Effects of Irrigation and In-Season Fertilization Strategies on Water Use and Nitrogen Use Efficiency and Yield of Irrigated Corn

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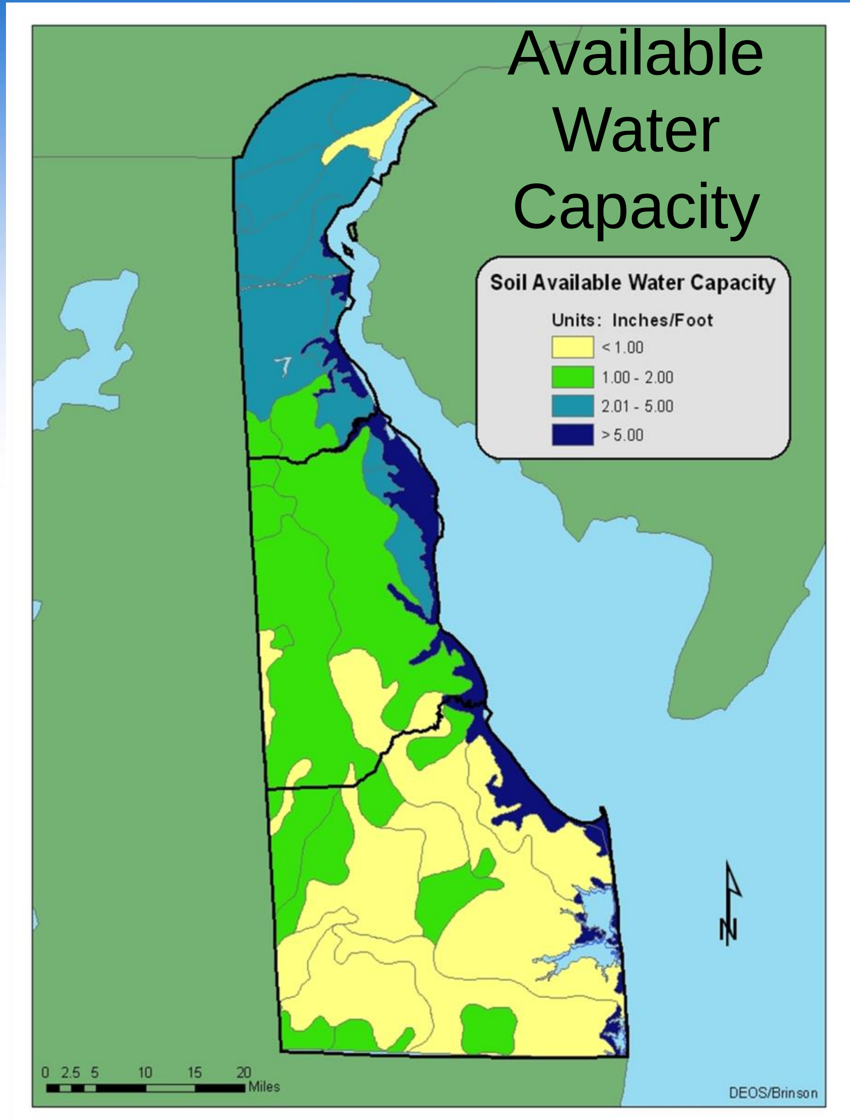
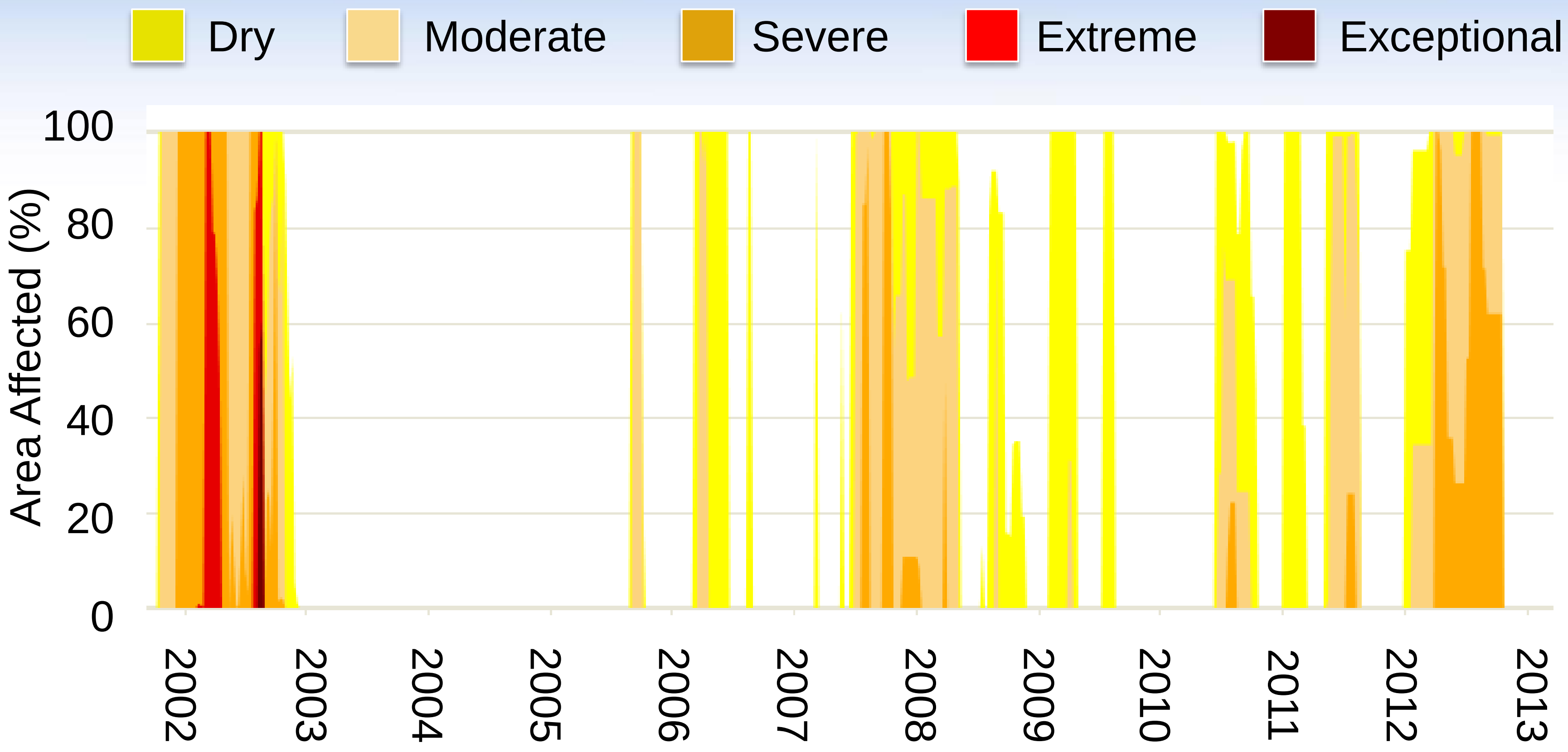


