Challenges and opportunities of irrigated cotton production in SW Kansas

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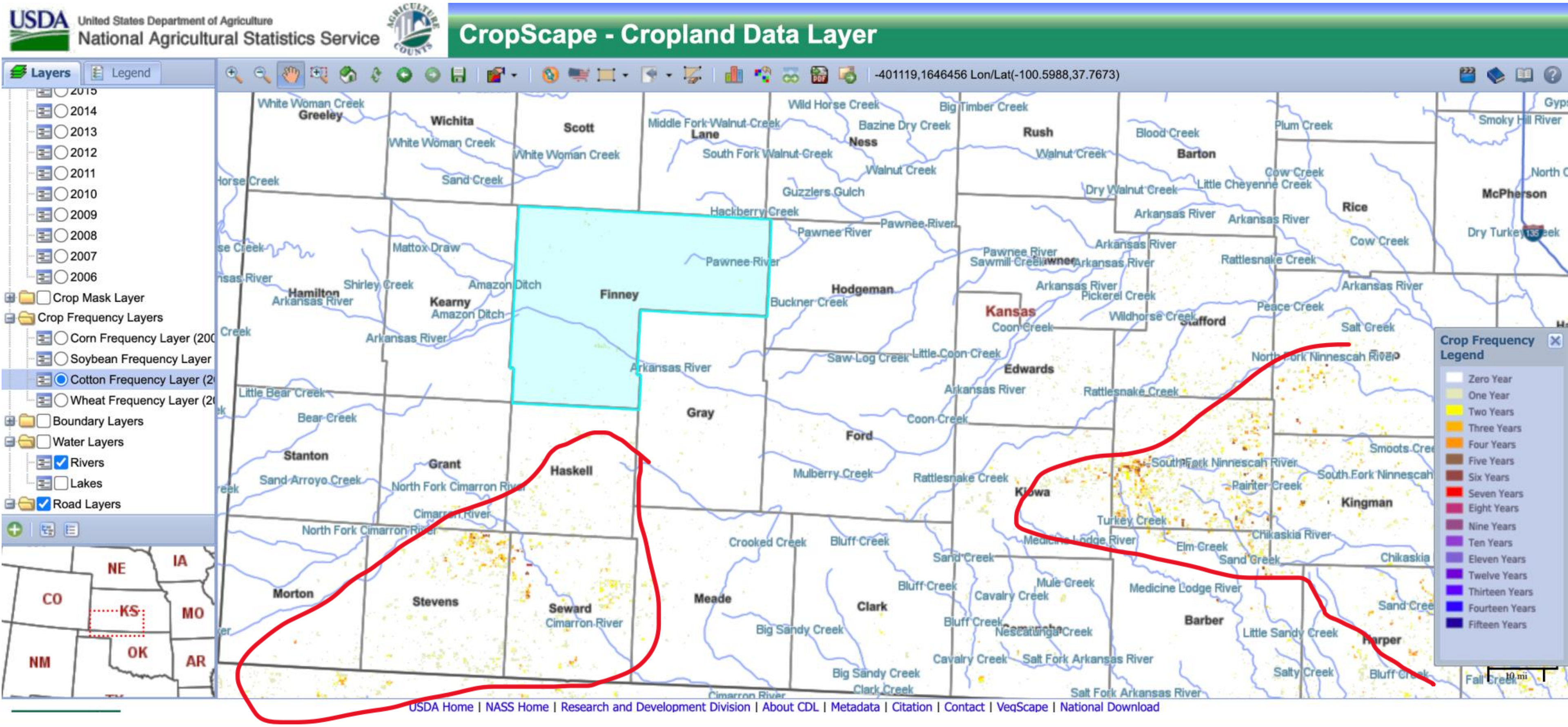
Our COTTON Story Started BECAUSE…

Farmers Asked

Partners Responded

We Proposed

Kansas cotton bales are not used to crossing the Arkansas River



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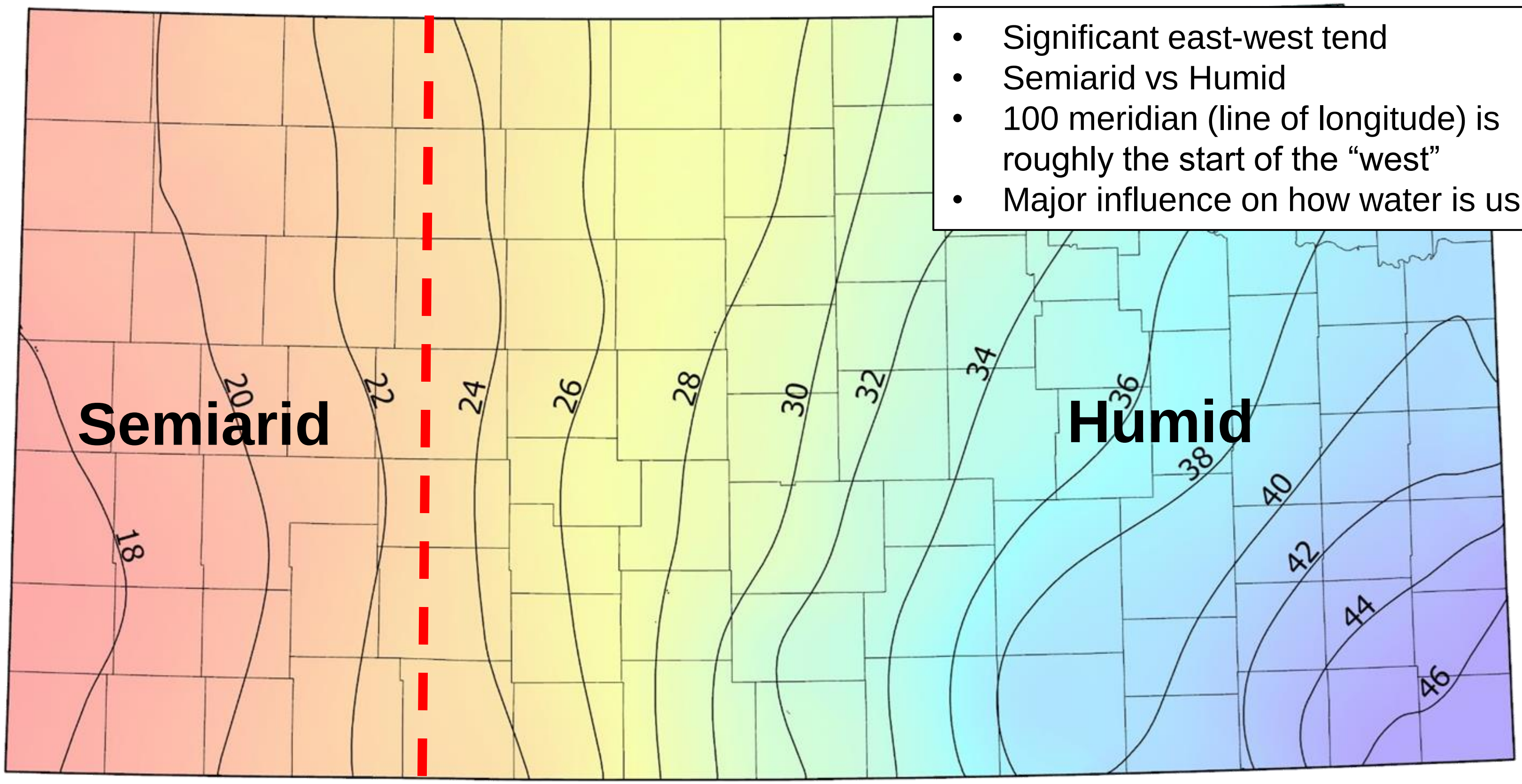
Why Cotton Research?

- Identified in the Kansas Water Vision document
- USDA RMA is looking for cotton data
- SWR Advisory Group recommended this alternative crop (2019 meeting)
- KSRE is poised to do this

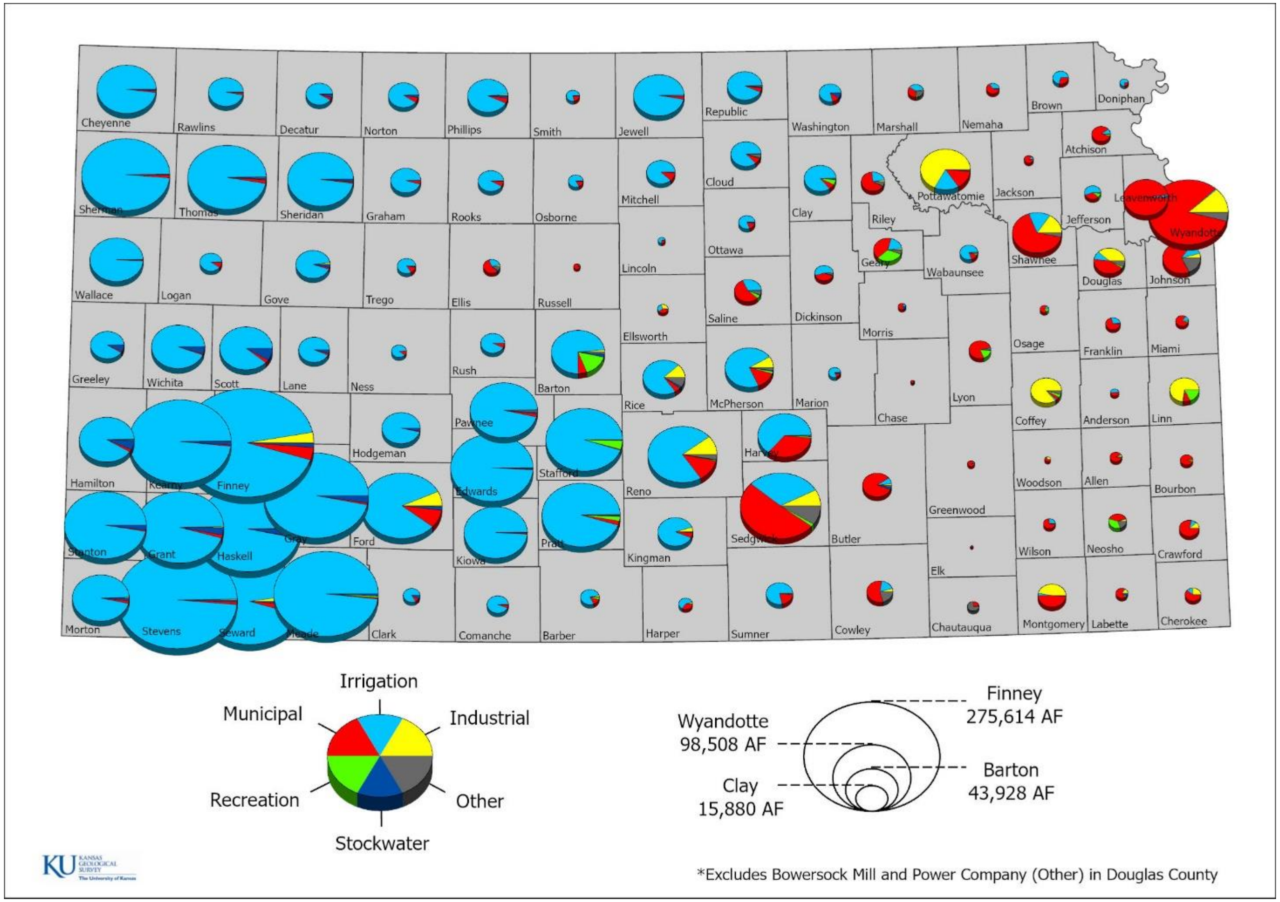
1991-2020 Normal Precipitation and Climate Zones

- Significant east-west tend
- Semiarid vs Humid
- 100 meridian (line of longitude) is roughly the start of the “west”
- Major influence on how water is used



