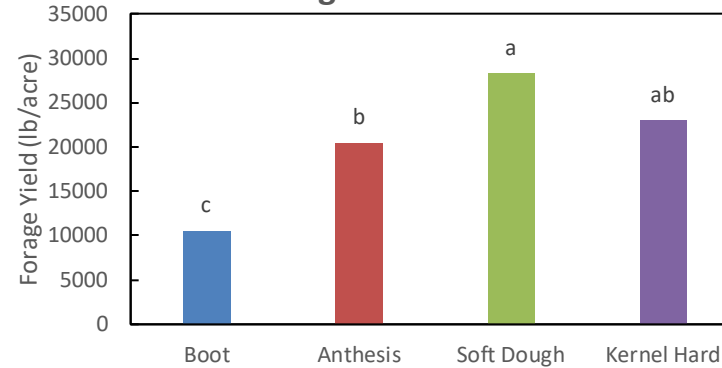
## Type III Test of Fixed Effects for BMR FS Water Use

Test of Fixed Effects	P>F
Year	0.0159
Cut	<.0001
Year x Cut	0.0003

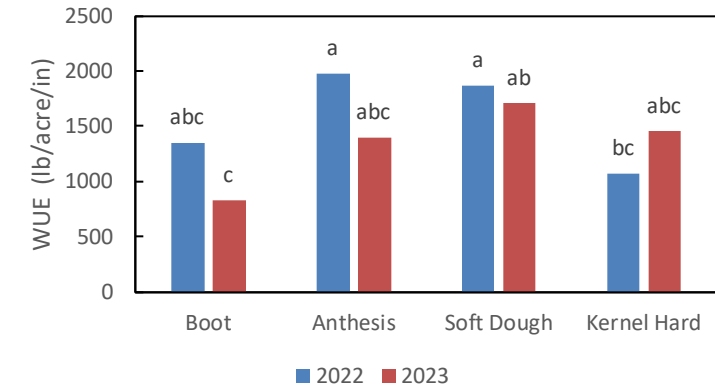
## Type III Test of Fixed Effects for BMR FS WUE

Test of Fixed Effects	P>F
Year	0.1818
Cut	0.0003
Year x Cut	0.0135

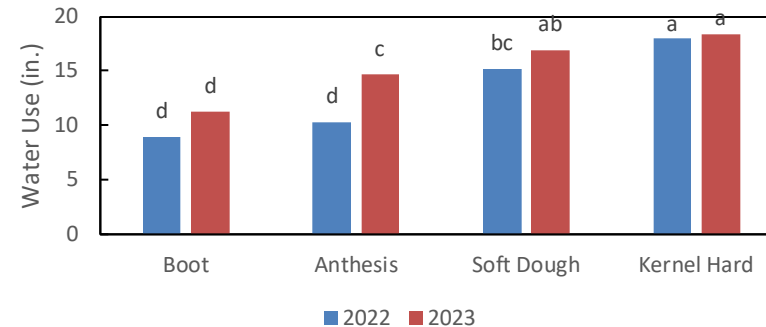
### BMR Forage Sorghum Yield by Cutting Stage Across Years



### BMR Forage Sorghum WUE by Cutting Stage



### BMR Forage Sorghum Water Use by Cutting Stage



Stage	2022	2023
Planting	6/17	5/30
Boot	8/22	7/27
Anthesis	8/30	8/14
Soft Dough	9/26	8/29
Kernel Hard	10/6	9/14



# Pearl Millet

## Type III Test of Fixed Effects for Pearl Millet Yield

Test of Fixed Effects	P>F
Year	0.2404
Cut	<.0001
Year x Cut	<b>0.0446</b>

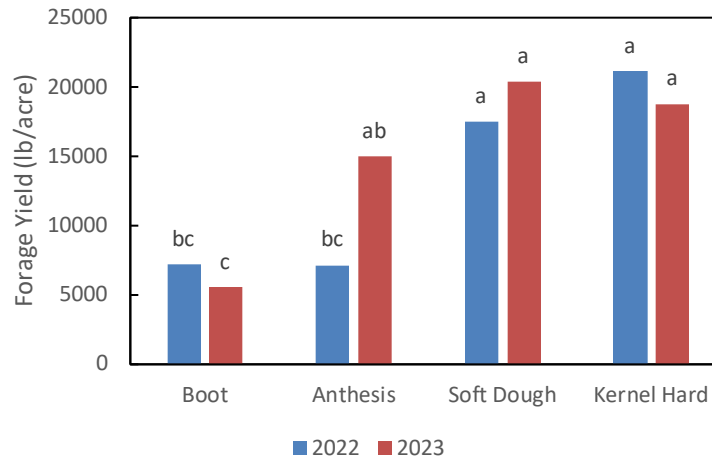
## Type III Test of Fixed Effects for Pearl Millet Water Use

Test of Fixed Effects	P>F
Year	0.2766
Cut	<.0001
Year x Cut	<b>&lt;.0001</b>

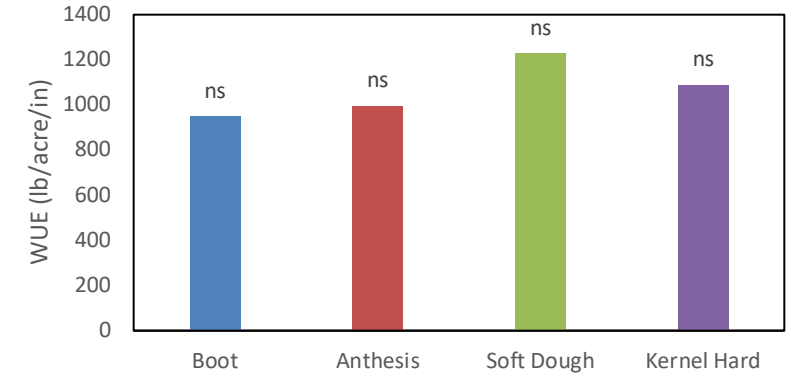
## Type III Test of Fixed Effects for Pearl Millet WUE