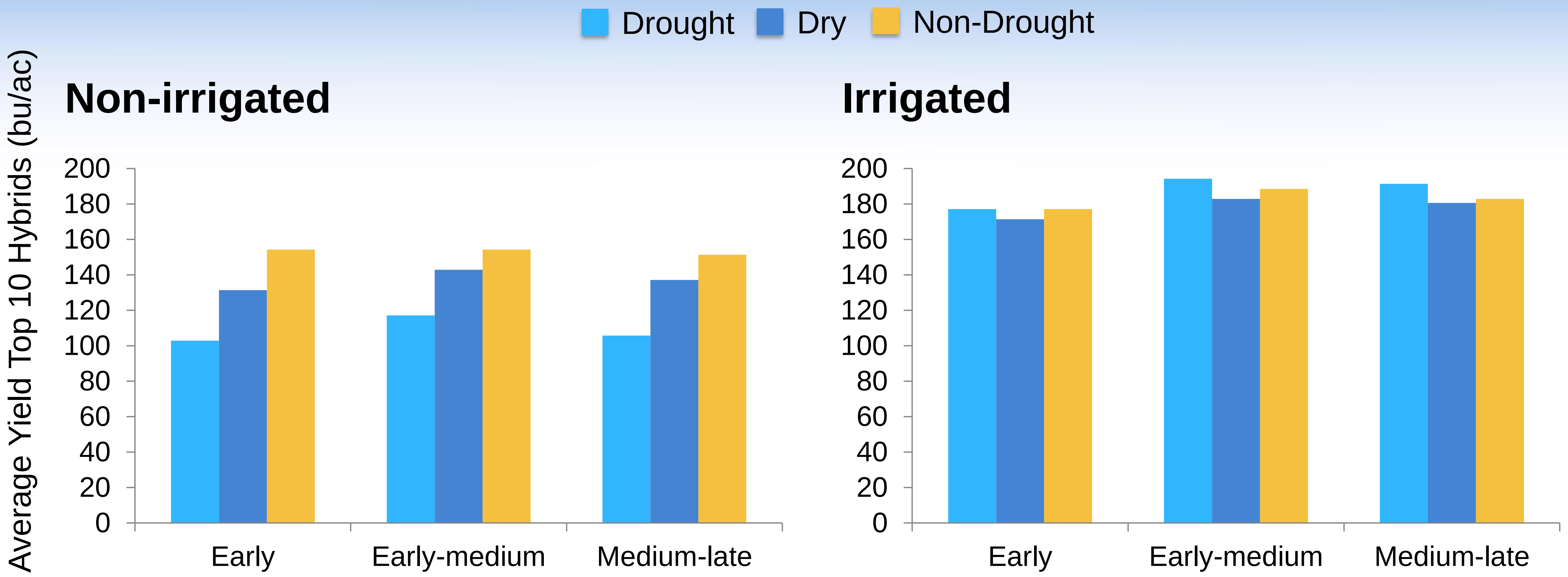
Soil Properties Affect Water Availability for Grain Production

- Agricultural soils tend to be sandy and low in organic matter
- Low moisture holding capacity
- Crops grown in these areas are highly susceptible to drought