Kansas Geological Survey

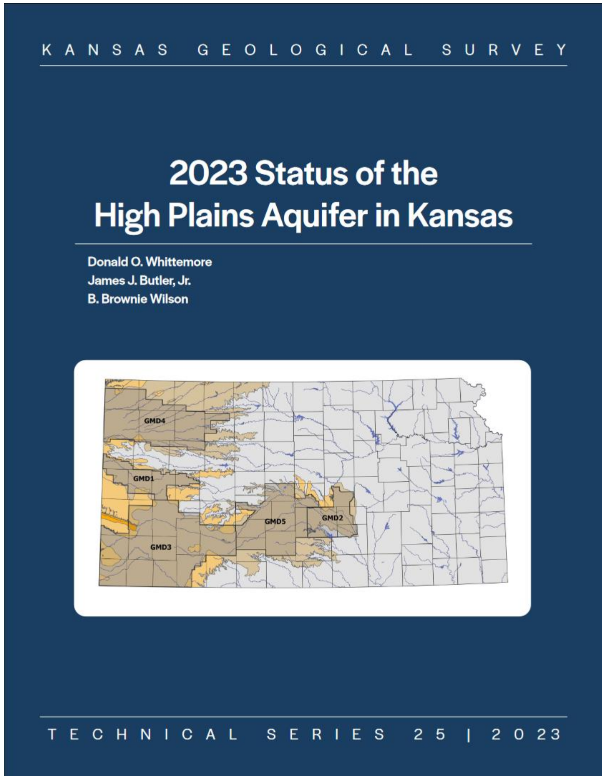
Average Reported Use Made of Water

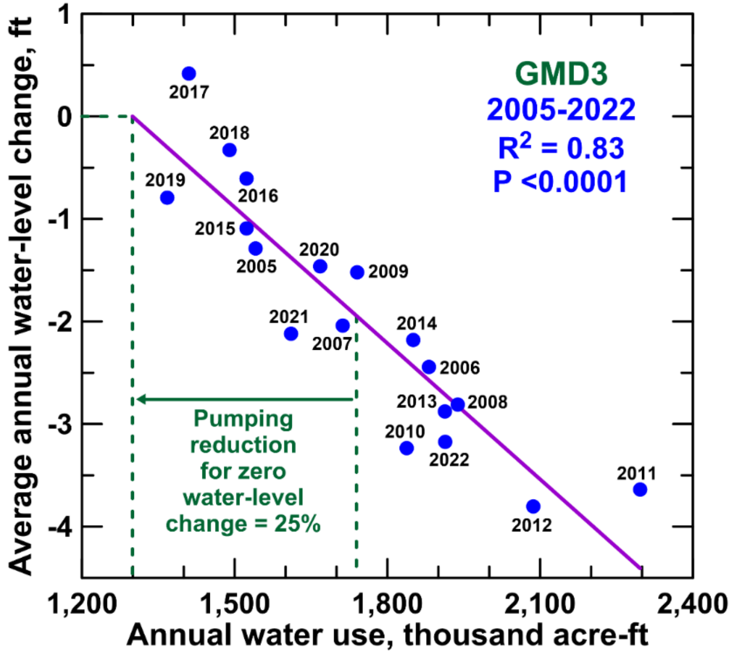


Kansas Geological Survey

- **Eastern Kansas typically municipal and industrial uses**
- **Irrigation dominates western and south-central Kansas**
- **Stockwater uses, although smaller, are found in greater concentrations in southwest Kansas**
- **Driven by precipitation, climate, and water availability**

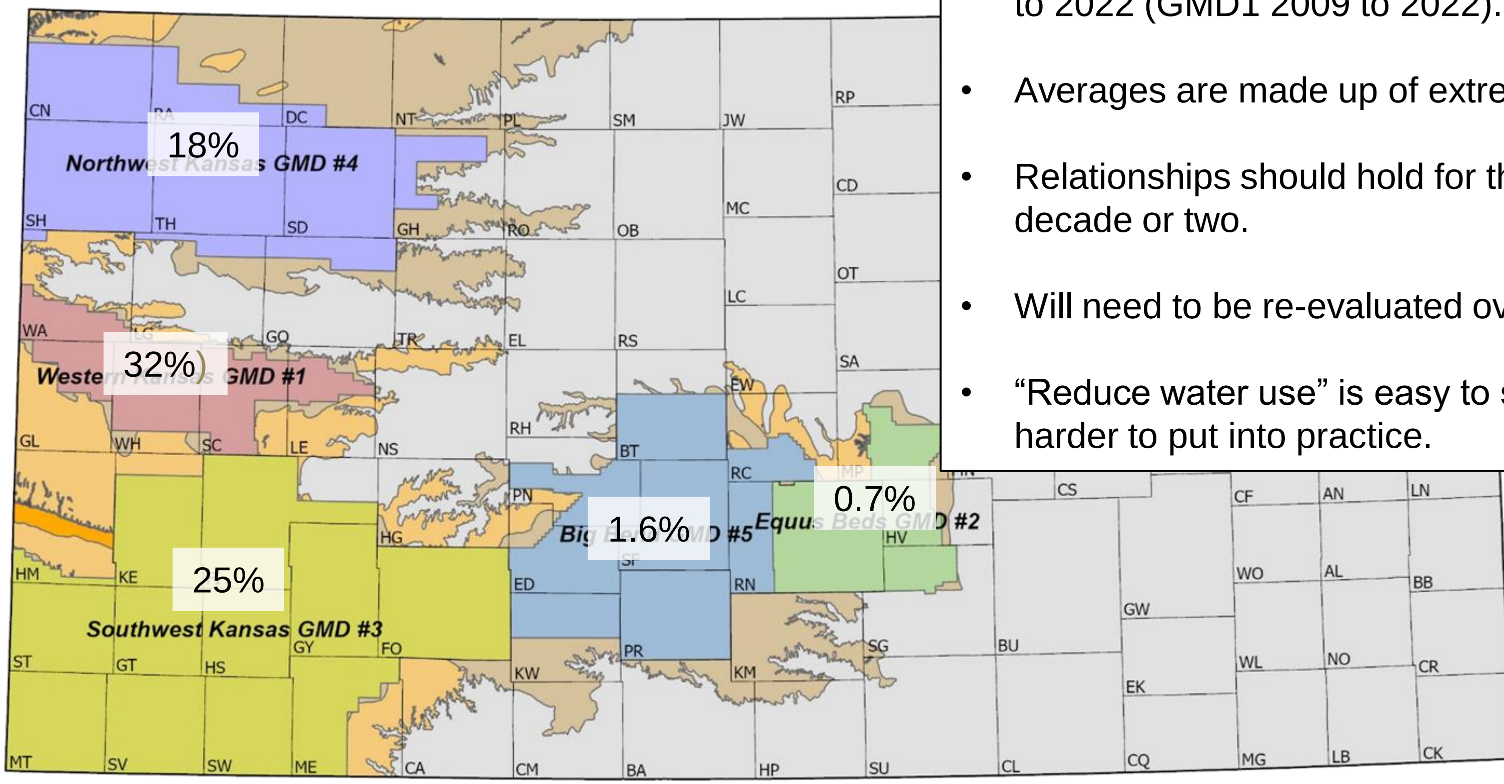
Status of the High Plains Aquifer in Kansas





Kansas Geological Survey

Reductions in Reported Water Use, by GMD, Needed to Stabilize Water Levels



- Based on average conditions from 2005 to 2022 (GMD1 2009 to 2022).
- Averages are made up of extremes.
- Relationships should hold for the next decade or two.
- Will need to be re-evaluated over time.
- “Reduce water use” is easy to say, harder to put into practice.

Kansas Geological Survey

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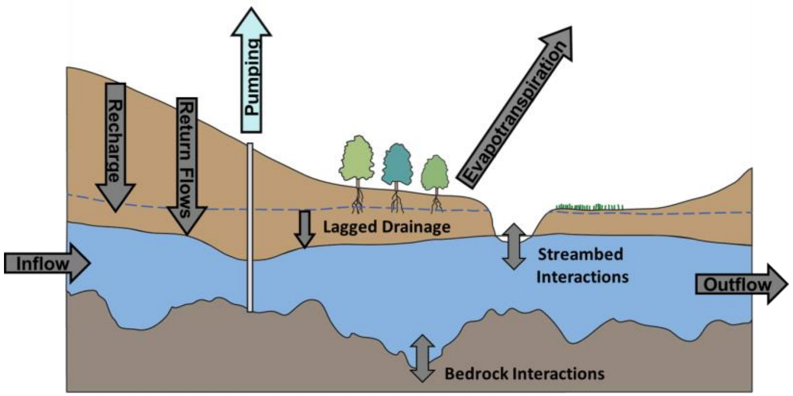
Stabilized vs Sustainable Water Levels

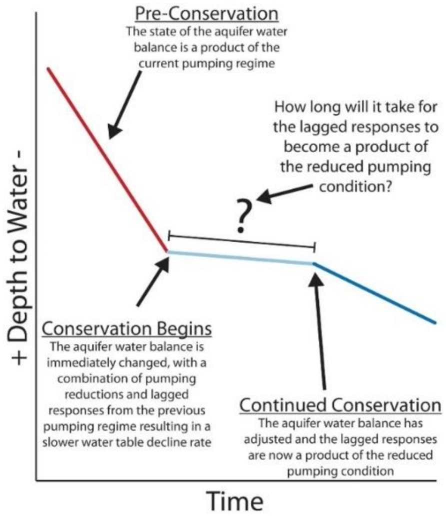


- **Several sources of inflows to the aquifer are tied to pumping.**
  - **Irrigation return flows**
  - **Gradient flows**
  - **Lagged drainage**

- **Eventually the system adjusts and further management efforts will be needed to achieve water-level reduction goals.**

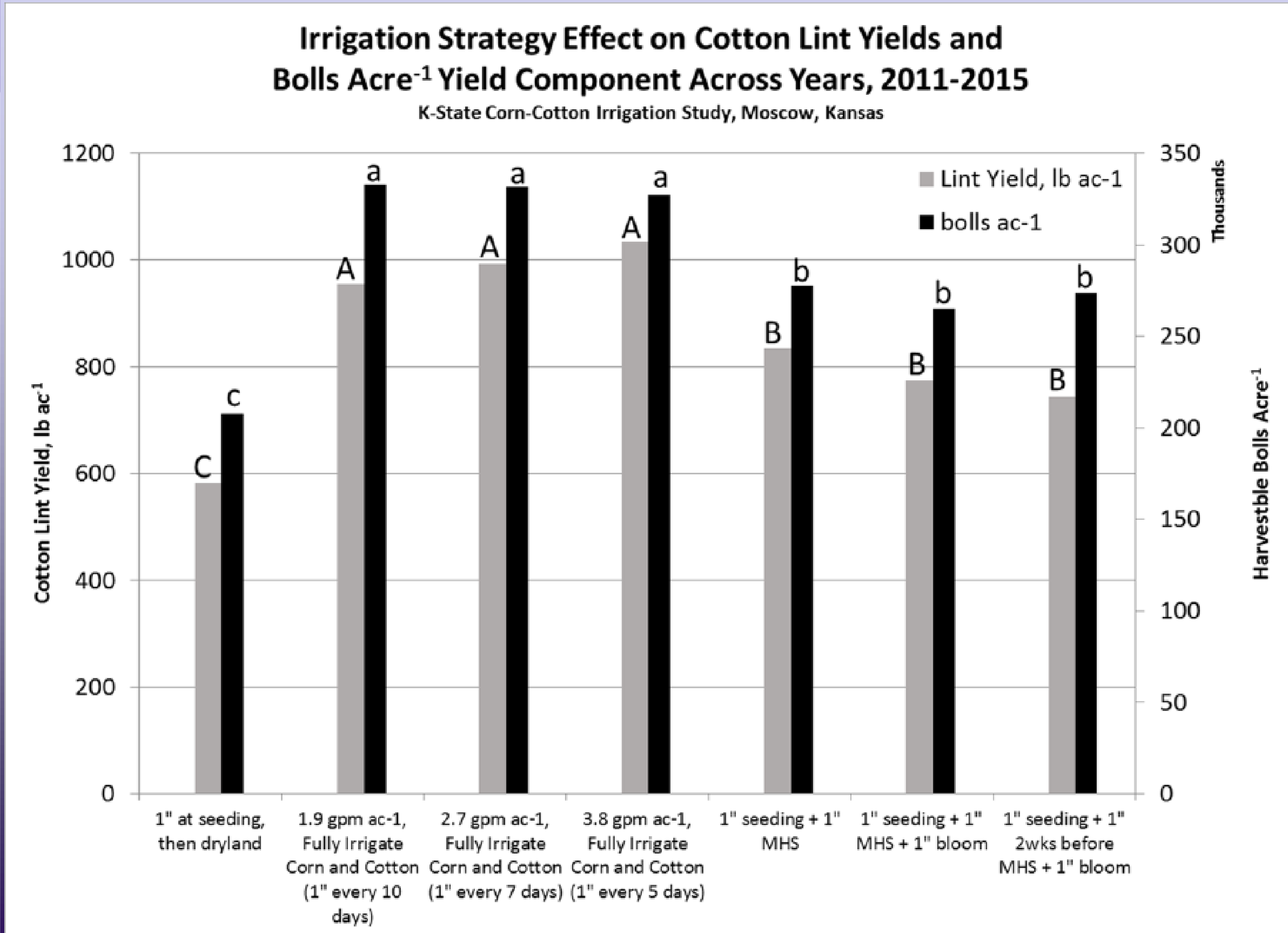
Butler, J.J., Jr., G.C. Bohling, D.O. Whittemore, and B.B. Wilson, Charting pathways towards sustainability for aquifers supporting irrigated agriculture, Water Resour. Res., v. 56, no. 10, doi: 10.1029/2020WR027961, 2020.

Glose, T.J., S. Zipper, D.W. Hyndman, A.D. Kendall, J.M. Deines, and J.J. Butler, Jr., Quantifying the impact of lagged hydrological responses on the effectiveness of groundwater conservation, Water Resource. Research., v. 58, doi: 10.1029/2022WR032295, 2022



Why Irrigated Cotton Research in Kansas?