Test of Fixed Effects	P>F
Year	0.9616
Cut	0.2775
Year x Cut	0.2479

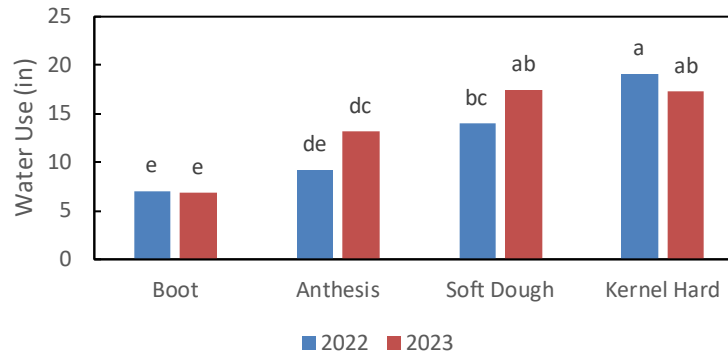
### Pearl Millet Yield by Cutting Stage



### Pearl Millet WUE by Cutting Stage Across Years



### Pearl Millet Water Use by Cutting Stage



Stage	2022	2023
Planting	6/17	5/30
Boot	8/8	7/20
Anthesis	8/15	8/9
Soft Dough	9/8	8/25
Kernel Hard	10/6	9/14

# Forage Soybean

## Type III Test of Fixed Effects for F. Soybean Yield

Test of Fixed Effects	P>F
Year	0.0024
Cut	<b>0.0261</b>
Year x Cut	0.54

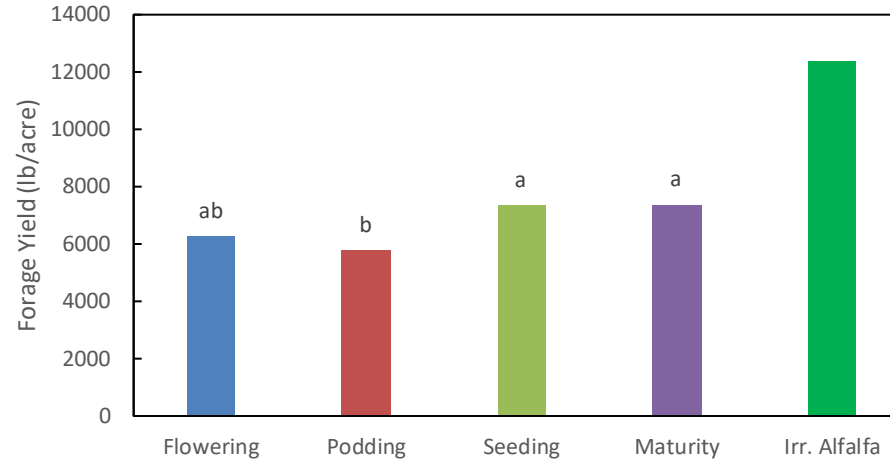
## Type III Test of Fixed Effects for F. Soybean Water Use

Test of Fixed Effects	P>F
Year	0.0049
Cut	<.0001
Year x Cut	<b>0.0247</b>

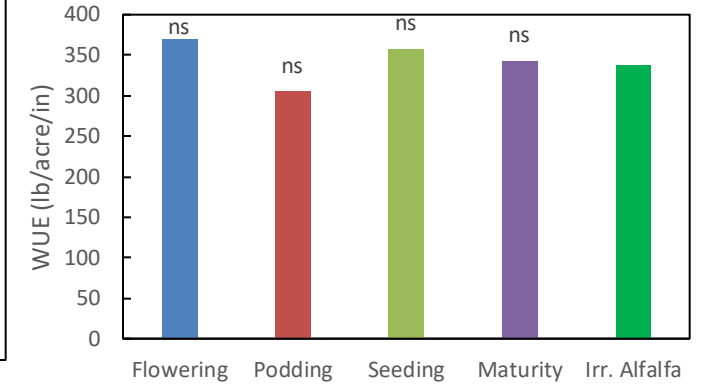
## Type III Test of Fixed Effects for F. Soybean WUE

Test of Fixed Effects	P>F
Year	0.3585
Cut	0.1463
Year x Cut	0.4399

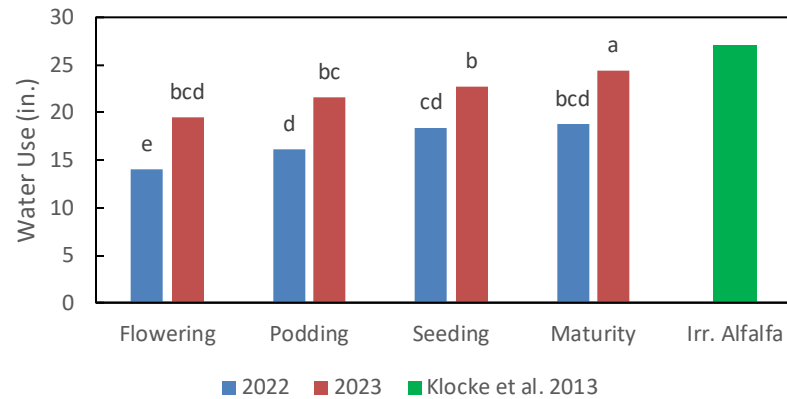
Forage Soybean Yield by Cutting Stage Across Years



Forage Soybean WUE by Cutting Stage Across Years



Forage Soybean Water Use by Cutting Stage



Stage	2022	2023
Planting	6/17	5/30
Flowering	9/14	9/14
Podding	9/26	9/19
Seeding	10/6	9/27
Maturity	10/11	10/10