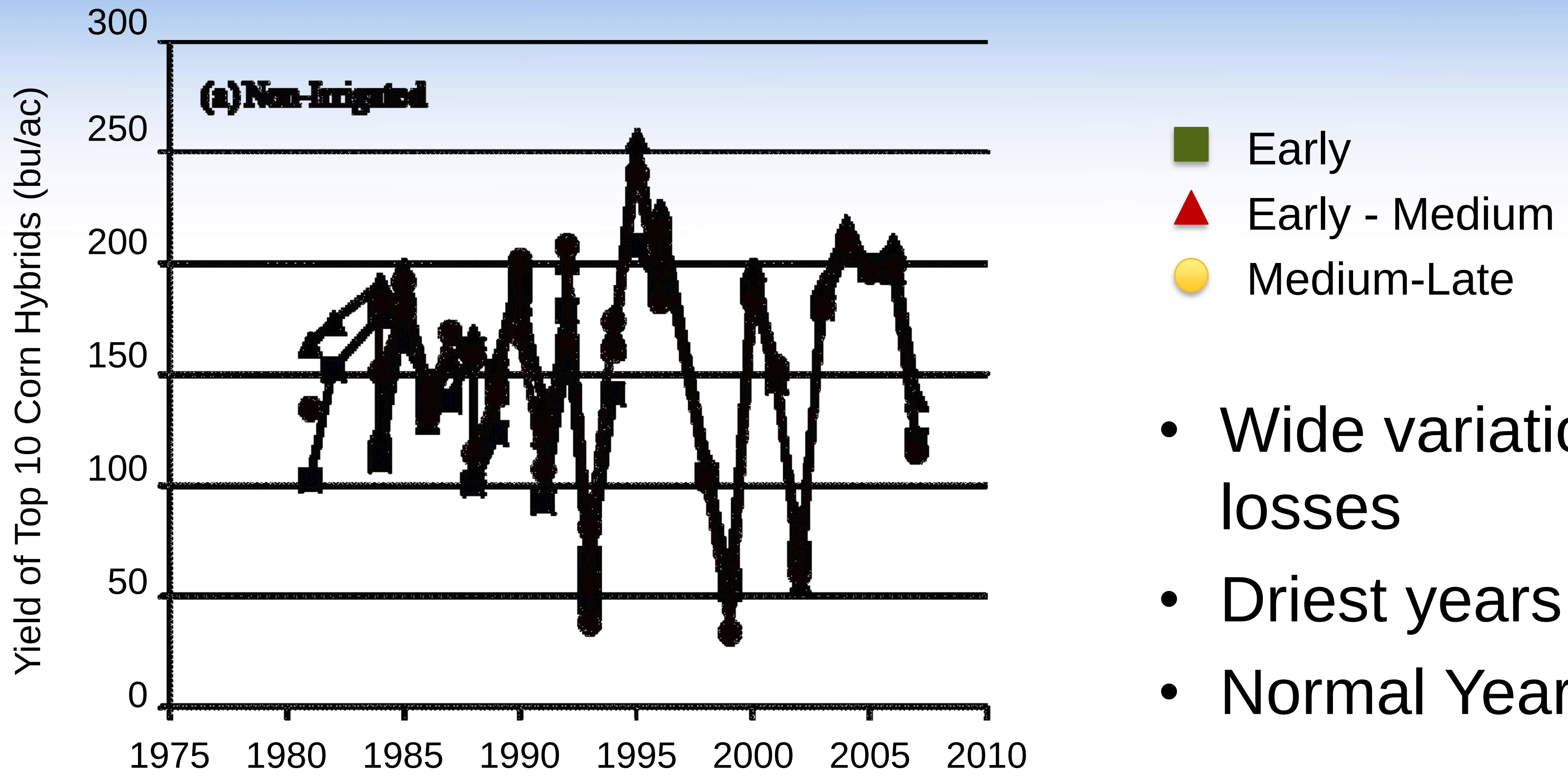
Several Years of Regional Drought



Drought Severity Affects Corn Yields

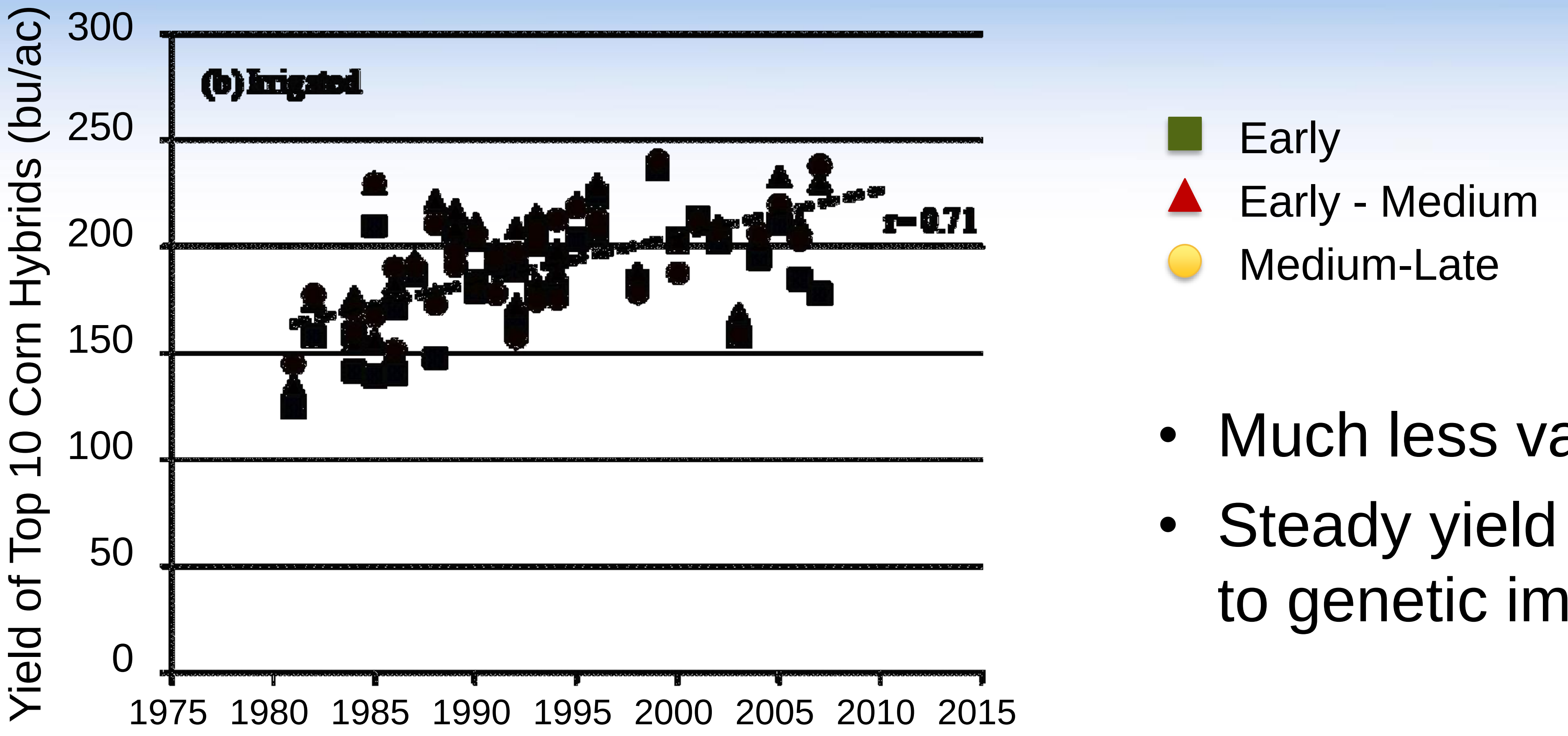


Non-Irrigated Corn Yields Subject to Climate



- Wide variation in yield & losses
- Driest years: 105 bu/ac
- Normal Years: 195 bu/ac

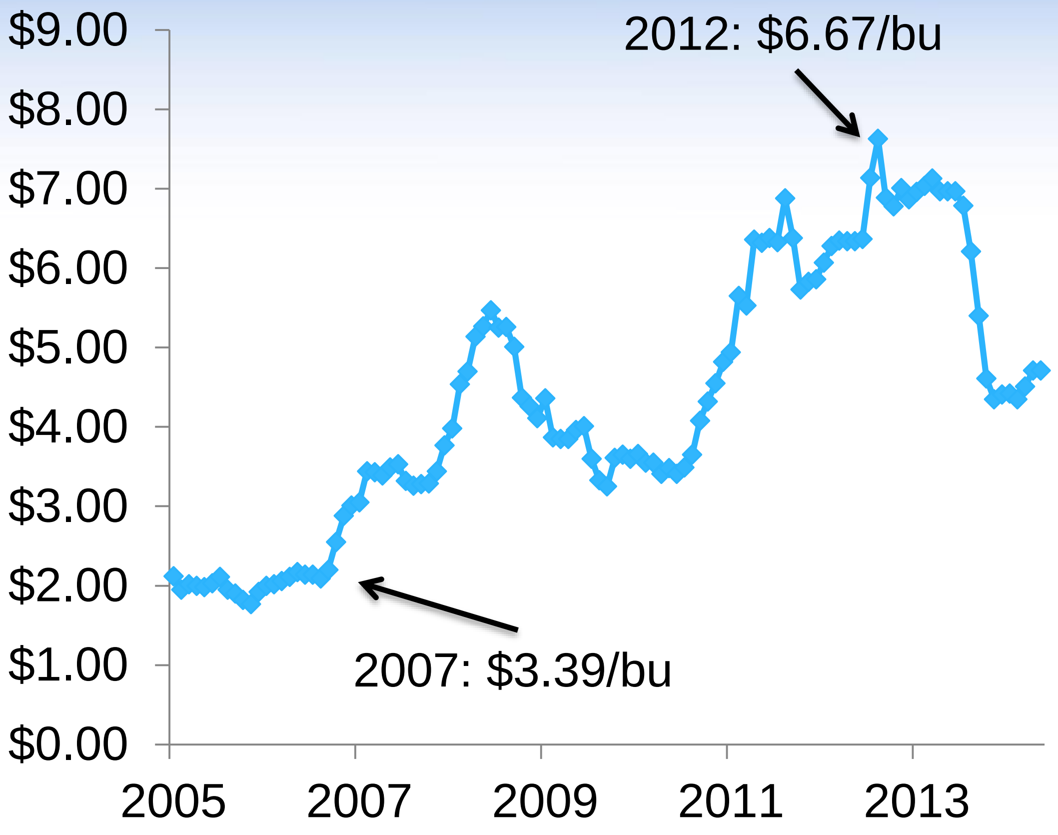
Irrigation Stabilizes Corn Yields



- Much less variation in yield
- Steady yield increase due to genetic improvements

Source: USDA-NASS; Delaware Dept. of Ag

A Surge in U.S. Corn Prices Made Irrigation More Attractive

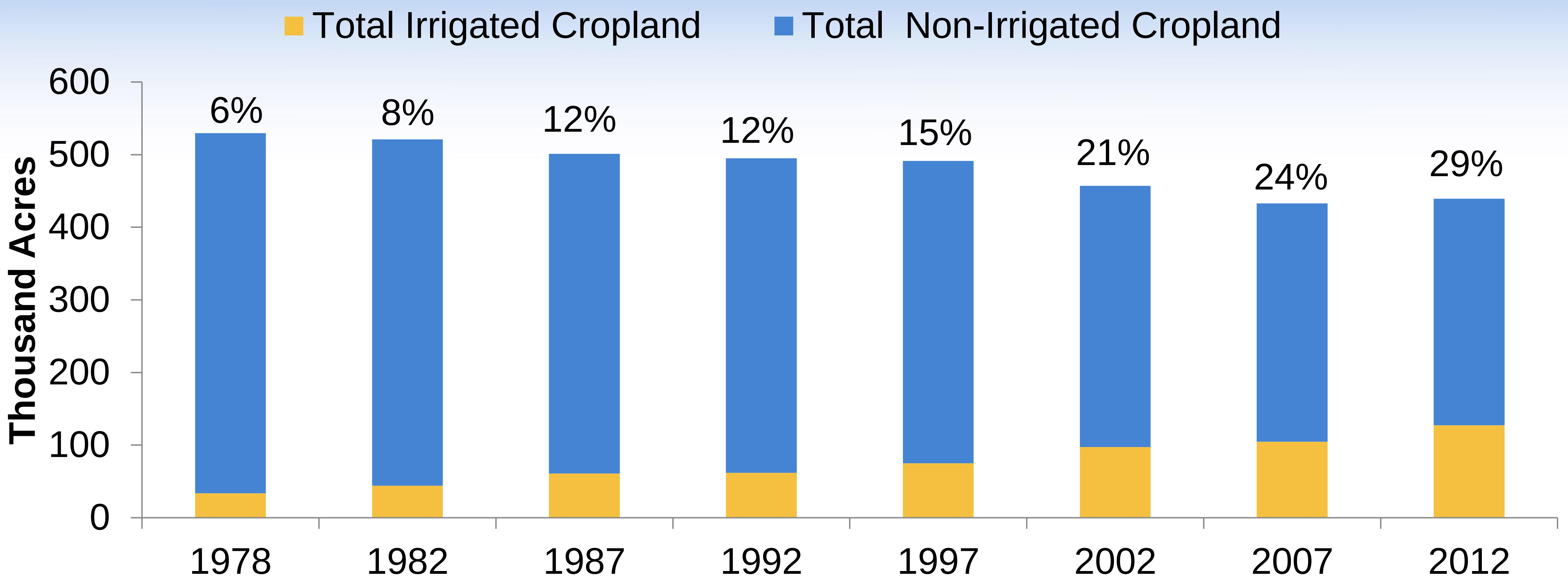


Cropping System		2007	2012
Yield (bu/ac)	Irrigated	164	157
	Non-irrigated	70	59
Price per acre	Irrigated	$556	$966
	Non-irrigated	$237	$363