- Declining water resources calls for use of other alternative crops
- Cotton is considered drought-tolerant
- Rapid growth of acreage in Kansas
  - 2015 → 16,000 acres
  - 2019 → 175,000 acres (160,000 ac. harvested)
- Availability of varieties with herbicide tolerance and has shorter season requirement



Duncan, 2019

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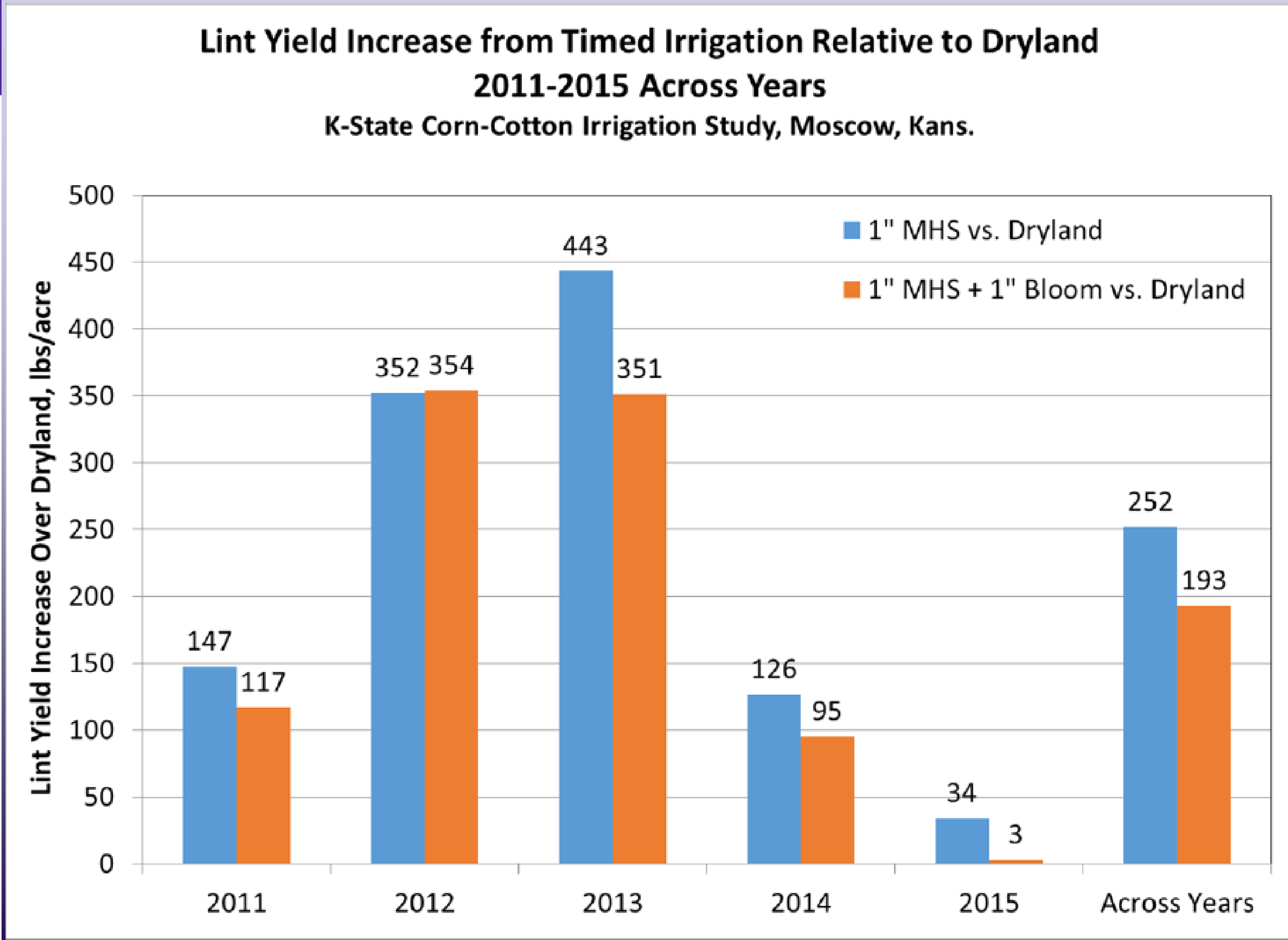
https://kwo.ks.gov/docs/default-source/governor's-water-conference/cotton-production-in-ks---duncan-(1).pdf



Duncan, 2019

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https://kwo.ks.gov/docs/default-source/governor's-water-conference/cotton-production-in-ks---duncan-(1).pdf

Cotton Research 2019

Simple QUESTIONS

1. Will cotton GROW or NOT in Garden City area?

2. If it grows, will it have a DECENT yield?

3. WHEN should we plant cotton?

Cotton Research 2019

Simple QUESTIONS

1. Will cotton GROW or NOT in Garden City area?

Yes, will grow

2. If it grows, will it have a DECENT yield?

Yes

3. WHEN should we plant cotton?

As early as conditions are favorable

2019 Results

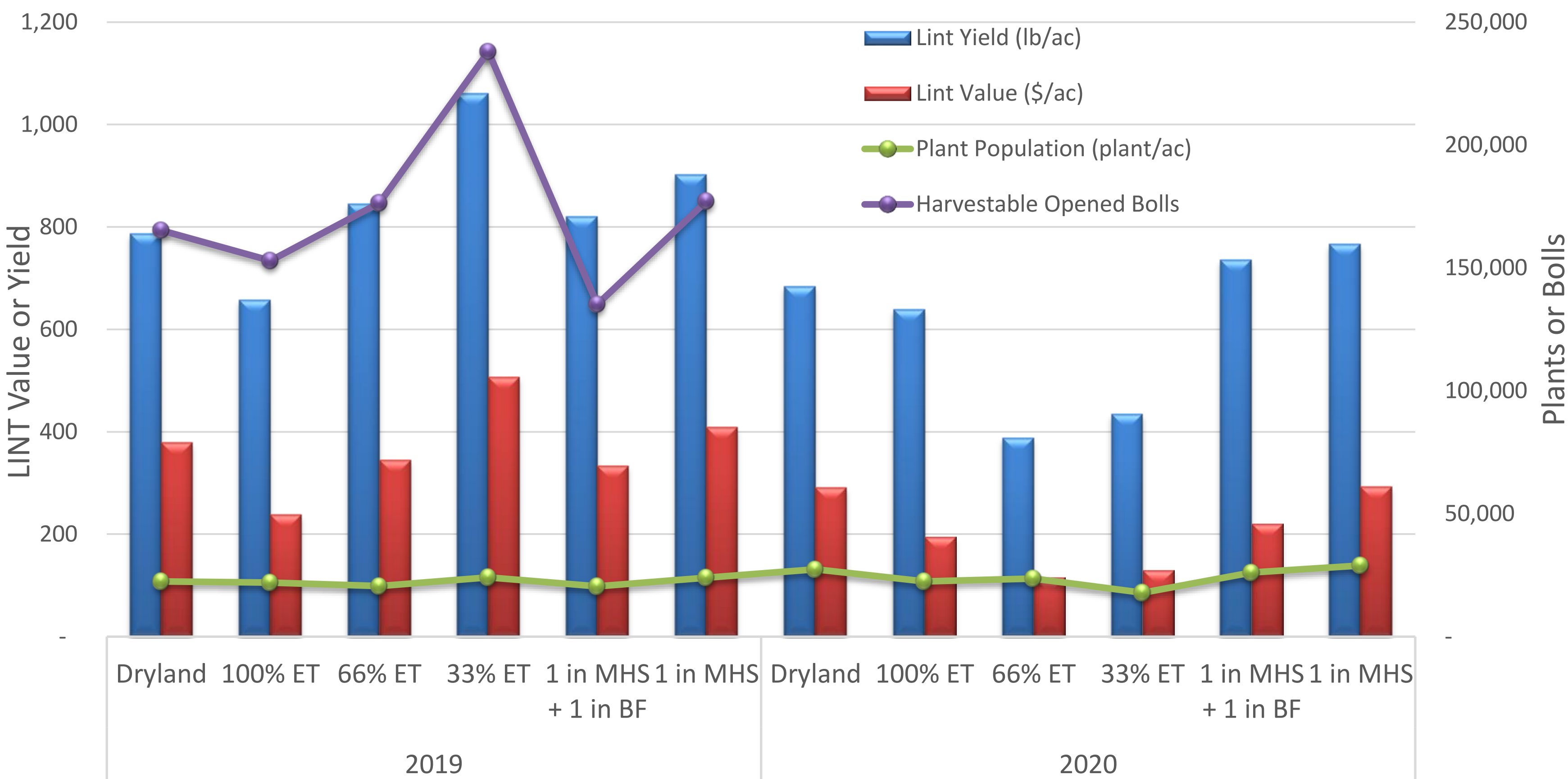
Treatments	Total Irrign. (in)	Loan Avg. ($'s/lb)	Lint Yield (lb/ac)	Average of MIC	Lint Value ($/ac)
Fully Irrigated (100% ET)	5	0.36	658	2.61	238
Partially Irrigated (66% ET)	4	0.41	845	2.87	344
Limited Irrigated (33% ET)	1	0.48	1,061	3.46	507
Dryland	0	0.48	787	3.67	379
One Irrigation (1.00 in.) at Match Head Square Only	1	0.45	902	3.28	408
One irrigation (1.00 in.) at Match Head Square and at Boll Formation	2	0.41	820	2.89	334
Average		0.43	845	3.13	368

Season Precipitation: 11.84 in

2020 Results

Treatments	Total Irrign. (in)	Loan Avg. ($'s/lb)	Lint Yield (lb/ac)	Average of MIC	Lint Value ($/ac)
Fully Irrigated (100% ET)	0.75	0.30	637	2.19	195
Partially Irrigated (66% ET)	0.75	0.29	388	2.15	116
Limited Irrigated (33% ET)	0.75	0.30	434	2.19	130
Dryland	0	0.36	684	2.45	291
One Irrigation (1.00 in.) at Match Head Square Only	0.75	0.39	767	2.45	292
One irrigation (1.00 in.) at Match Head Square and at Boll Formation	0.75	0.30	735	2.20	221
Average		0.43	603	2.26	203