# Sunnhemp

Type III Test of Fixed Effects for Sunnhemp Yield

Test of Fixed Effects	P>F
Year	0.3166
Cut	0.0014
Year x Cut	0.4759

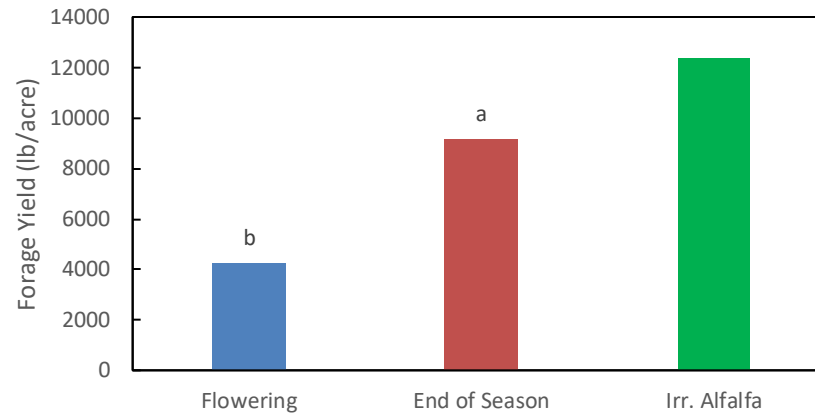
Type III Test of Fixed Effects for Sunnhemp Water Use

Test of Fixed Effects	P>F
Year	0.0712
Cut	<.0001
Year x Cut	0.0011

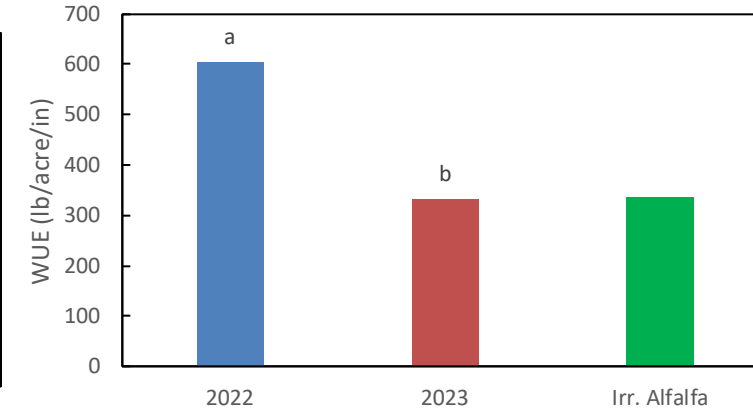
Type III Test of Fixed Effects for Sunnhemp Water Use

Test of Fixed Effects	P>F
Year	0.0302
Cut	0.4027
Year x Cut	0.328

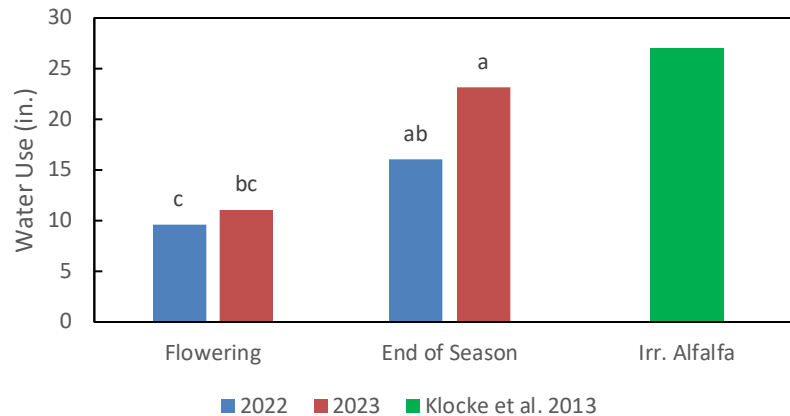
Sunnhemp Yield by Cutting Stage Across Years



Sunnhemp WUE by Year Across Cutting Stages



Sunnhemp Water Use by Cutting Stage

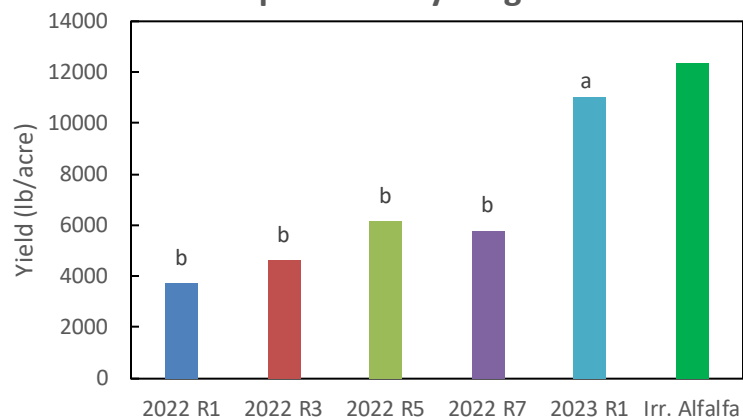


Stage	2022	2023
Planting	6/17	5/30
Flowering	8/30	7/27
End of Season	10/11	10/10

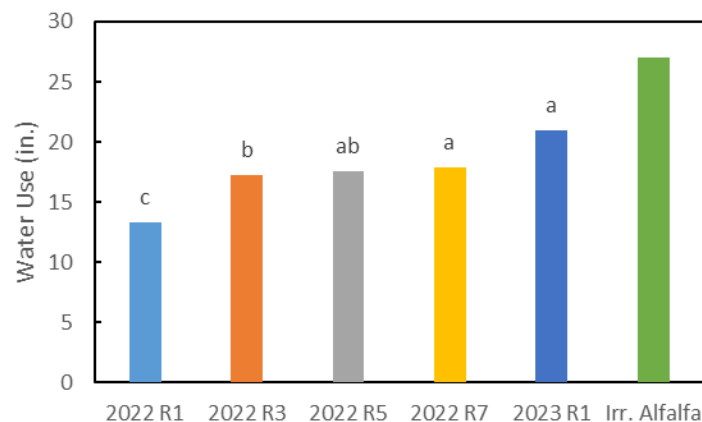
# Cowpea (Variety: Iron and Clay)