Rental income (2010)

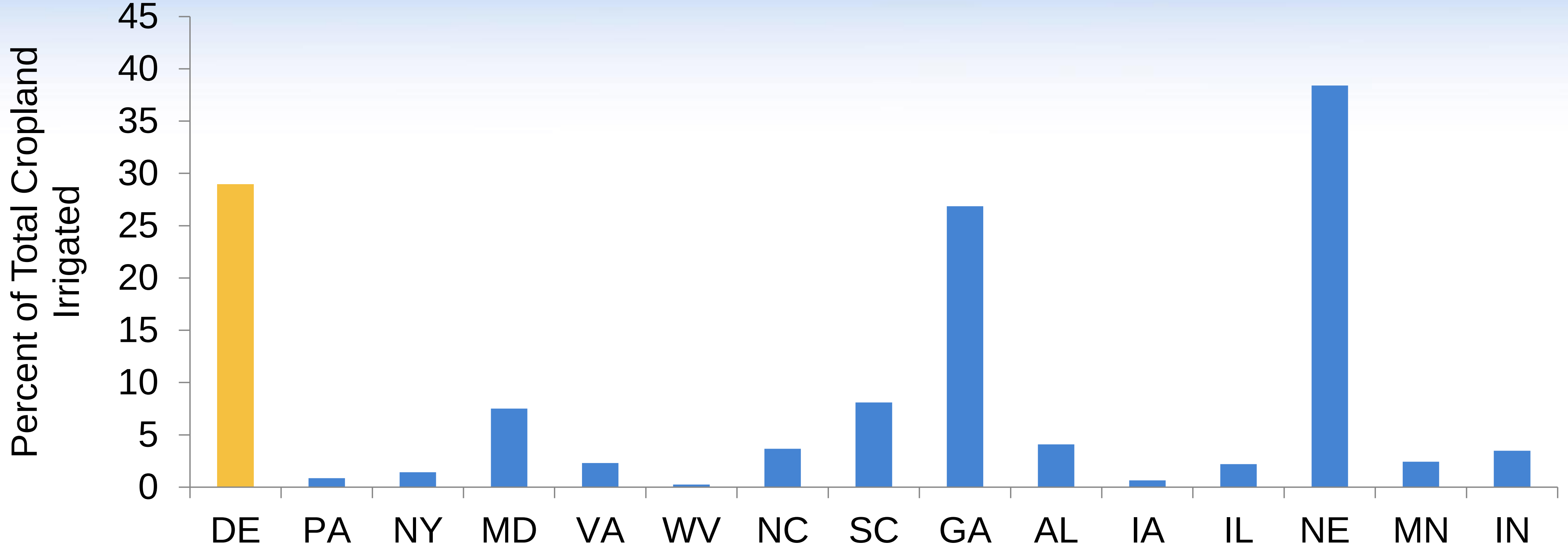
- Irrigated: $105/ac
- Non-irrigated: $69/ac