Season Precipitation: 11.04 in



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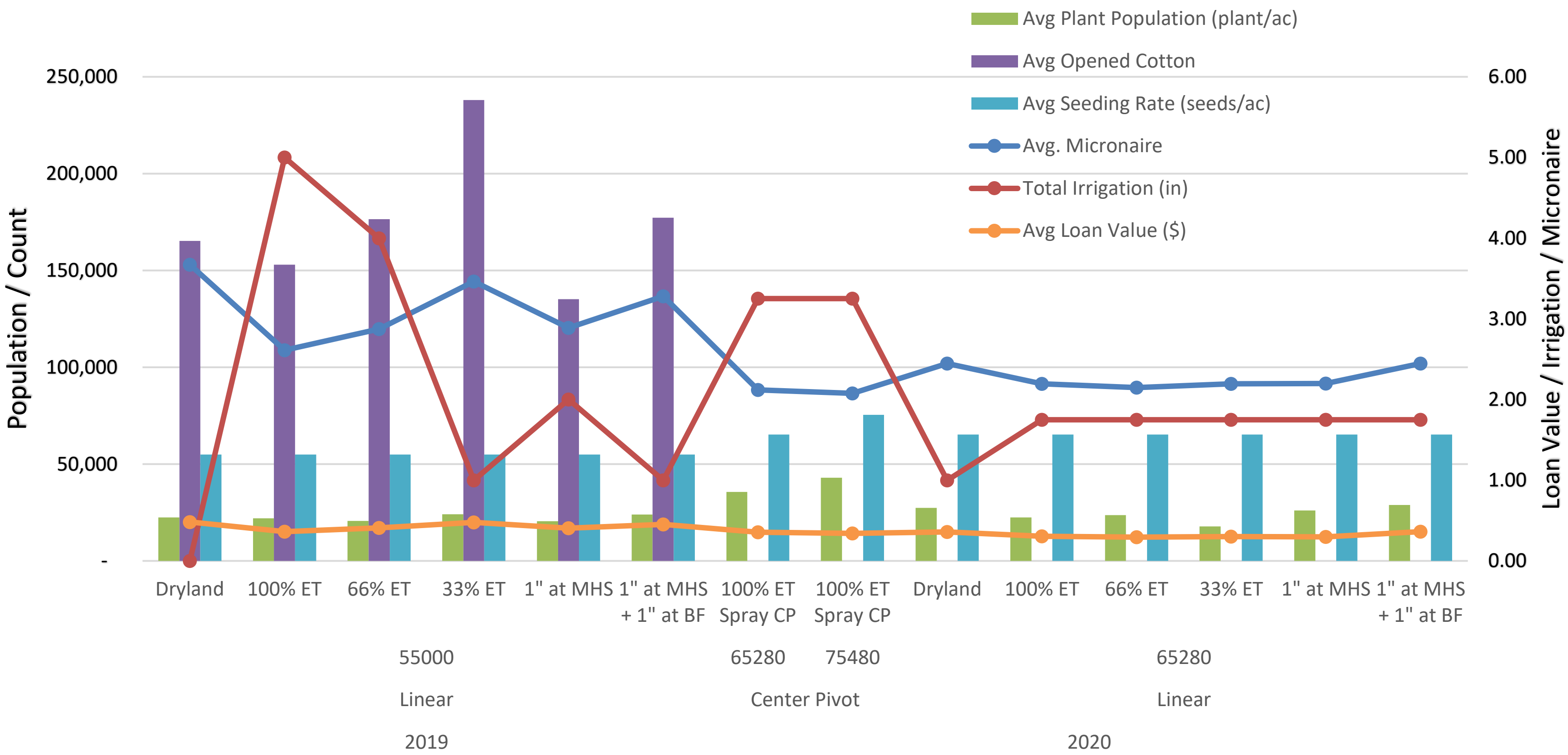
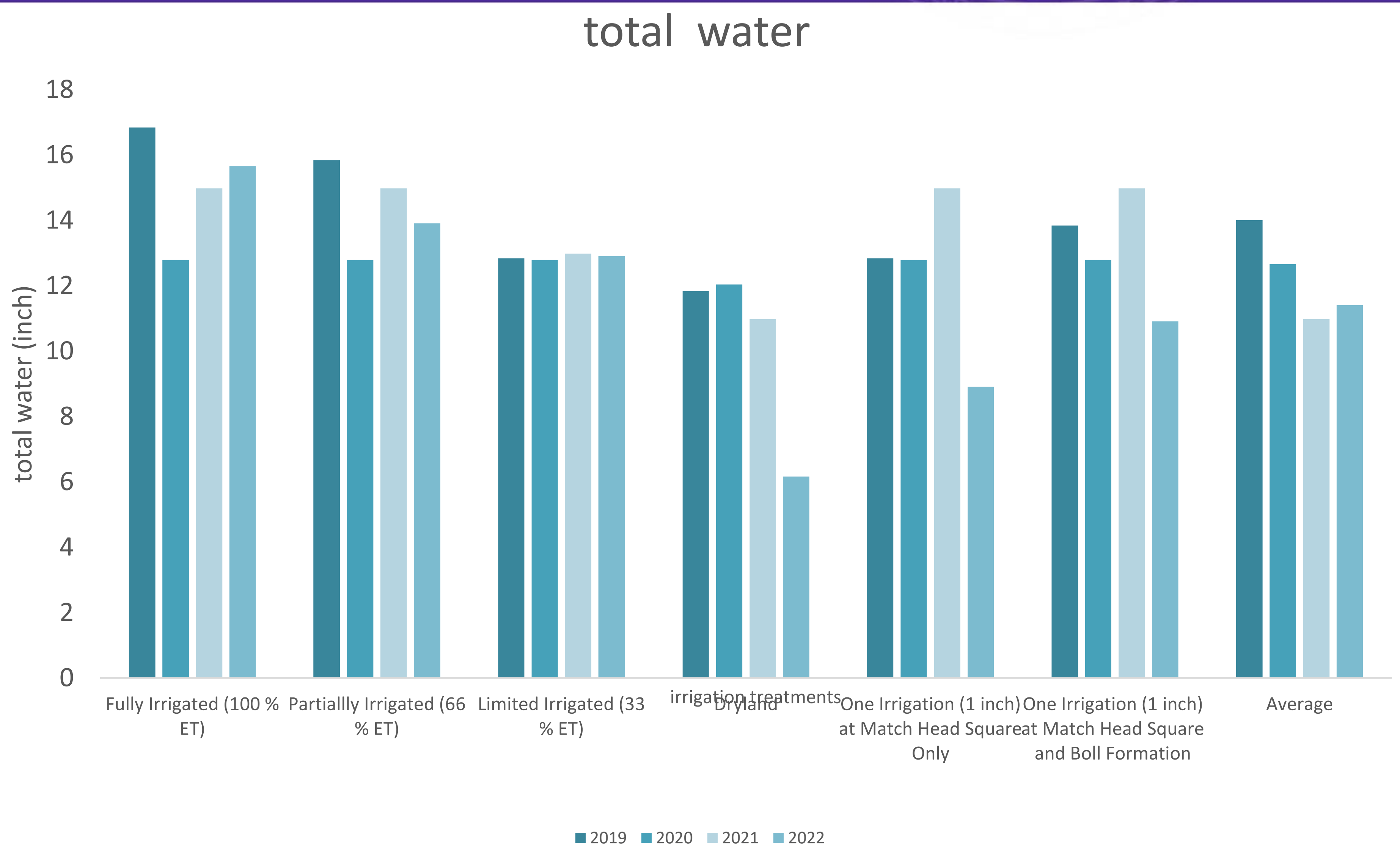
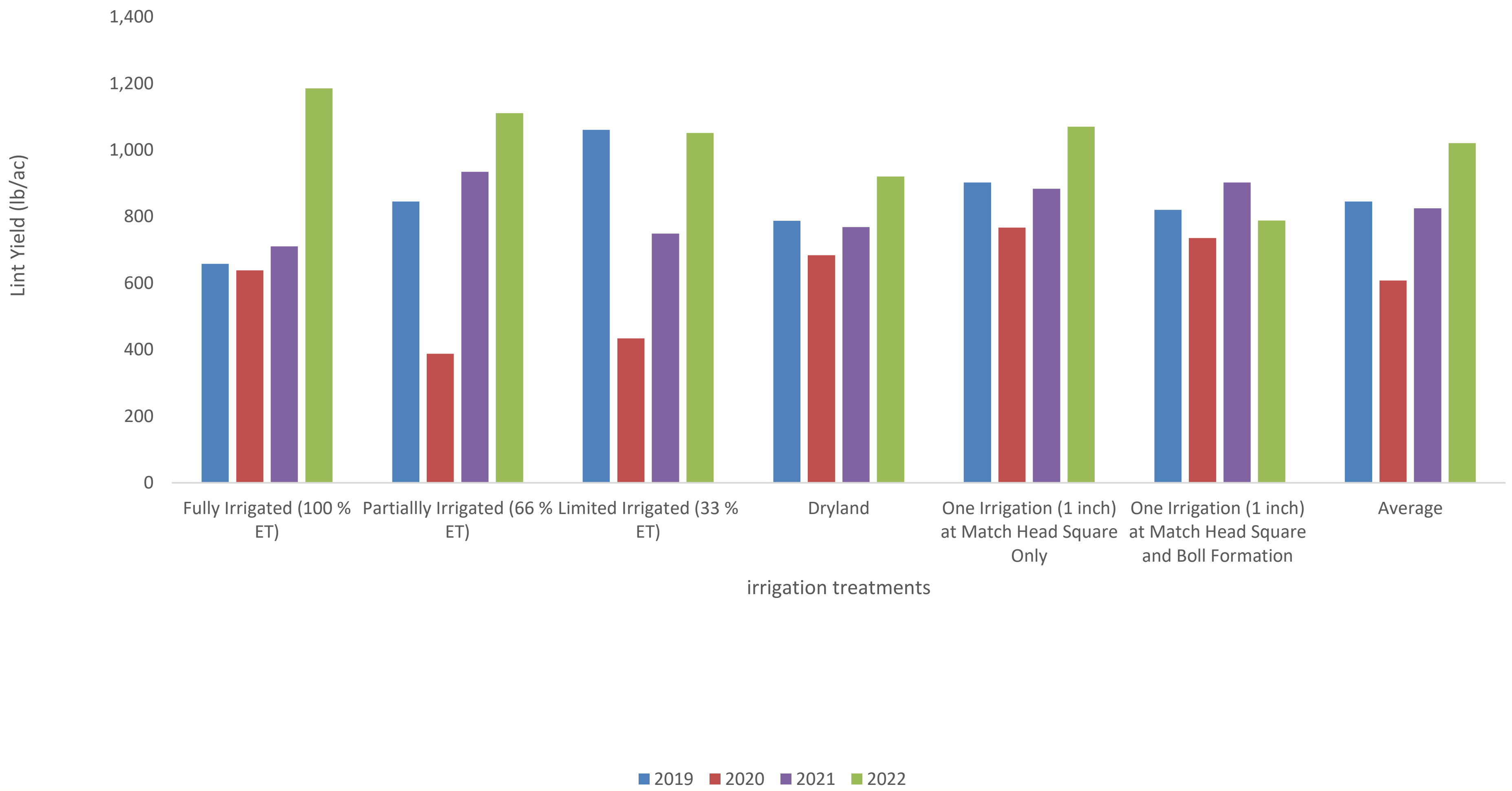

Avg Plant Population (plant/ac)
Avg Opened Cotton
Avg Seeding Rate (seeds/ac)
Avg. Micronaire
Total Irrigation (in)
Avg Loan Value ($)
Population / Count
Loan Value / Irrigation / Micronaire
250,000
200,000
150,000
100,000
50,000
-
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Dryland
100% ET
66% ET
33% ET
1" at MHS
1" at MHS + 1" at BF
100% ET Spray CP
100% ET Spray CP
Dryland
100% ET
66% ET
33% ET
1" at MHS
1" at MHS + 1" at BF
55000
65280
75480
65280
Linear
Center Pivot
Linear
2019
2020


total water
total water (inch)
18
16
14
12
10
8
6
4
2
0
irrigation treatments
Fully Irrigated (100 % ET)
Partiallly Irrigated (66 % ET)
Limited Irrigated (33 % ET)
Dryland
One Irrigation (1 inch) at Match Head Square Only
One Irrigation (1 inch) at Match Head Square and Boll Formation
Average
2019
2020
2021
2022

Lint Yield summary



Cotton Production in “Thermally” Limited Environments

Inconsistencies in cotton management led to collaborative cotton research initiative between Texas and western Kansas to optimize lint yield and quality in the Texas Panhandle and western Kansas.

Problem

- Expanding cotton acres in northern Texas High Plains and SW Kansas
  - Declining groundwater
- Lack of agronomic research for thermally limited/growing degree day limited region
- All previous growth models from "traditional" cotton production regions

Event	DD-60s from Planting
Emergence (stand establishment)	45-130
1st Square	440-530
1st Flower	780-900
Peak Bloom	1350-1500
1st Open Boll	1650-1850
Defoliation	1900-2600

From Dan Krieg, Texas Tech University

Problem

Event	South Plains DD-60s from Planting (Krieg)	Panhandle DD-60s from Planting (Bell)*	Kansas DD-60s from Planting (Aguilar)*
Emergence (stand establishment)	45-130	100-250	93-100
1st Square	440-530	600-750	-
1st Flower	780-900	1100-1350	764-774
Peak Bloom	1350-1500	1450-1700	1447 -1457
1st Open Boll	1650-1850	1850-1950	-
Defoliation	1900-2600	2100-2300	1680 - 1764

*GDDs depend on planting date.

Objective : Develop cotton production functions for thermally limited Southern Great Plains cotton systems

- Kansas field plots - K-State Southwest Research-Extension experiment station at Garden City, Kansas under a 4-span linear irrigation system.
- Texas field plots - USDA-ARS Conservation and Production Research Laboratory and Texas A&M AgriLife Research Farm at Bushland under center pivot irrigation.
- Treatments represent genetic x environmental x management interactions and follow the same protocol at both locations.
- Two Enlist (2,4-D tolerant) varieties evaluated
  - Phytogen 205 W3FE: a broadly adapted early, more determinant variety
  - Phytogen 332 W3FE: early-med maturing less determinant variety
- Three populations (25K, 50K, and 75K plants ac^{-1}). Plots over planted and thinned to the desired population.
- Two planting dates (early- and late- May) and two irrigation levels (2- and 6- gallon per minute per acre well capacities).