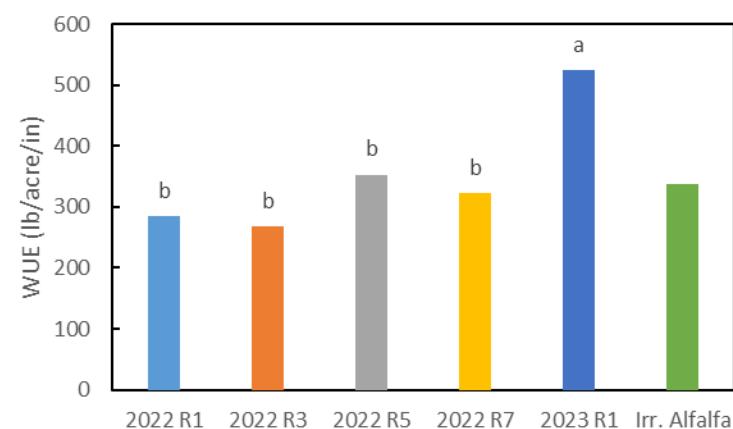
**Cowpea Yield by Stage**



**Cowpea Water Use by Stage**



**Cowpea WUE by Cutting Stage**



Stage	2022	2023
Planting	6/17	5/30
Flowering	9/14	10/4
Podding	10/6	
Seeding	10/11	
Maturity	10/14	



Cowpea on 10/13/22

- Cowpea did not reach reproductive stage in Colby or Hays either year



Cowpea on 10/4/23

- Did not progress past flowering before first freeze



# Forage Quality

Crude Protein (CP)

Total Digestible Nutrients  
(TDN)

Relative Feed Quality (RFQ)

*Type III Test of Fixed Effects for Crude Protein*

Test of Fixed Effects	P>F
Species	<.0001
Year	0.6856
Cut	<.0001
Species x Year	0.0001
Species x Cut	<b>&lt;.0001</b>
Year x Cut	0.2406
Species x Year x Cut	0.0918

*Type III Test of Fixed Effects for TDN*

Test of Fixed Effects	P>F
Species	<.0001
Year	0.8815
Cut	<.0001
Species x Year	<.0001
Species x Cut	<b>&lt;.0001</b>
Year x Cut	0.0647
Species x Year x Cut	0.3471

*Type III Test of Fixed Effects for RFQ*

Test of Fixed Effects	P>F
Species	<.0001
Year	0.5149
Cut	<.0001
Species x Year	0.0006
Species x Cut	<b>0.0003</b>
Year x Cut	0.6149
Species x Year x Cut	0.2222

# BMR Forage Sorghum



*Type III Test of Fixed Effects for BMR FS Crude Protein*

Test of Fixed Effects	P>F
Year	0.4355
Cut	<b>0.0008</b>
Year x Cut	0.2905

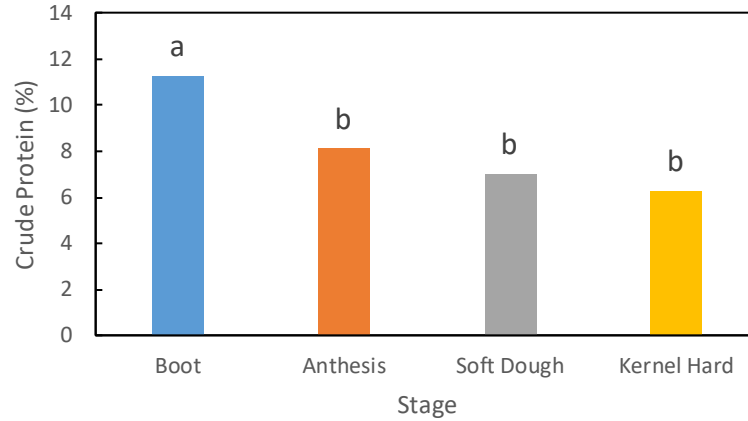
*Type III Test of Fixed Effects for BMR FS TDN*

Test of Fixed Effects	P>F
Year	0.709
Cut	<b>&lt;.0001</b>
Year x Cut	0.6292

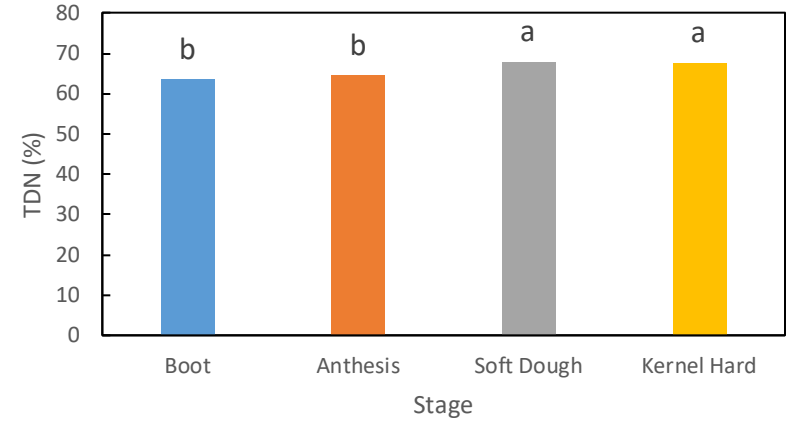
*Type III Test of Fixed Effects for BMR FS RFQ*