Delaware Irrigation Trends



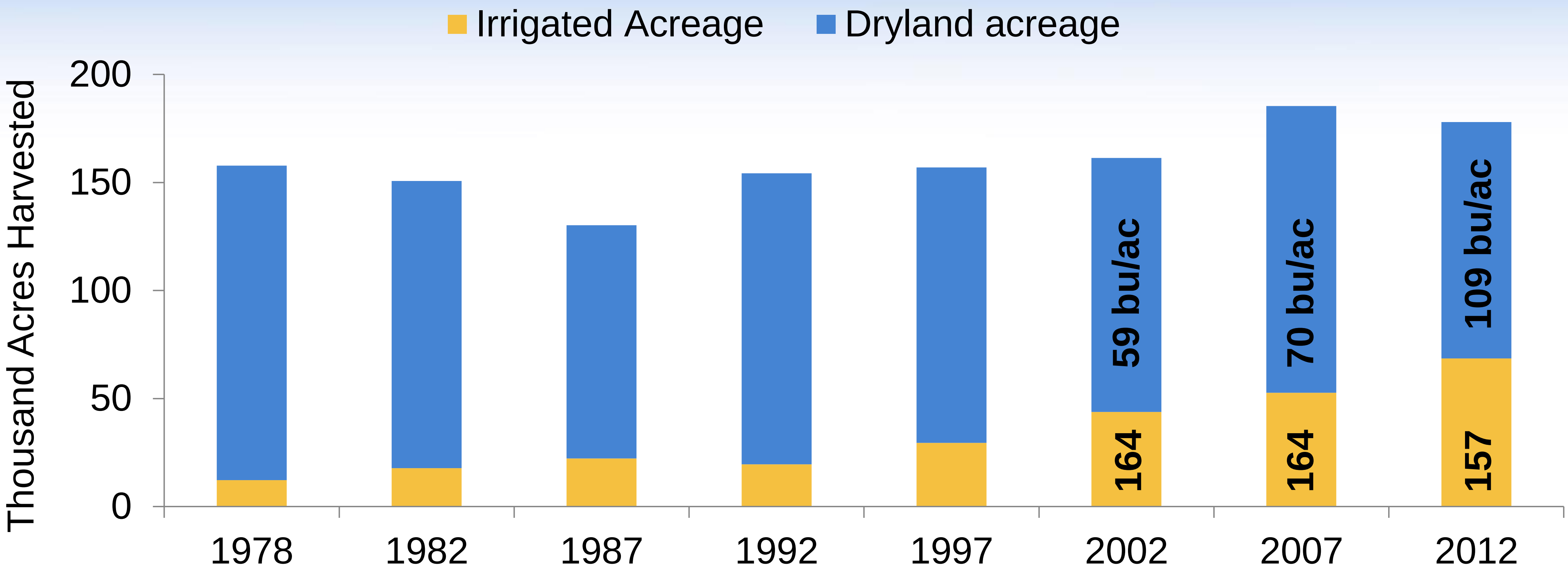
Source: USDA-NASS, 2014

Delaware is a National Leader in Irrigation



Source: USDA-NASS

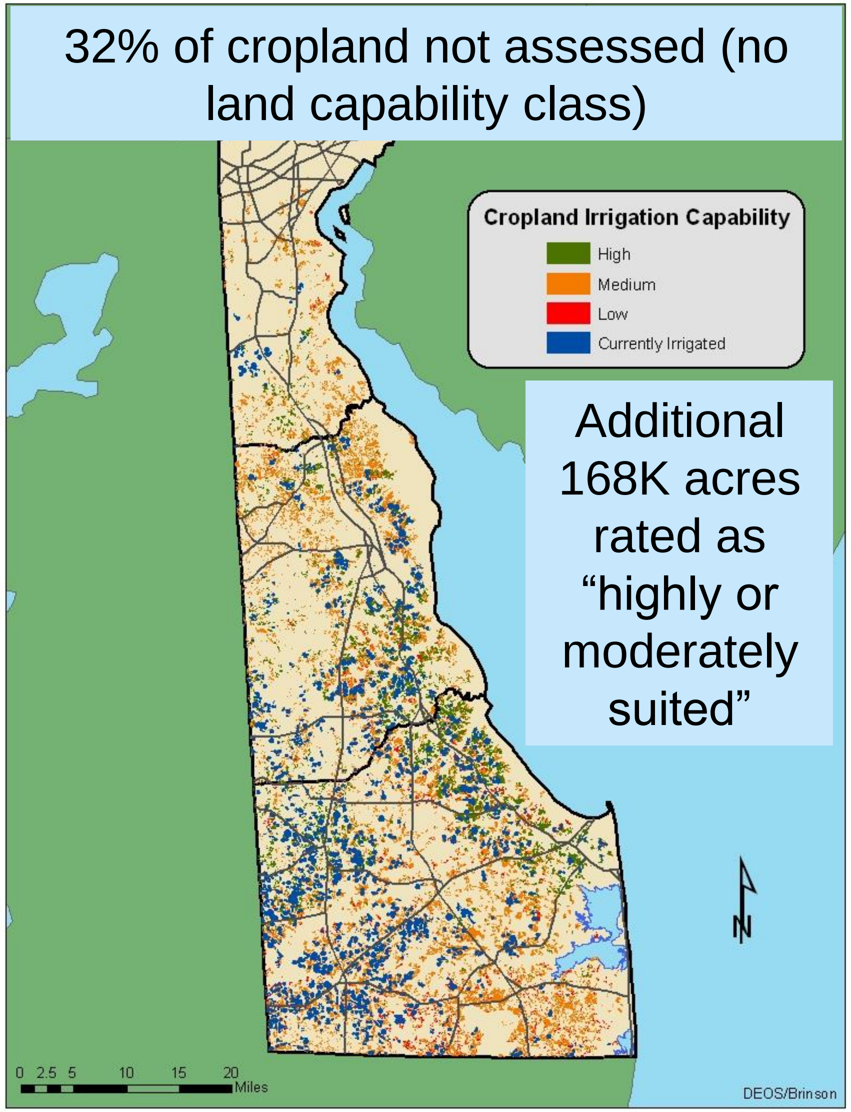
Irrigation of Corn in Delaware



Continued Expansion of Irrigation

Should it be supported to:

- Stabilize yields and reduce crop failure?
- Mitigate climate change?
- Improve nutrient management and water quality?



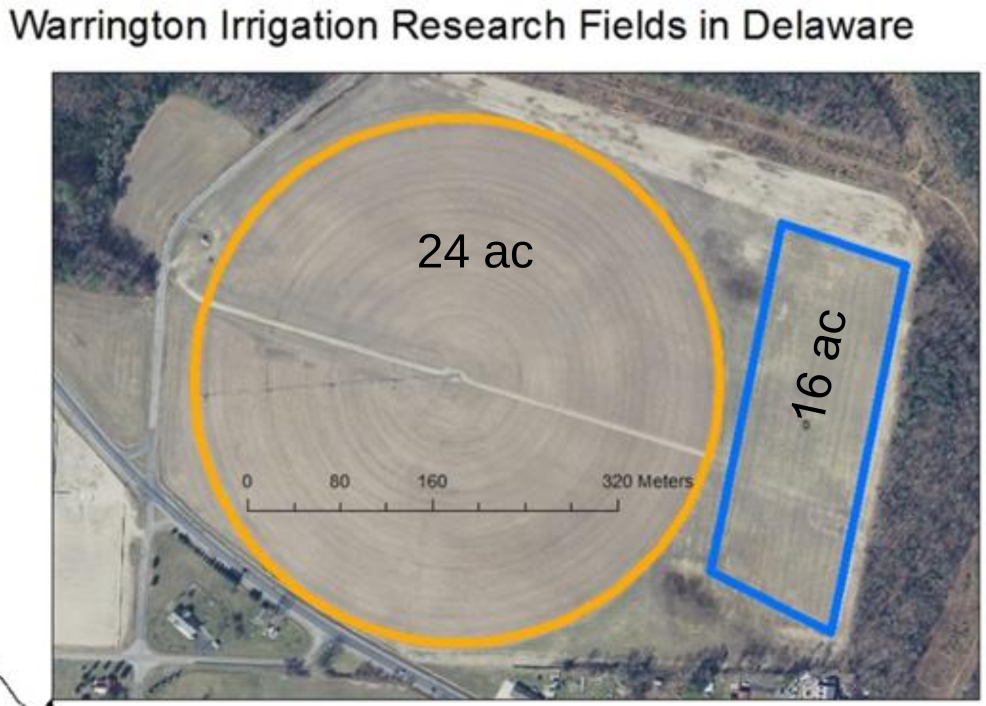
Project Objectives

1. Quantify the effects of 1) irrigation treatments and 2) selected fertilizer strategies on WUE and NUE of corn under center pivot irrigation
2. Compare WUE and NUE of farmer managed corn under irrigated and non-irrigated conditions
3. Evaluate long-term NUE estimates for irrigated and non-irrigated corn in UD Variety Trials

Objective 1

WARRINGTON FARM EXPERIMENTAL DESIGN

UD Irrigation Study Site



Rosedale-Pepperbox loamy sand soils
Organic Matter ≈ 1.3%
Corn, wheat, double-crop soybean or
Corn, soybean rotation

Poultry Litter Applied (3 ton/ac)

Parameter	2014	2015	2016
Total N, lb/ton	54.4	50.8	72.8
Total NH_4-N, lb/ton	9.48	9.10	8.50
Plant Available N, lb/ton	34.6	32.4	45.4
Moisture, %	37.1	39.0	14.1
Dry matter, %	62.9	60.9	85.9