Kansas Cotton 2021 Data

- Total Irrigation 4 inches
- Rainfall:6.62 inches
- Seeding rate: 100K/ac
- Early Planted: May 27 Late planted: June 7 failed

Variety	Average of Emerged	Min of Emerged	Max of Emerged	Turnout Avg.	Average of Yield (lb/ac)
PHY205	45,883	17,424	69,696	45.9	813
PHY332	45,157	26,136	64,469	46.3	728
Average	**45,520**	**17,424**	**69,696**	**46.1**	**770**

Kansas Cotton 2022 Data

- Total Irrigation: 2.75 - 7.75 inches
- Rainfall: 4.38 - 6.16 inches
- Seeding rate: 150K/ac
- Early Planted: May 9 Late planted: May 31

Row Labels	Average of Emerged	Min of Emerged	Max of Emerged	Average of Gross Yield
5/9/22	**62,592**	**19,747**	**91,766**	**1,776**
PHY205	57,458	19,747	91,766	1,930
PHY332	68,583	45,302	91,766	1,596
5/31/22	**75,456**	**41,818**	**114,998**	**1,659**
PHY205	73,810	41,818	97,574	1,629
PHY332	77,101	42,979	114,998	1,688
Grand Total	**68,767**	**19,747**	**114,998**	**1,720**

Kansas Cotton in 2023 Data

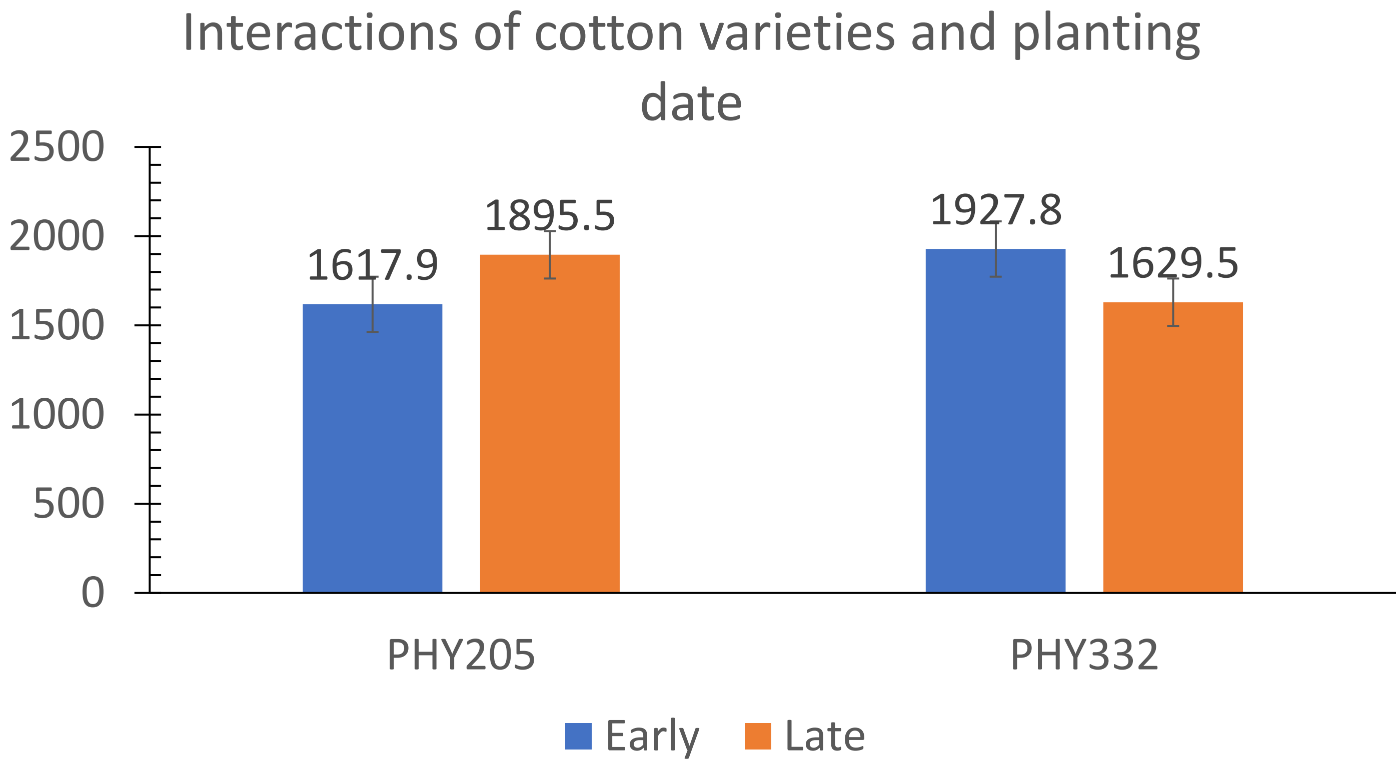
- Total Irrigation: 2.75 - 4.75 inches
- Rainfall: 14.72 - 18.06 inches
- Seeding rate: 150K/ac
- Early Planted: May 4   Late planted: May 18
- Hailed June 9, 2023 (and maybe June 17th)
- First freeze Oct. 15, 2023

Row Labels	Average Population Harvested	Average Yield
5/4/23	**49, 128**	**886**
PHY205	47,553	993
PHY332	55,931	759
5/18/23	**35,392**	**940**
PHY205	35,937	1120
PHY332	34,847	759
Grand Total	**42,114**	**914**

Plant Stand Concerns

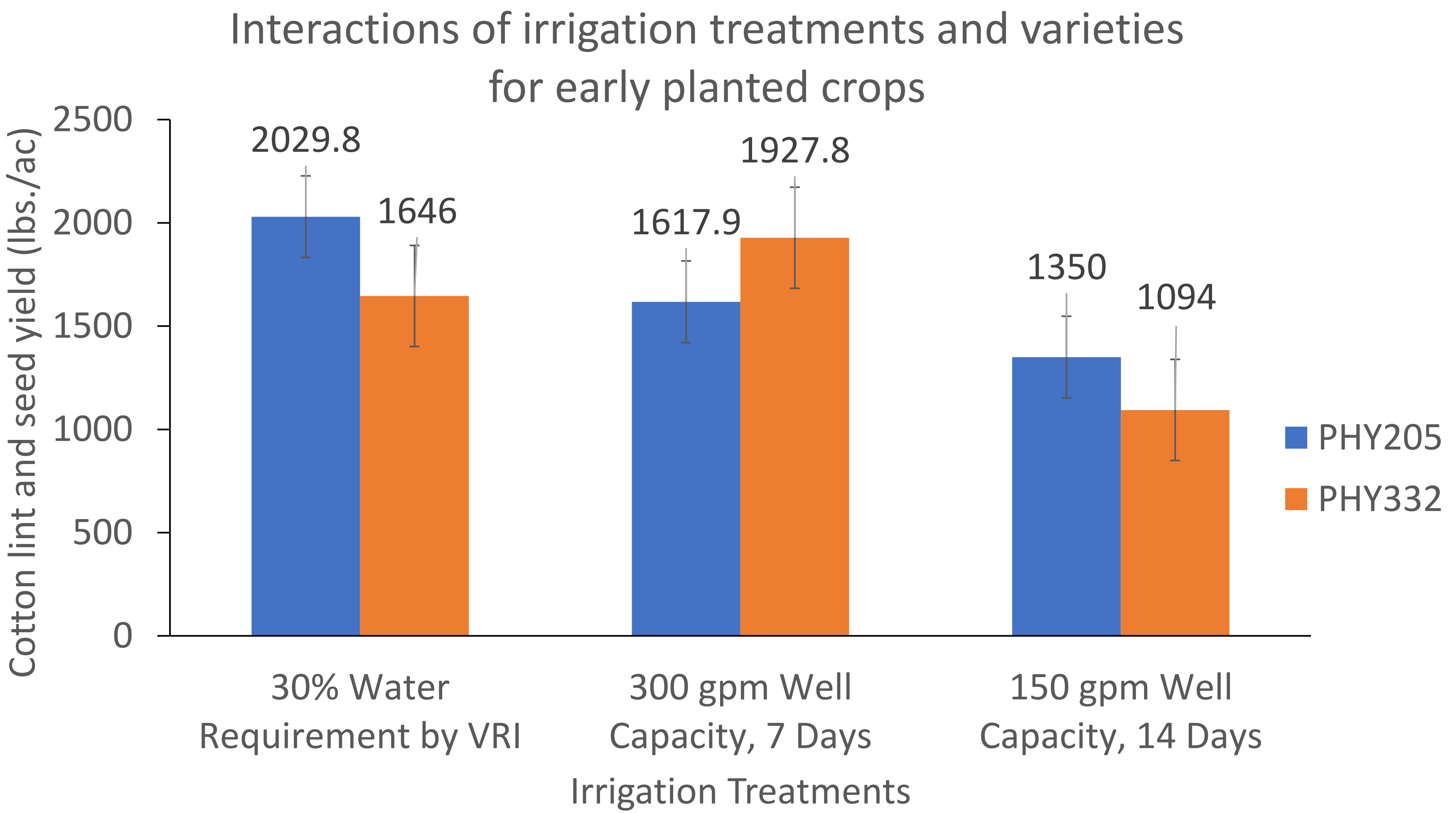
- 7-years of Panhandle AgriLife data demonstrates that final stands are ~50% (range 30-75%) of the planted population.
- Example: Average Seed Cost $337/Bag
- Planting 50,000 Seeds per Acre = $76.60/Acre Seed Cost
- At 50% germination, you **lost** ~$38.30/acre the minute you put your planter in the ground.
- We need to optimize planting
- AND consider the cost of the replant

Kansas Cotton 2022 Data

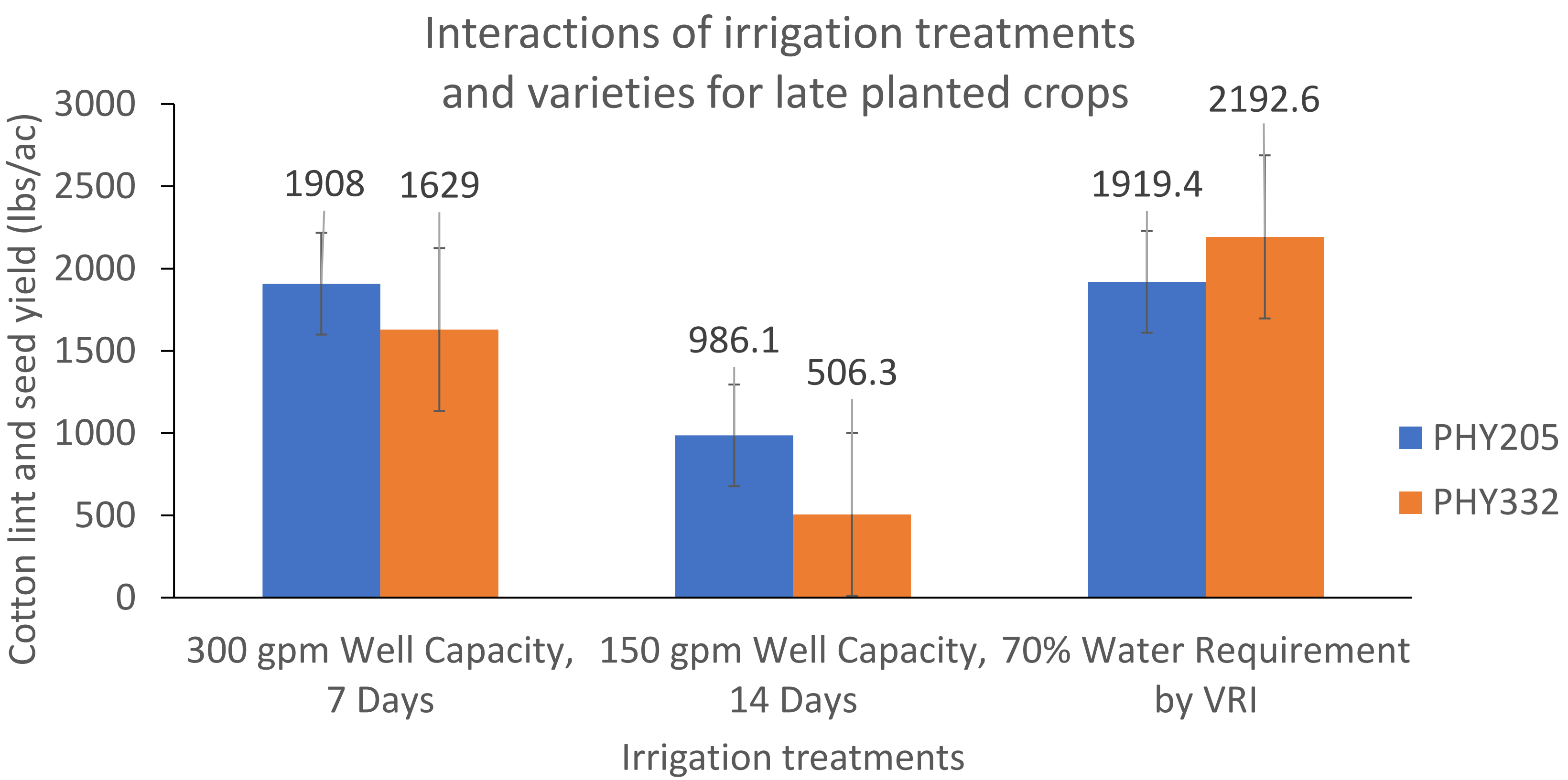


The comparison of means results showed no significant difference between the effects of cotton varieties and planting date on the plant yield. However, the results indicate that the early planted PHYTOGEN 332 had highest yield comparing to other treatments