Test of Fixed Effects	P>F
Year	0.819
Cut	<b>0.0471</b>
Year x Cut	0.5229

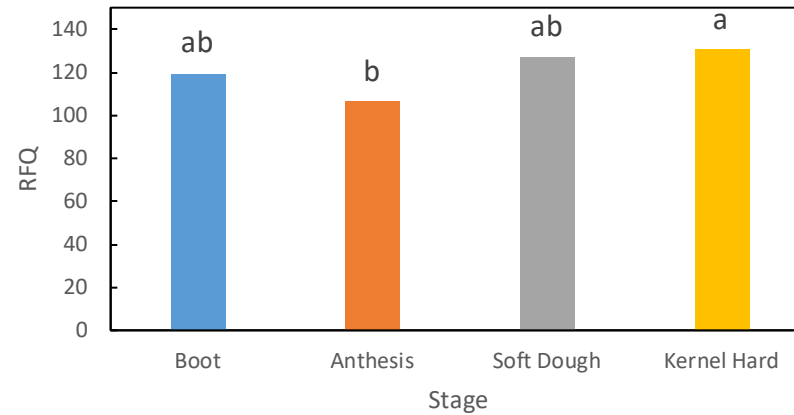
**BMR F. Sorghum Crude Protein by Stage**



**BMR F. Sorghum TDN by Stage**



**BMR F. Sorghum RFQ by Stage**



# Pearl Millet



## Type III Test of Fixed Effects for Pearl Millet Crude Protein

Test of Fixed Effects	P>F
Year	0.5829
Cut	<.0001
Year x Cut	<b>0.0132</b>

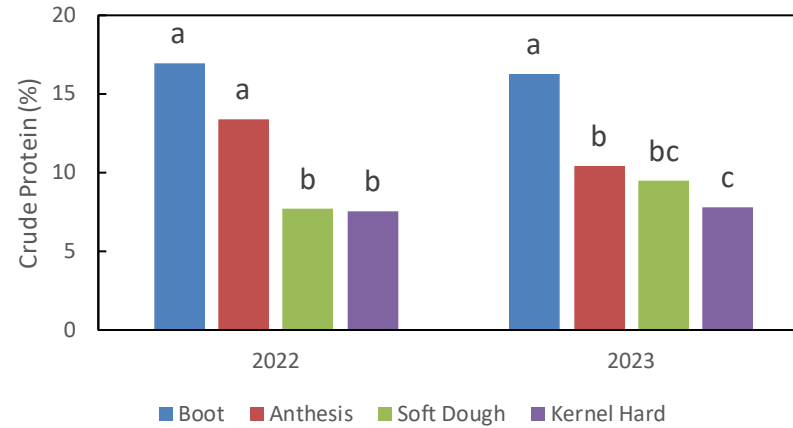
## Type III Test of Fixed Effects for Pearl Millet TDN

Test of Fixed Effects	P>F
Year	0.0305
Cut	0.3284
Year x Cut	<b>0.0301</b>

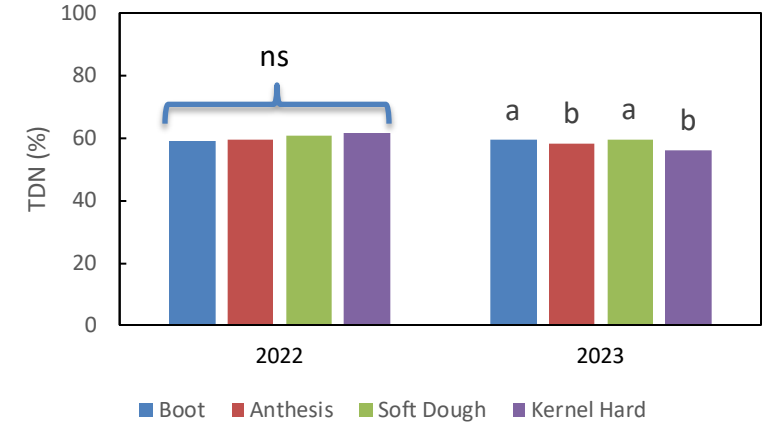
## Type III Test of Fixed Effects for Pearl Millet RFQ

Test of Fixed Effects	P>F
Year	0.0992
Cut	0.0522
Year x Cut	<b>0.0395</b>

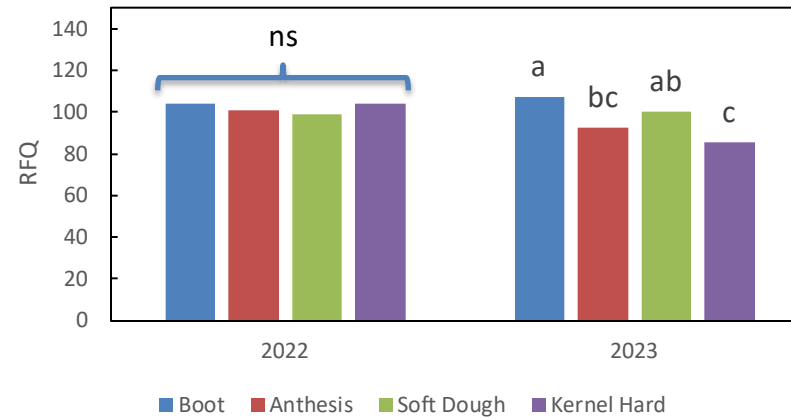
### Pearl Millet Crude Protein by Year and Stage