- PAN = 60% of total N + some % of NH_4-N based on when manure incorporated

Manure PAN applied

– 2014: 104 lb/ac

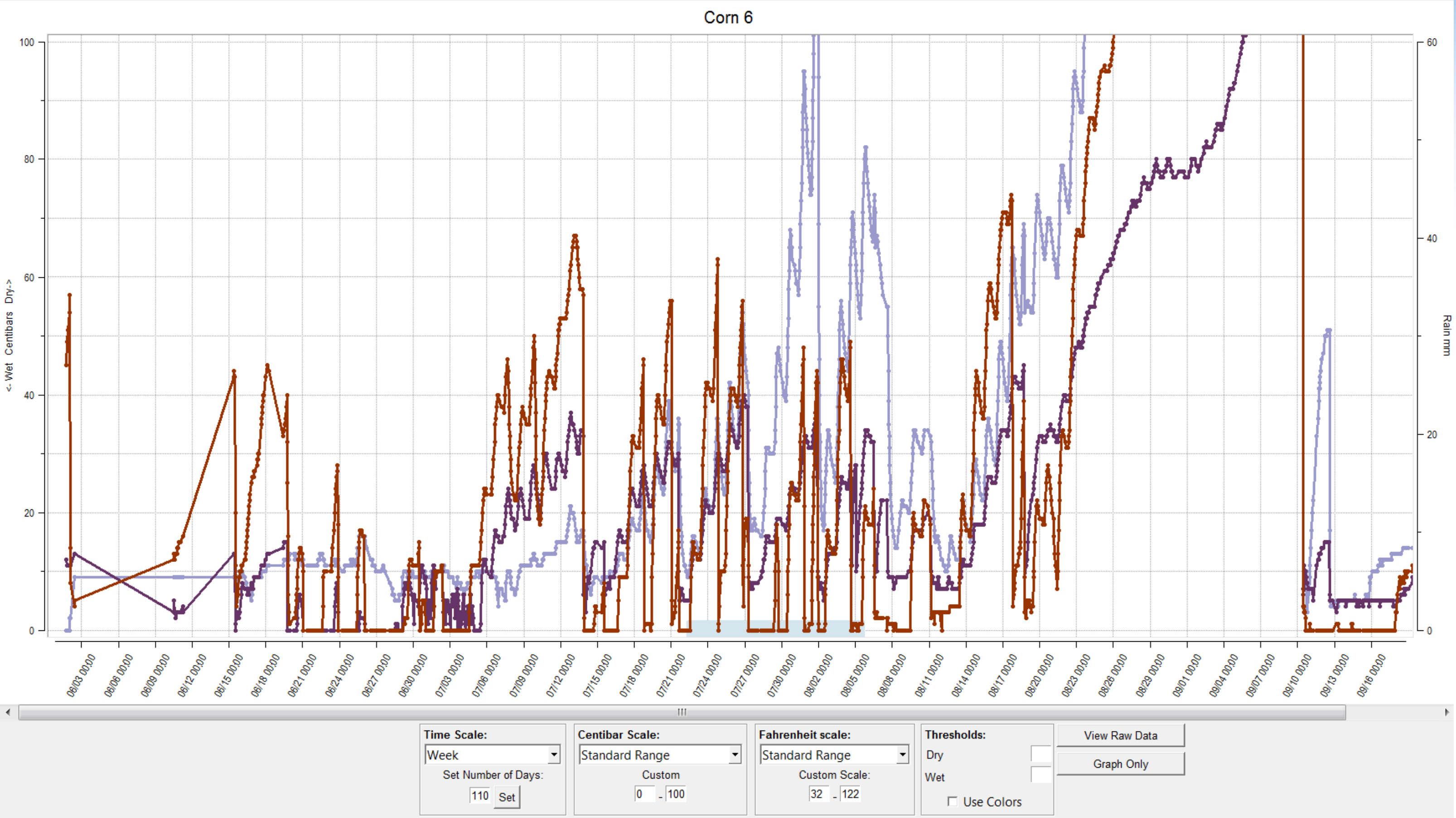
– 2015: 97 lb/ac

– 2016: 136 lb/ac

Center Pivot Irrigation

- Four span system with 85 low drift nozzles
- Precision variable rate irrigation (VRI) controller
- Soil matric potential monitored at 15, 30, and 45 cm

Monitoring Soil Moisture



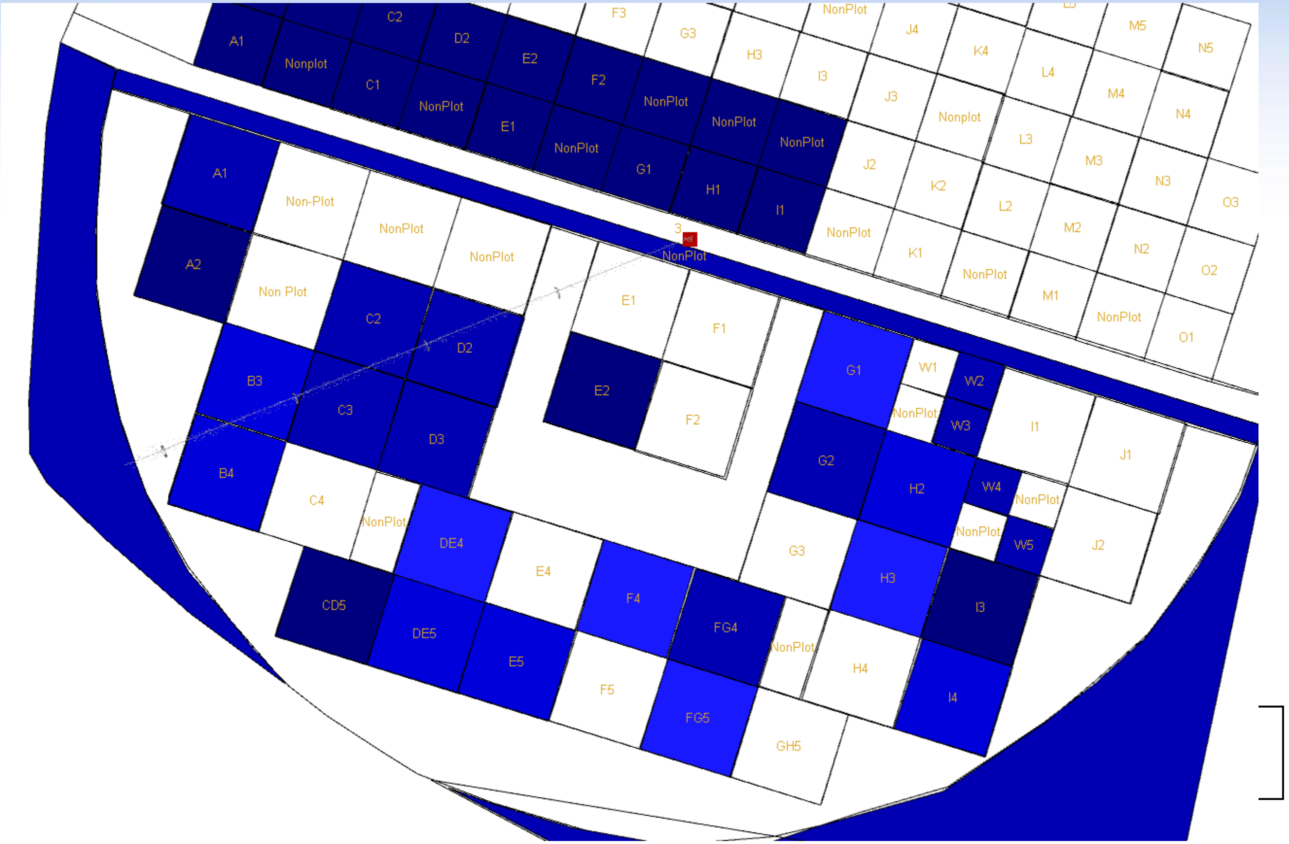
Irrigation Treatments

Treatment #	Treatment	Description
1	20 cbar	Irrigation triggered when soil moisture at 15 cm reaches threshold from emergence to maturity
2	30 cbar	
3	40 cbar	
4	50 cbar	
5	20-40-20 cbar	Irrigation triggered when soil moisture at 15 cm meets threshold from 1) emergence to V16; 2) from V16 to R3; 3) from R3 to maturity
6	40-20-40 cbar	

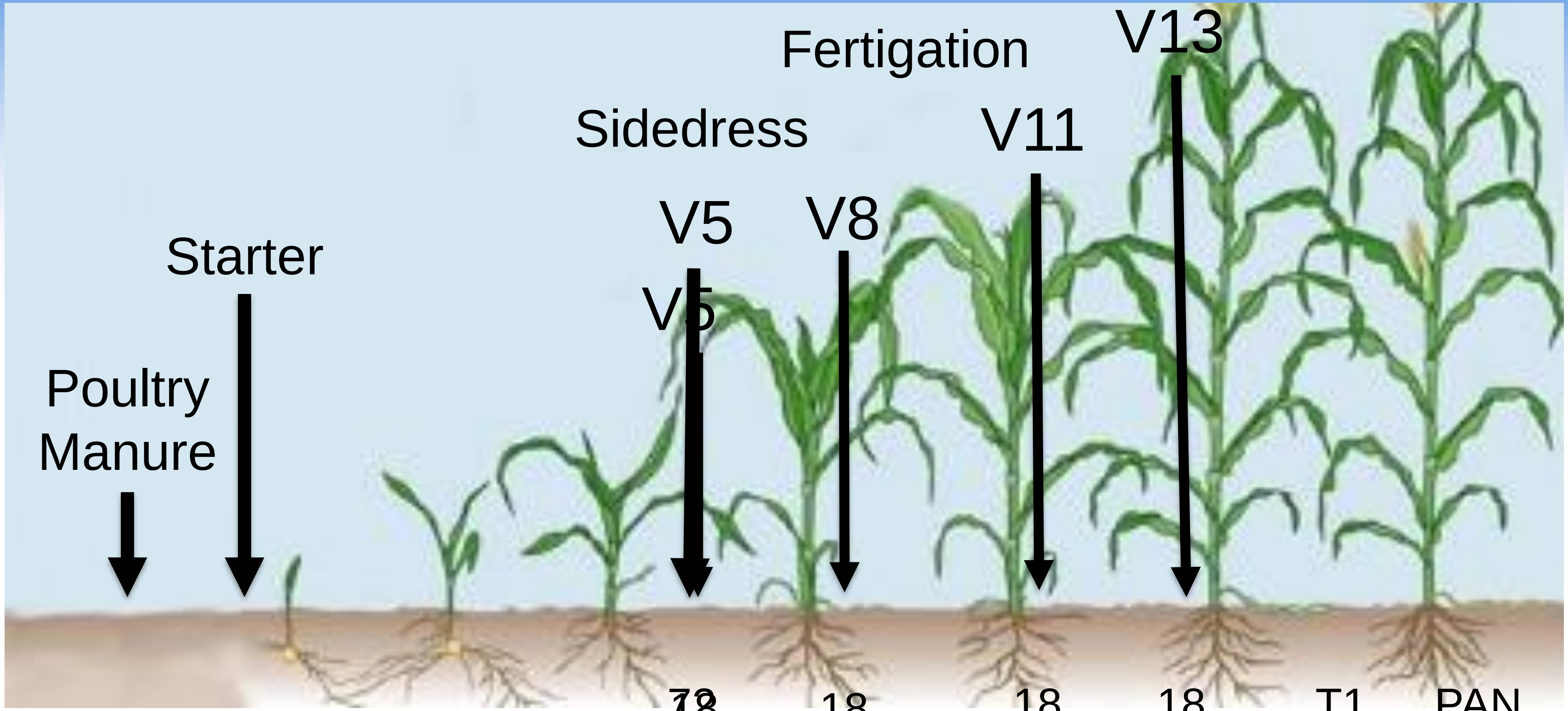
Irrigation Treatments (Continued)