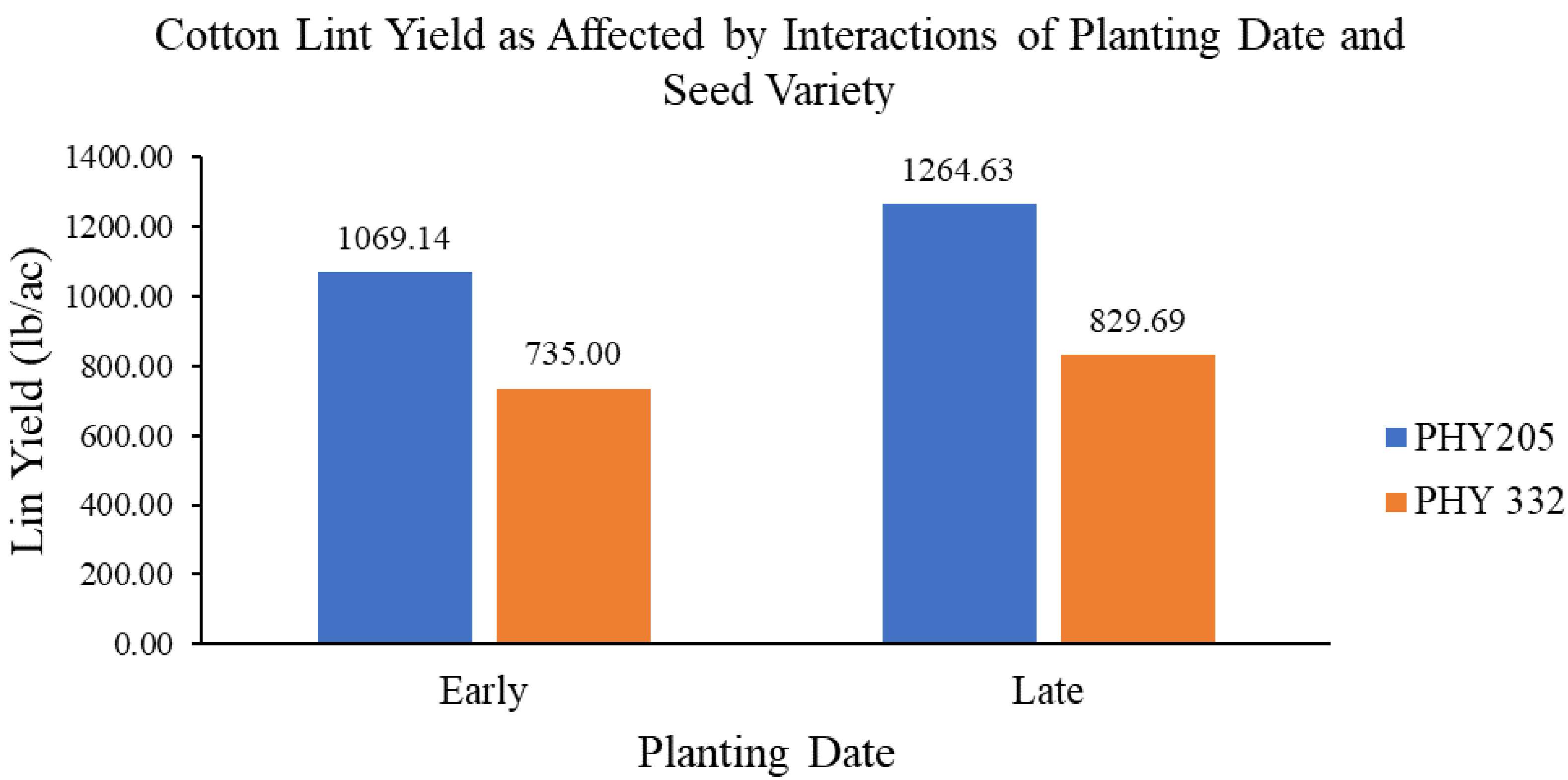
Kansas Cotton 2022 Data



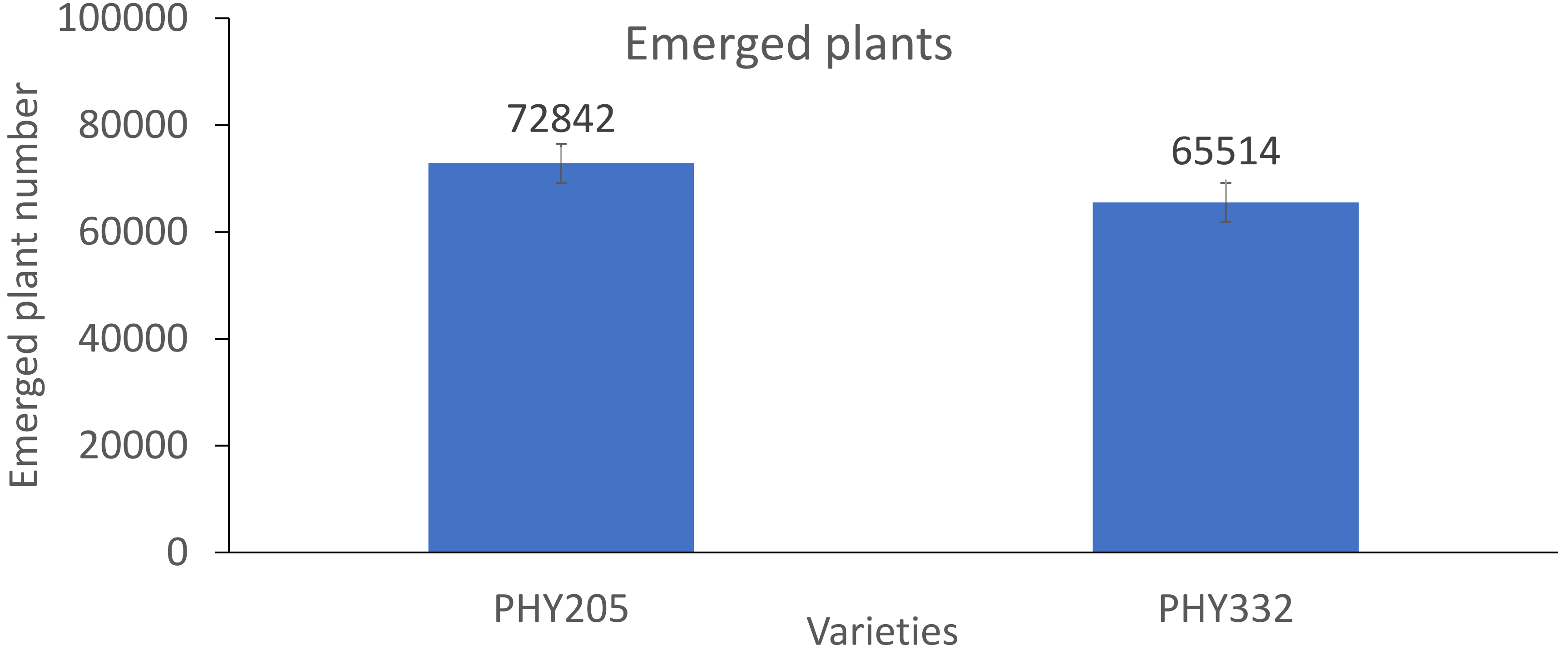
Kansas Cotton 2022 Data



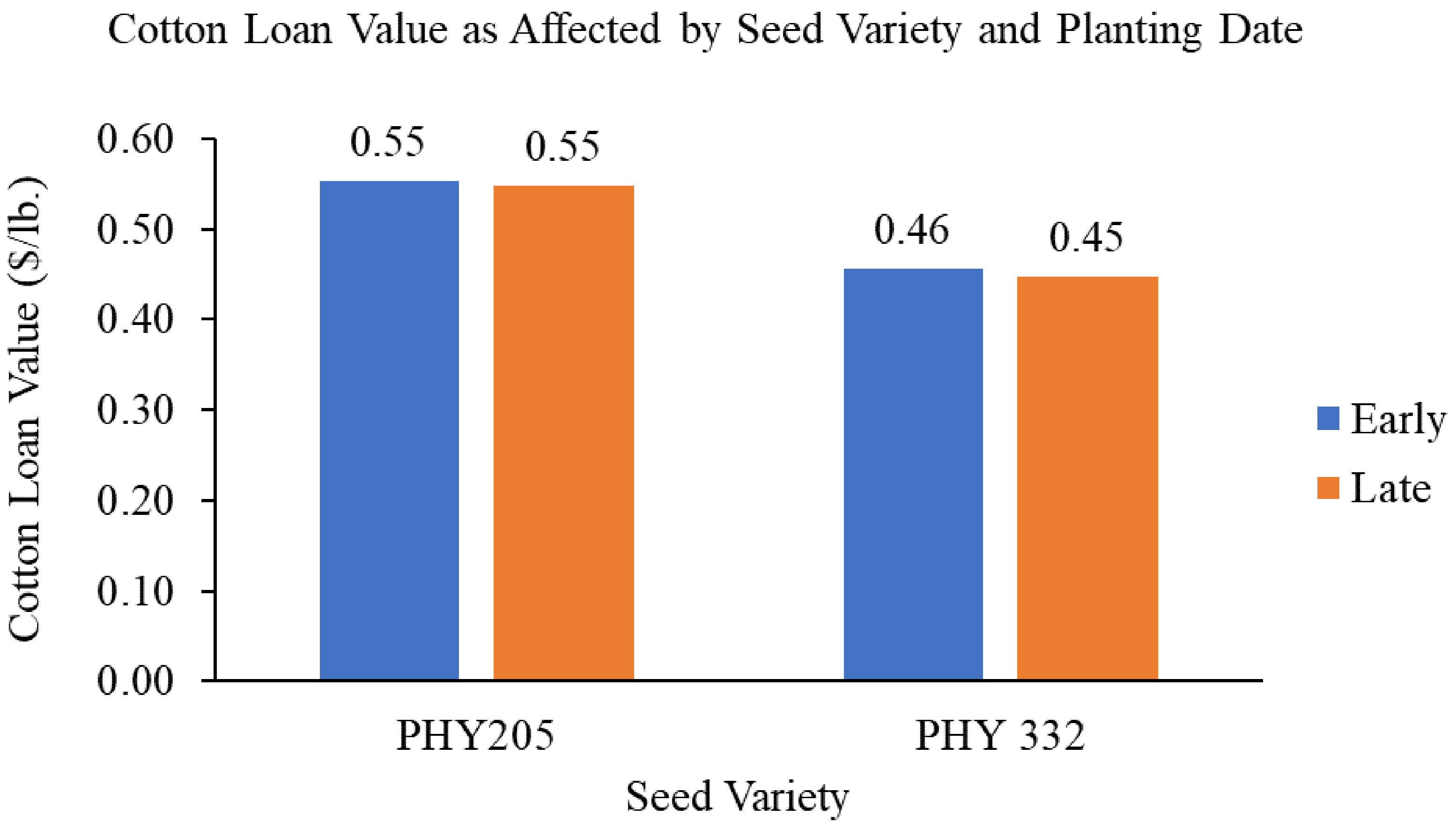
Kansas Cotton 2023 Data



Kansas Cotton 2022 Data



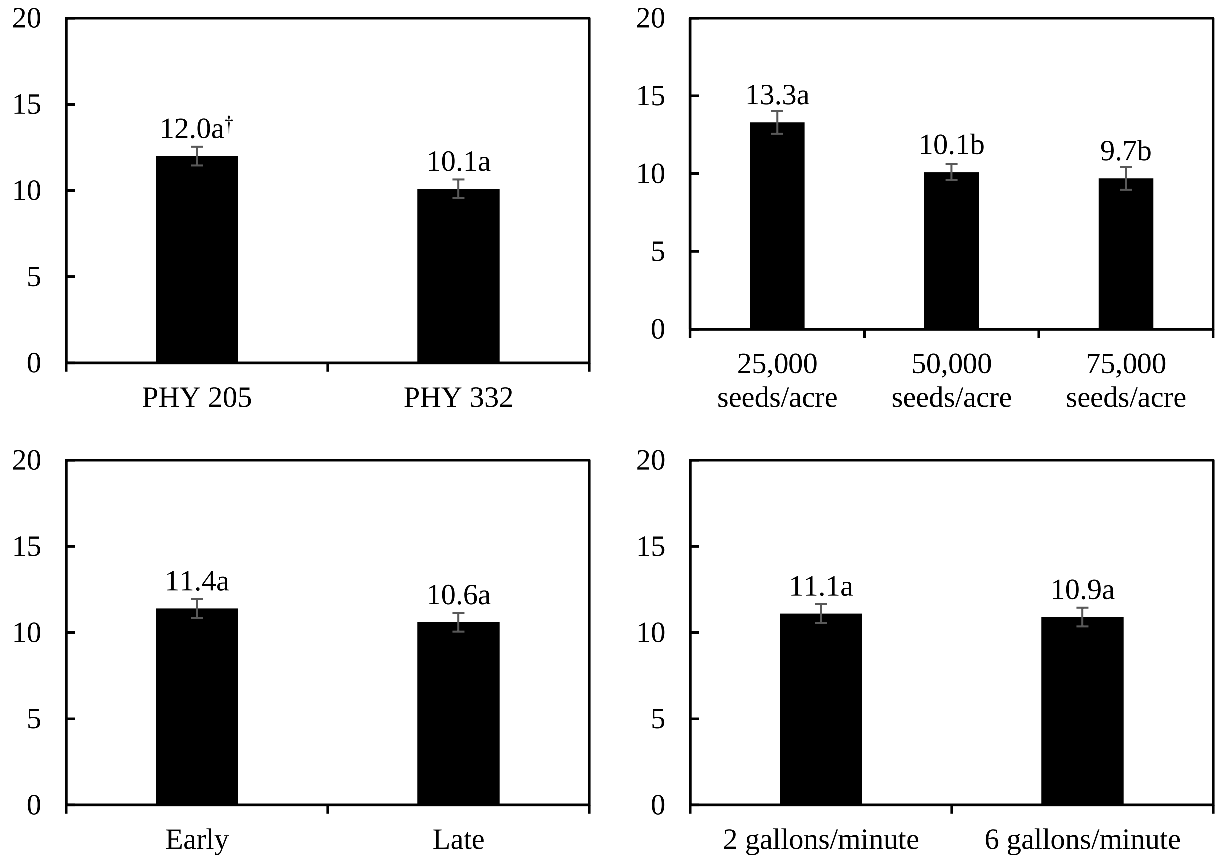
Kansas Cotton 2023 Data



MIC 3.63

MIC 2.79

Kansas Cotton 2024 Data



Quantifying ET, water stress, and economic benefits for sustainable cotton production in Kansas