### Pearl Millet TDN by Year and Stage



### Pearl Millet RFQ by Year and Stage



# Forage Soybean



## Type III Test of Fixed Effects for F. Soybean Crude Protein

Test of Fixed Effects	P>F
Year	0.9839
Cut	0.0626
Year x Cut	0.3013

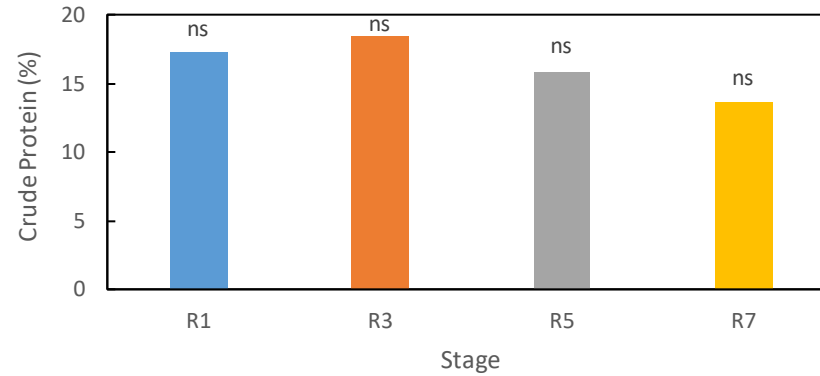
## Type III Test of Fixed Effects for F. Soybean TDN

Test of Fixed Effects	P>F
Year	0.7846
Cut	<b>0.0308</b>
Year x Cut	0.1203

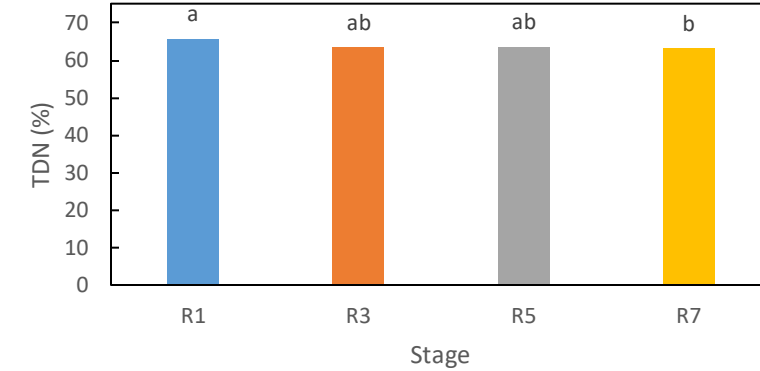
## Type III Test of Fixed Effects for F. Soybean RFQ

Test of Fixed Effects	P>F
Year	0.5298
Cut	0.1383
Year x Cut	0.1899

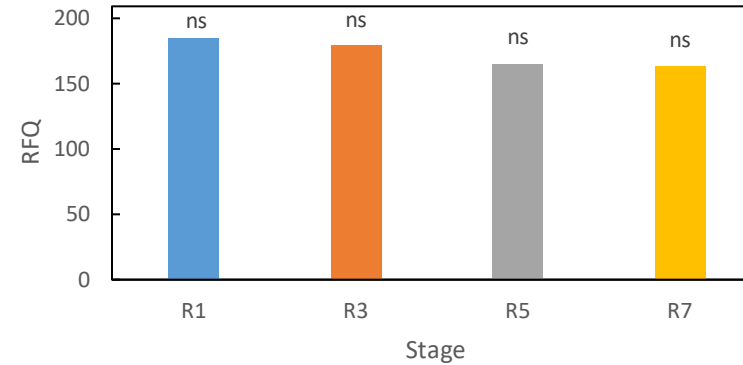
F. Soybean Crude Protein by Stage Across Year



F. Soybean TDN by Stage Across Year



F. Soybean RFQ by Stage Across Years





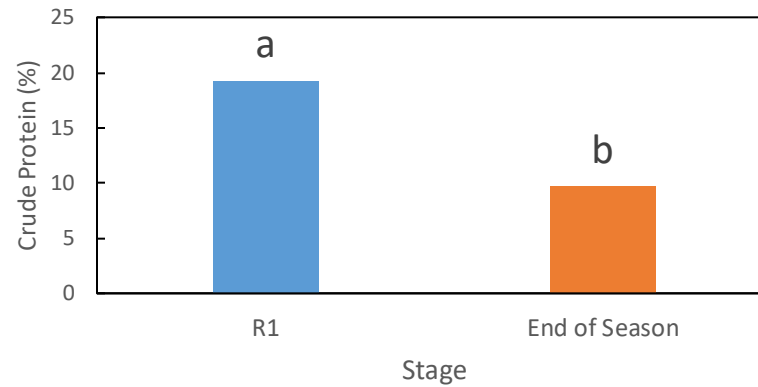
# Sunnhemp



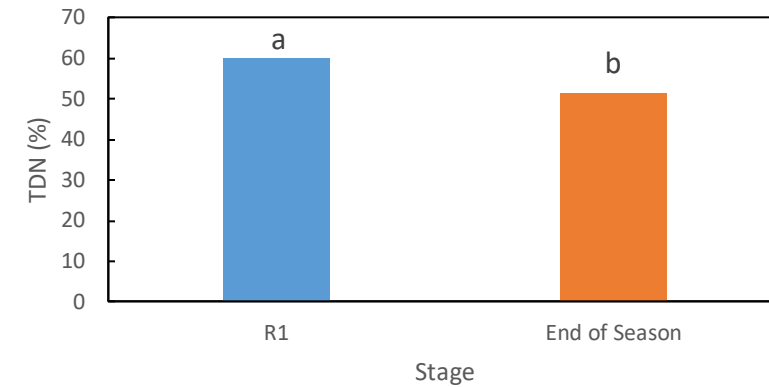
## Type III Test of Fixed Effects for Sunnhemp Crude Protein