Treatment #	Treatment	Description
7	30 cbar to R5	Irrigation triggered when soil moisture at 15 cm reaches 30 cbar from emergence to GS listed
8	30 cbar to milk	
9	100% ET*	Standard ET, no soil moisture monitoring, irrigation at 50% field capacity
10	80% ET	Apply 80% of the water applied with 100% ET
11	No Irrigation	No water applied

Scheduling Irrigation with VRI



In-Season N Fertilization



		72 18	18	18	18	T1	PAN
varies	36	124 32	32	32	32	T2	Rate
		176 44	44	44	44	T3	lb/ac

Plant Tissue Sampling, Analysis, and Yield

- Three whole plants cut at ground in each plot
- Harvest index = dry grain/dry whole plant
- Total N analysis of grain and tissue
- Yield from center of plot with Harvest Master graingage

Water Use Efficiency

Water Use Efficiency	Irrigation Water Use Efficiency
$\frac{Dry\ Yield}{ET_c}$	$\frac{(Y_{irr} - Y_{dry})}{IRR_i}$

ET_c = crop water use from KanSched 2
Y_{irr} = irrigated yield
Y_{dry} = non-irrigated yield
IRR_i = Irrigation water applied

Nitrogen Use Efficiency

Partial Factor Productivity (PFP_N)

$$\frac{Yield}{Fertilizer}$$

Mass Balance (e_f)

$$\frac{(N_{Crop}) - (N_{soil}) - (N_{other})}{N_{supplied}}$$

$$N_{UA} = (1 - e_f) \times N_{supplied}$$

N_{crop} is N in aboveground biomass N

N_{soil} is estimated using a 7 d anaerobic incubation

N_{atm} based on regional rainfall chemistry and volume

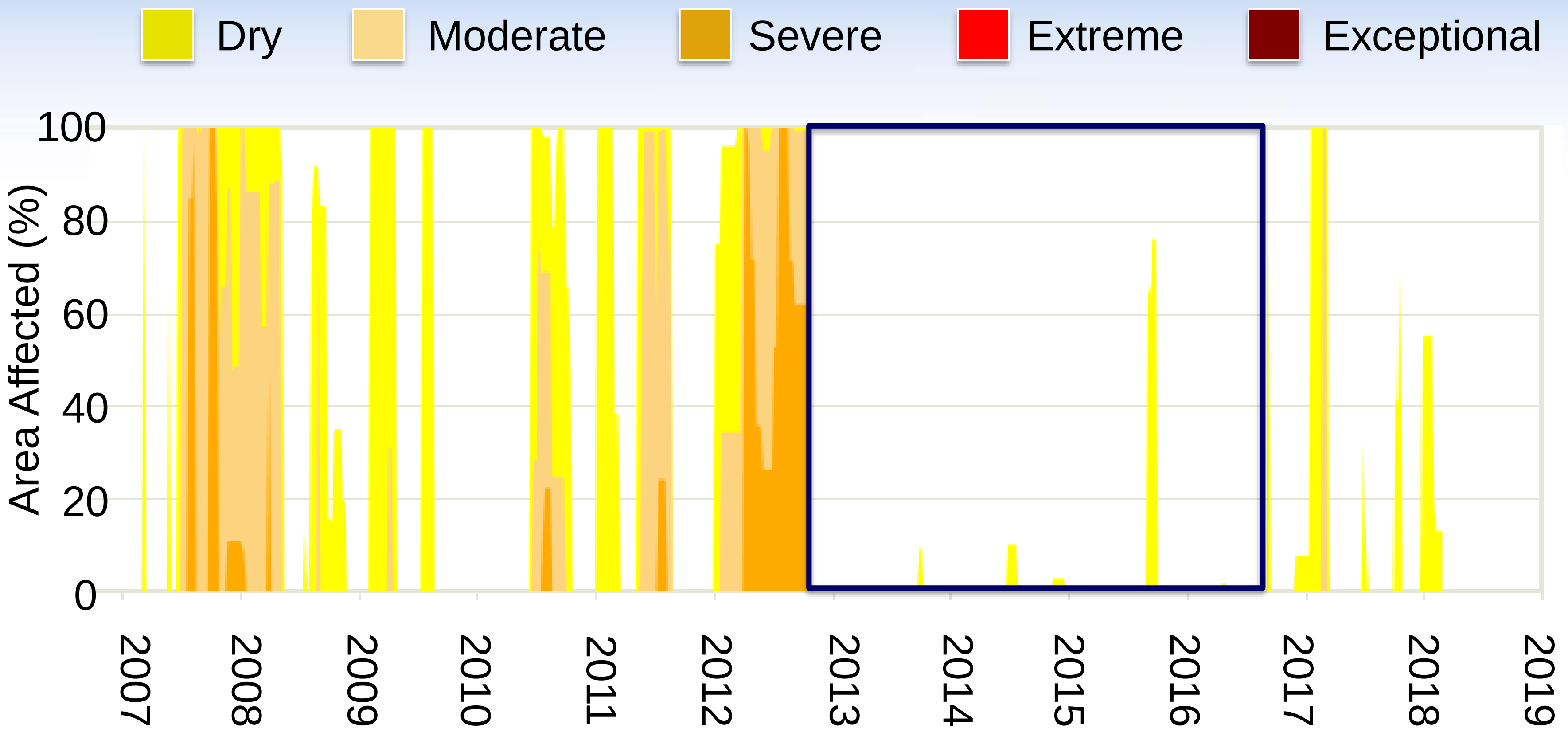
N_{irr} was estimated based on quarterly nutrient content