A. Sheshukov, J. Aguilar, L. Haag, B. Golden, D. Devlin

Supported by the KSU Global Food Systems Grant and Kansas Department of Agriculture

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Materials & Methods

2.1. Study area and experimental design

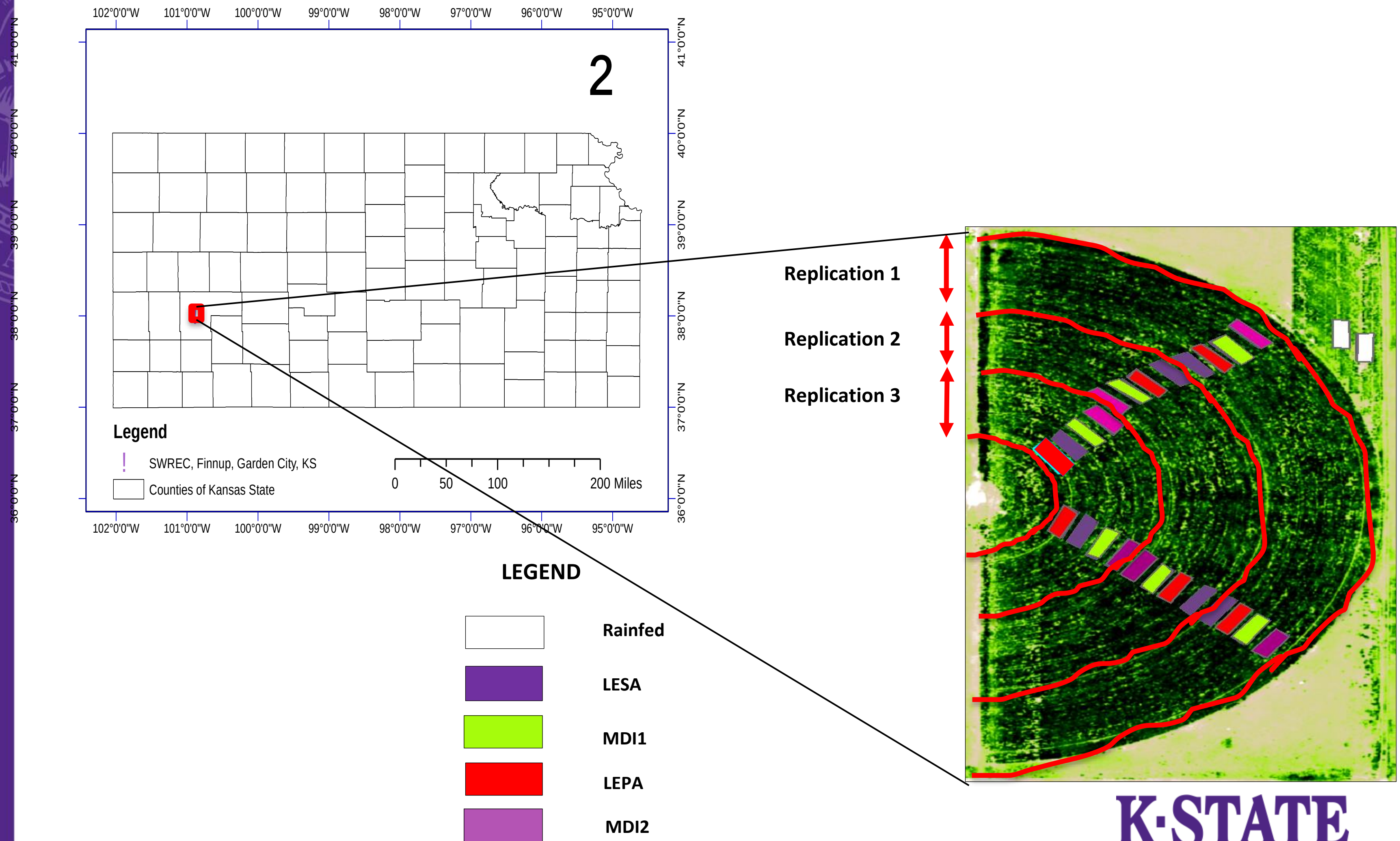

Figure 1: Map of the study location and plots, SWREC, Garden City

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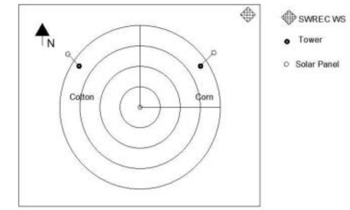
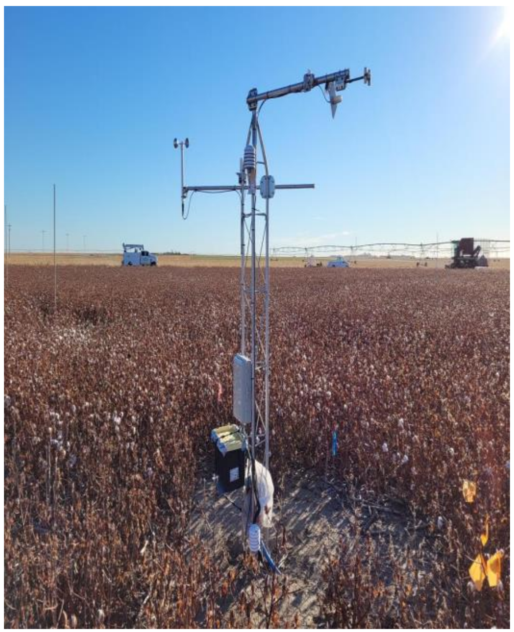
Two growing crops



Cotton



Corn

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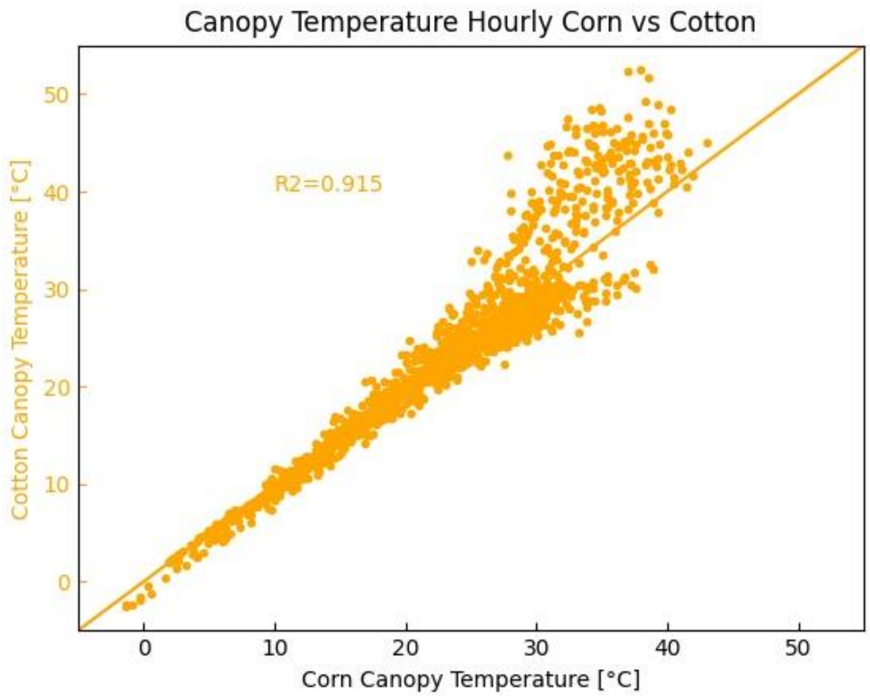
Canopy skin temperature



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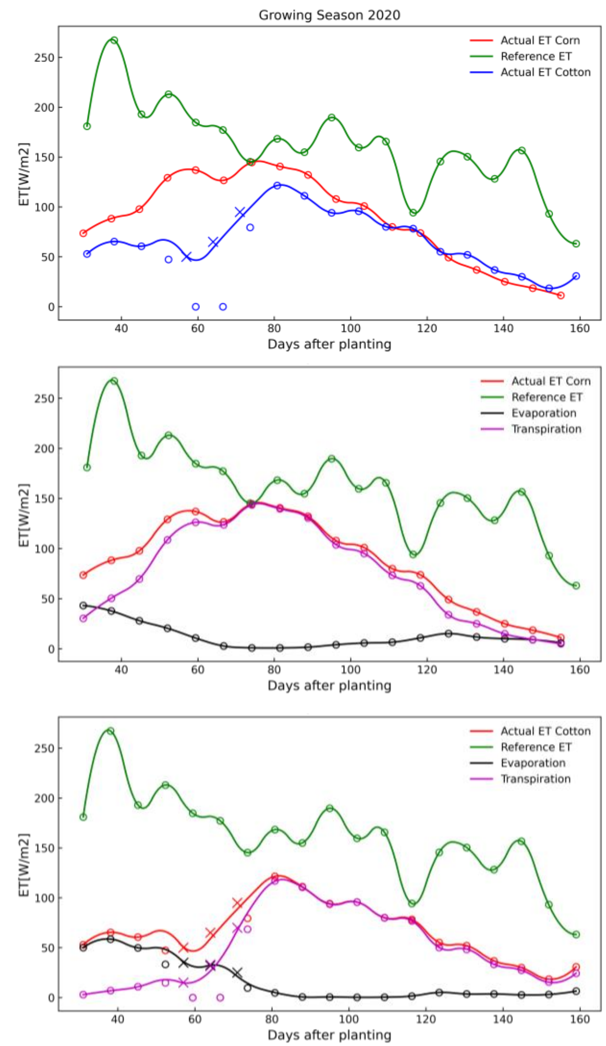
ETc: Cotton vs Corn

- Actual ET reached its maximum value at the development stage and started to decline at the mid stage.
- Maximum actual ET was higher for corn than cotton but smaller during the maturity stage.
- Evaporation fluxes were higher during the initial stage, while transpiration fluxes were dominant during the mature stage for both crops
- Delayed development of cotton reflected in delayed ET rates