Test of Fixed Effects	P>F
Year	0.0079
Cut	<b>0.0002</b>
Year x Cut	0.0541

## Sunnhemp Crude Protein by Stage Across Years



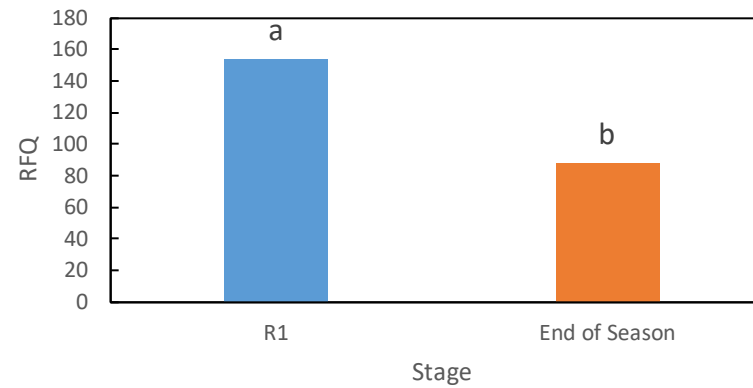
## Sunnhemp TDN by Stage Across Years



## Type III Test of Fixed Effects for Sunnhemp TDN

Test of Fixed Effects	P>F
Year	0.0129
Cut	<b>0.0010</b>
Year x Cut	0.992

## Sunnhemp RFQ by Stage Across Years



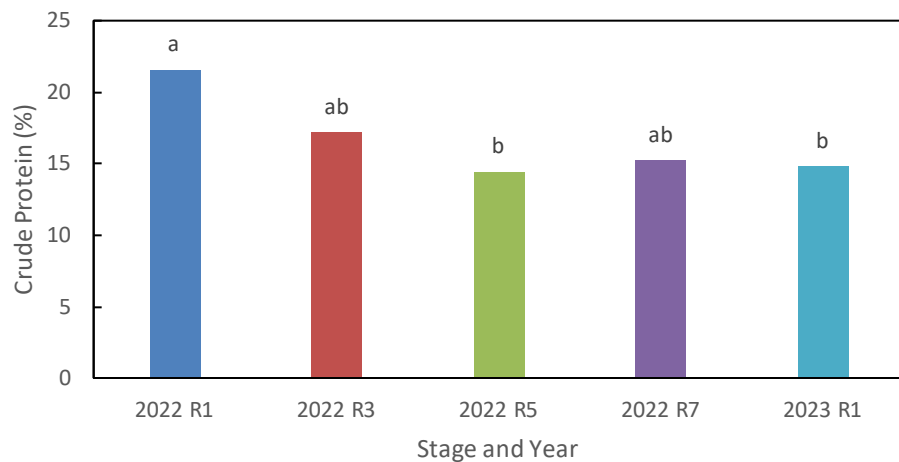
## Type III Test of Fixed Effects for Sunnhemp RFQ

Test of Fixed Effects	P>F
Year	0.0149
Cut	<b>0.0022</b>
Year x Cut	0.2385

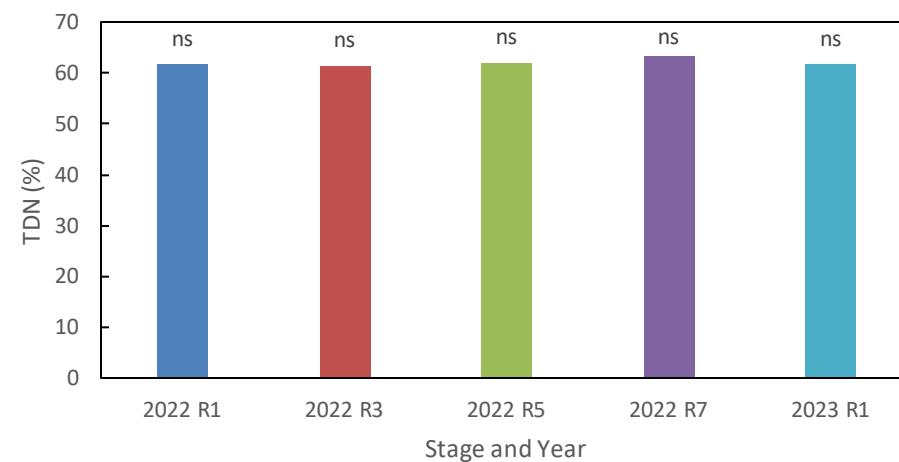
# Cowpea



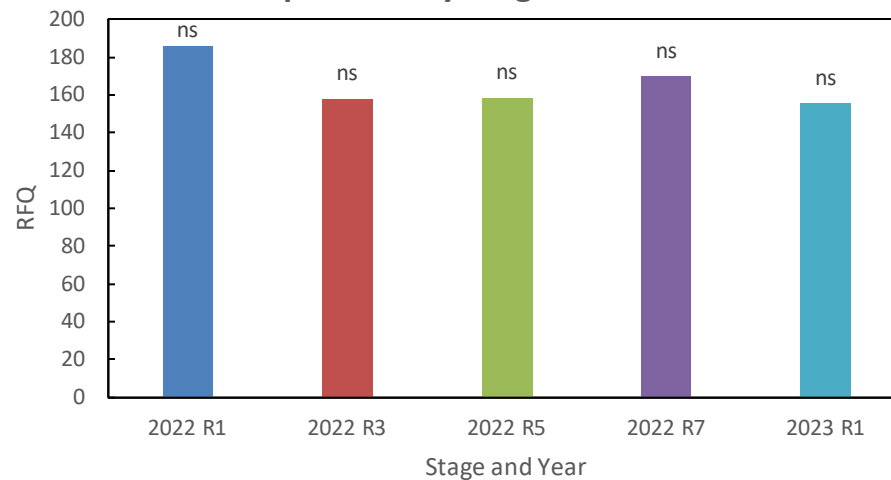
### Cowpea Crude Protein by Stage and Year