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3. Results & Discussion

3.1. GDD and TU during the growing season

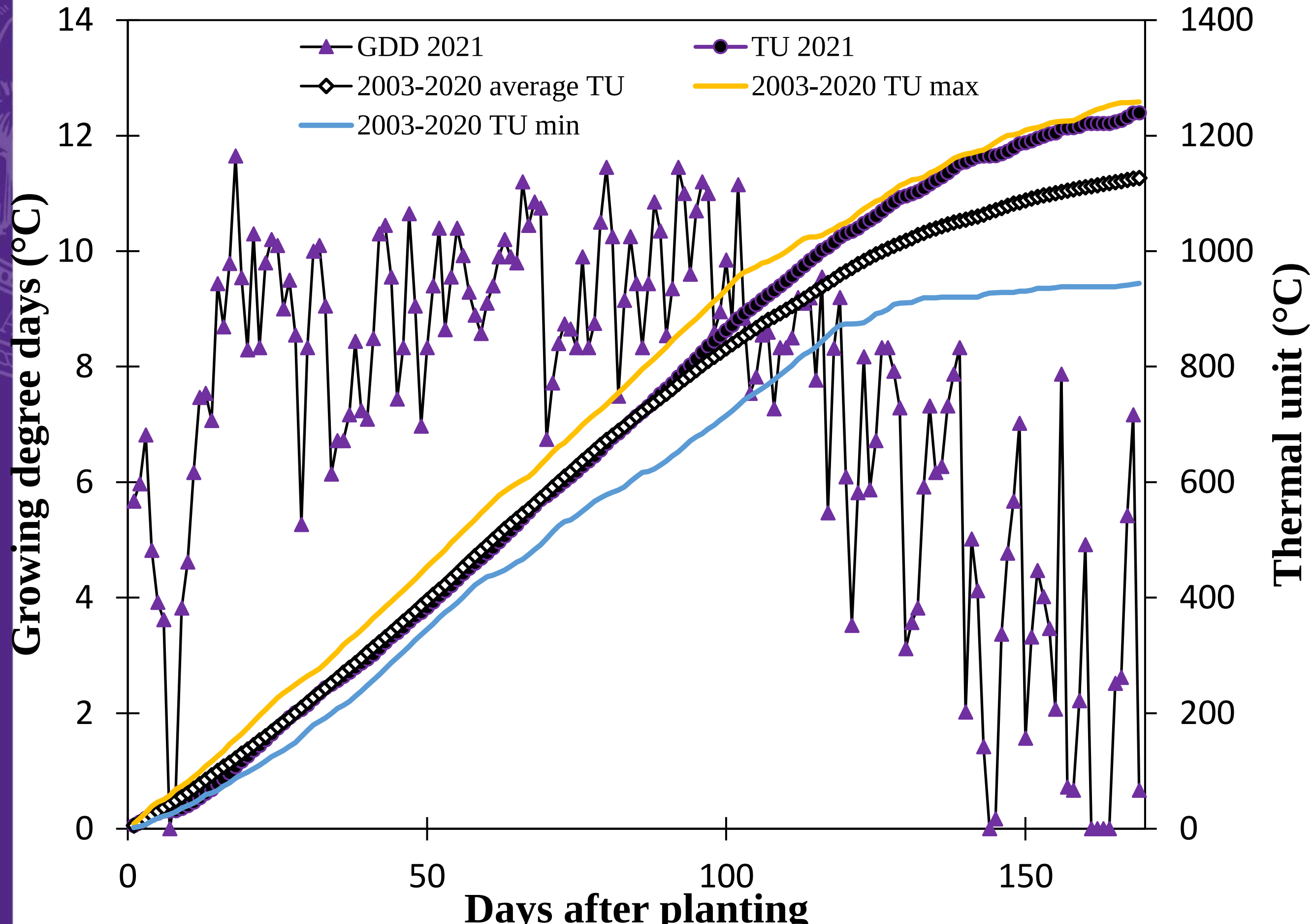

Figure 2: Variation in the Growing Degree Days (GDD) and Thermal Unit (TU)

- Thermal Unit (TU) during 2021 growing season was 1239.65°C.
- 2021 TU is **higher** than 2003-2020 average TU (113 °C).
- 2021 TU is **closer to max** 2003-2020 average TU (# of 18 °C)

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3. Results & Discussion

3.2. Total water, actual evapotranspiration, and irrigation water use efficiency under different irrigation technologies and rainfed treatments

Treatment		Irrigation (mm)	ETa (mm)	Yield (kg ha^{-1})	CWUE (kg m^{-3})	ETWUE (kg m^{-3})	IWUE (kg m^{-3})
LESA	D1	146.05	498.9	821.6	0.26	0.16	0.34
	D2	146.05	469.8	815.8	0.26	0.17	0.25
LEPA	D1	146.05	465.7	968.1	0.30	0.21	0.44
	D2	146.05	485.9	932.6	0.29	0.19	0.33
MDI1	D1	146.05	500.5	916.7	0.29	0.18	0.41
	D2	146.05	480.1	898.7	0.28	0.19	0.31
MDI2	D1	146.05	489.6	827.0	0.26	0.17	0.34
	D2	146.05	477.2	755.5	0.24	0.16	0.21
Rainfed	D1	0	280.8	324.2	0.19	0.12	-
	D2	0	293.5	444.9	0.26	0.15	-

D1: High density, D2: Low density

- The **LEPA** irrigation technology had the maximum averaged CWUE, ETWUE, and IWUE
- **1 cubic meter of water provides more Kg of lint yield under LEPA.**

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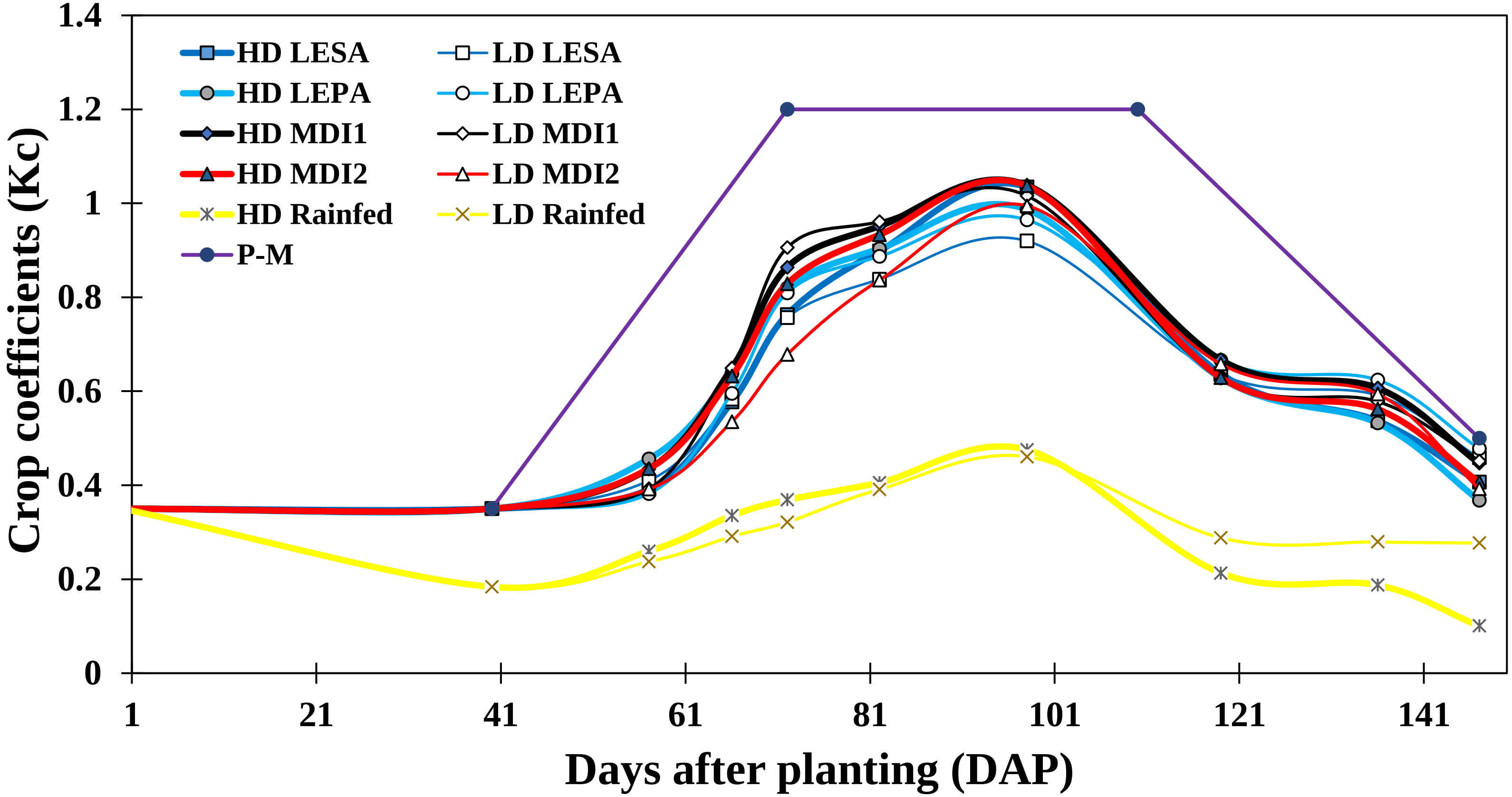
3.3. Crop coefficients under different irrigation technologies and rainfed treatments



- Irrigated cotton crop coefficients were estimated at 0.35, 0.92 to 1.04, and 0.39 to 0.48 for initial, mid, and late season stages, respectively.
- Rainfed conditions Kc were 0.18, 0.46 to 0.48, and 0.10 to 0.28 for the respective growth stages.

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3. Results & Discussion

3.4. Cotton ETa determined using the Soil Water Balance and estimated from the Two-Step Approach

Treatment		ETa from water balance (mm)	ETa from ETo × Kc adj. (mm)	Difference (%)
LEPA	D1	498.9	628.88	26
	D2	469.8	629.22	34
LESA	D1	465.7	629.13	35
	D2	485.9	629.19	29
MDI1	D1	500.5	629.74	26
	D2	480.1	629.97	31
MDI2	D1	489.6	629.88	29
	D2	477.2	629.95	32
Rainfed	D1	280.8	627.42	123
	D2	293.5	625.99	113

D1: High density, D2: Low density

- The difference between the two ETa ranged from 26% to 35% for the irrigated field averaging 30%, while for the rainfed treatments, it averaged 118%.
- **Two-step approach using FAO adjusted crop coefficients overestimated cotton ETa.**

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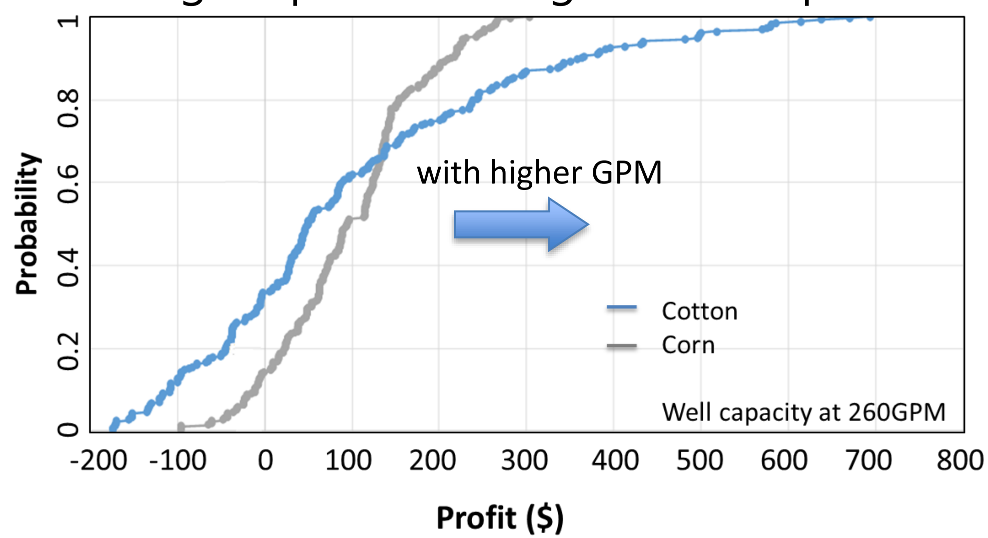
Risk vs profit

- Cotton tends to be more profitable than corn but with more risk
- At lower well capacities, cotton has the potential to generate significantly higher profits
- Risk graphs similar at different well capacities
- Curves shift to higher profits for higher well capacities



Cotton production benefits

- Cotton provides higher profits with higher risk and uses less irrigation than corn

	Profit*	Irrigation use*
Low capacity wells (260 GPM)	2%	-43%
Medium capacity wells (470 GPM)	18%	-43%
High capacity wells (780 GPM)	52%	-28%
Average	31%	-27%

* Values show % difference from corn

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Conclusions

- Cotton production
  - Sufficient heat units for cotton to grow in Southwest Kansas
  - Cotton ET rates are lower than presented in FAO, thus ET can be overestimated with standard single-term crop coefficient and FAO Penman-Monteith approach
  - Rainfed cotton shows lower ET and higher number of days under stress than irrigated cotton
- LEPA recorded the **highest fiber yield** and MDI2 the **lowest** among the irrigation technologies. Inversely, MDI2 had the **highest biomass** and LEPA the **lowest** biomass.
- Irrigated cotton lint yield increased by **106%, 113%, 136%, and 147%** compared with the rainfed for **MDI2, LESA, MDI1, and LEPA**, respectively.

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Research and Extension

Challenges

- Germination rate is very low (<50%)
- Limited cotton varieties available
- Support (agronomic and machinery) is limited or far
- Some BMPs developed in the south needs to be tweaked for implementation in the region
- Irrigation strategies are yet to be honed
- Inadequate information on production curve and ET estimates

Initial Recommendations

- Prepare the field early and be ready to plant when the condition becomes favorable
- Lean towards higher seeding rate (55,000 or more) to compensate on germination / emergence issues
- Adopt an irrigation schedule with ET-, soil-, and/or plant-based feedback and follow through with it
- Irrigate at least once at match head square
- Aim to keep your field weed-free
- For starters, seek help from those who know this crop

Thank you

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Photo 8: Picture of bale of cotton harvested at the experiment site, Garden City