### Cowpea TDN by Stage and Year

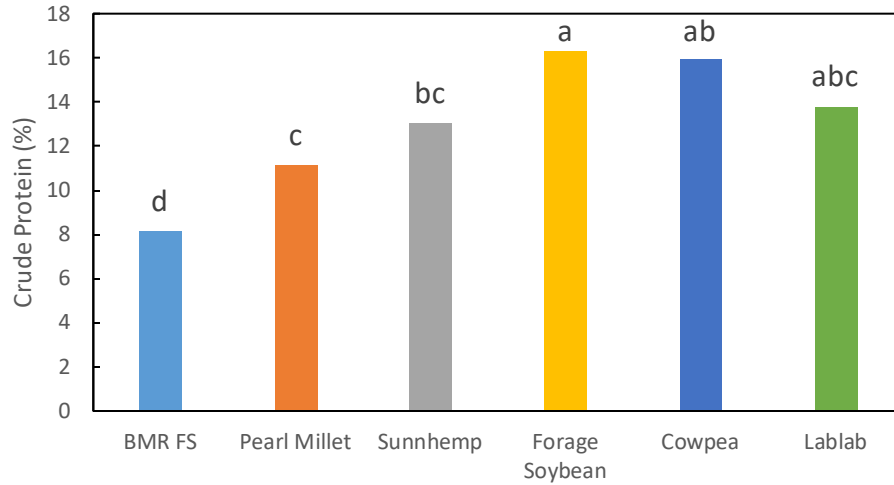


### Cowpea RFQ by Stage and Year

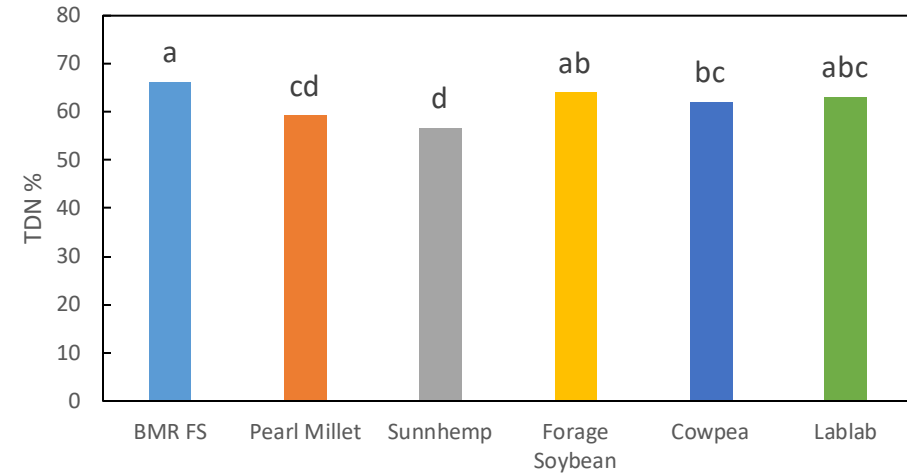


# Comparing Average Quality Measures By Species

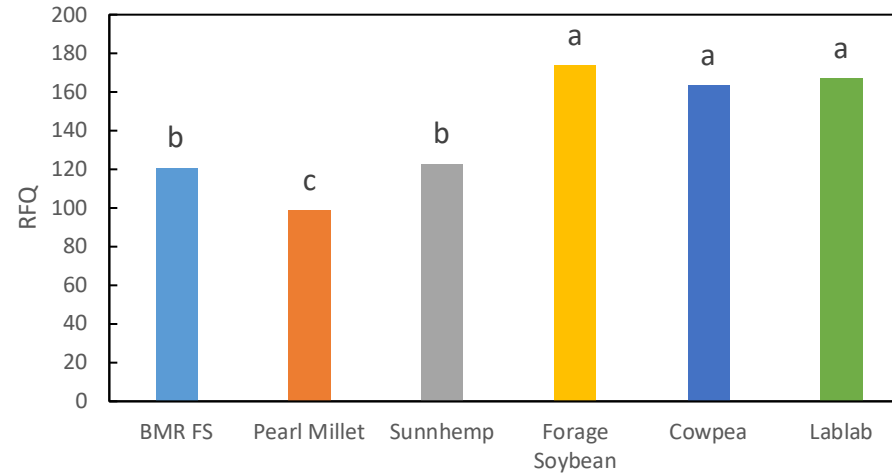
Crude Protein Content by Species Across Cutting Stage and Year



TDN by Species Across Cutting Stage and Year



RFQ by Species Across Cutting Stage and Year



# Conclusions (Yield and Water)

- Lablab and Cowpea were the only two legumes that established at every site when planted
- They were comparable to Alfalfa in terms of yield, water use, and WUE in both dryland and irrigated environments
- Weed pressure, herbicide limitations, seed quality/cultivar consistency, best management practices, and wildlife feeding are all concerns with summer annual legumes
- Yield and water use generally increase with maturity, but relationship between cutting stage and WUE is species dependent

# Conclusions (Quality)

- Legumes were higher in CP and RFQ than Grasses
- Forage quality of BMR Forage Sorghum, Pearl Millet and Sunnhemp were more influenced by cutting stage than Forage Soybean or Cowpea
- Forage Soybean, Cowpea, and Lablab were not significantly different from each other regarding CP, TDN, and RFQ
- In all species, other than forage soybean, CP significantly decreased as maturity increased.

# Further Research/Analysis

- Identify cutting stages that optimize quality and yield by using milk per acre and crude protein per acre
- Direct comparison between alfalfa and cowpea or lablab under low irrigation and dryland
- Compare economic return of annual legumes, grass, and alfalfa
- Further investigation into planting date and cutting time and regrowth is needed



# Questions?

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References: Klocke, N. L., Currie, R. S., & Holman, J. D. (2013). Alfalfa response to irrigation from limited water supplies. *Transactions of the ASABE*, 56(5), 1759-1768.