Collection of Soil Water Samples to Evaluate Leaching Potential

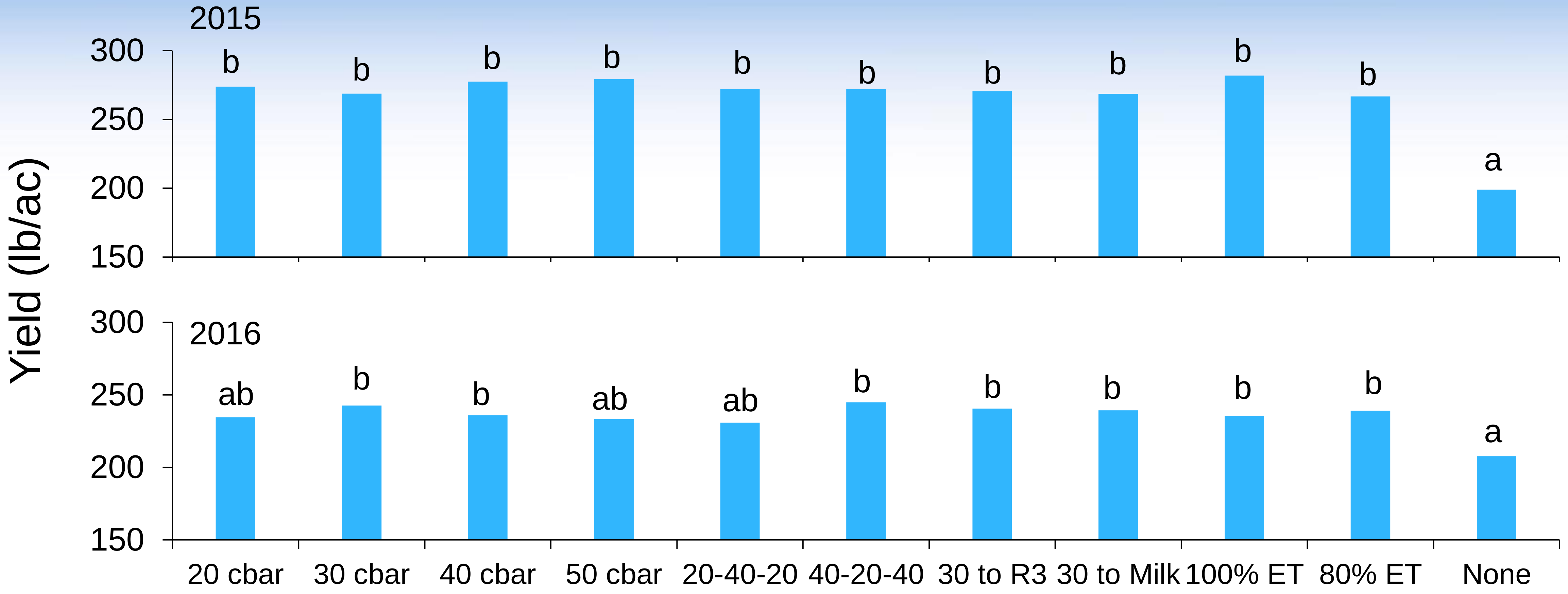
Objective 1

WARRINGTON FARM KEY RESULTS, 2014-2016

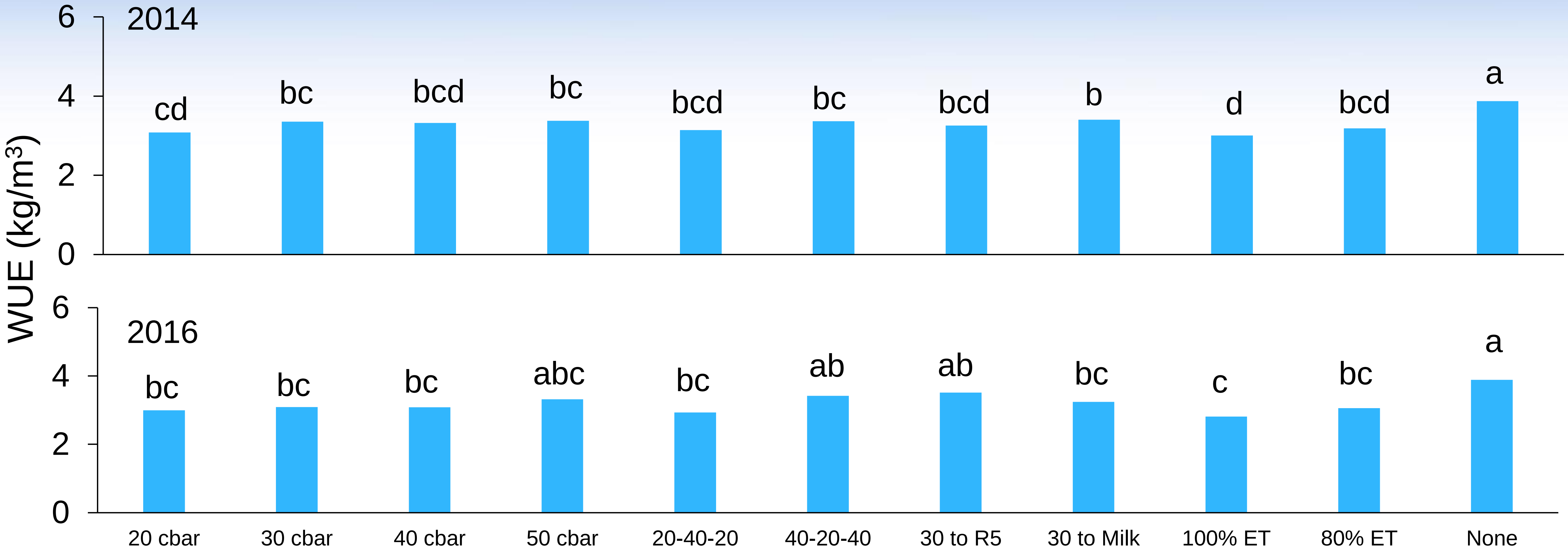
No Drought During Study Period



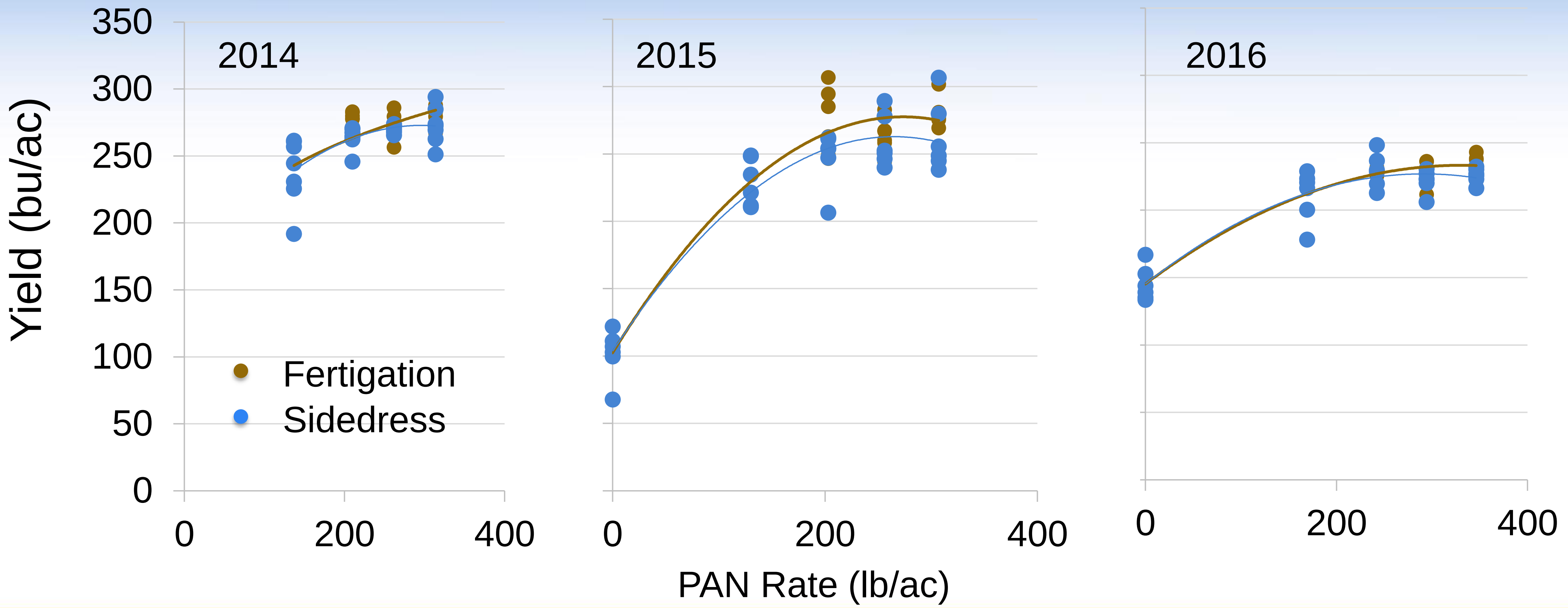
Irrigation Affected Yield in Two of Four Years



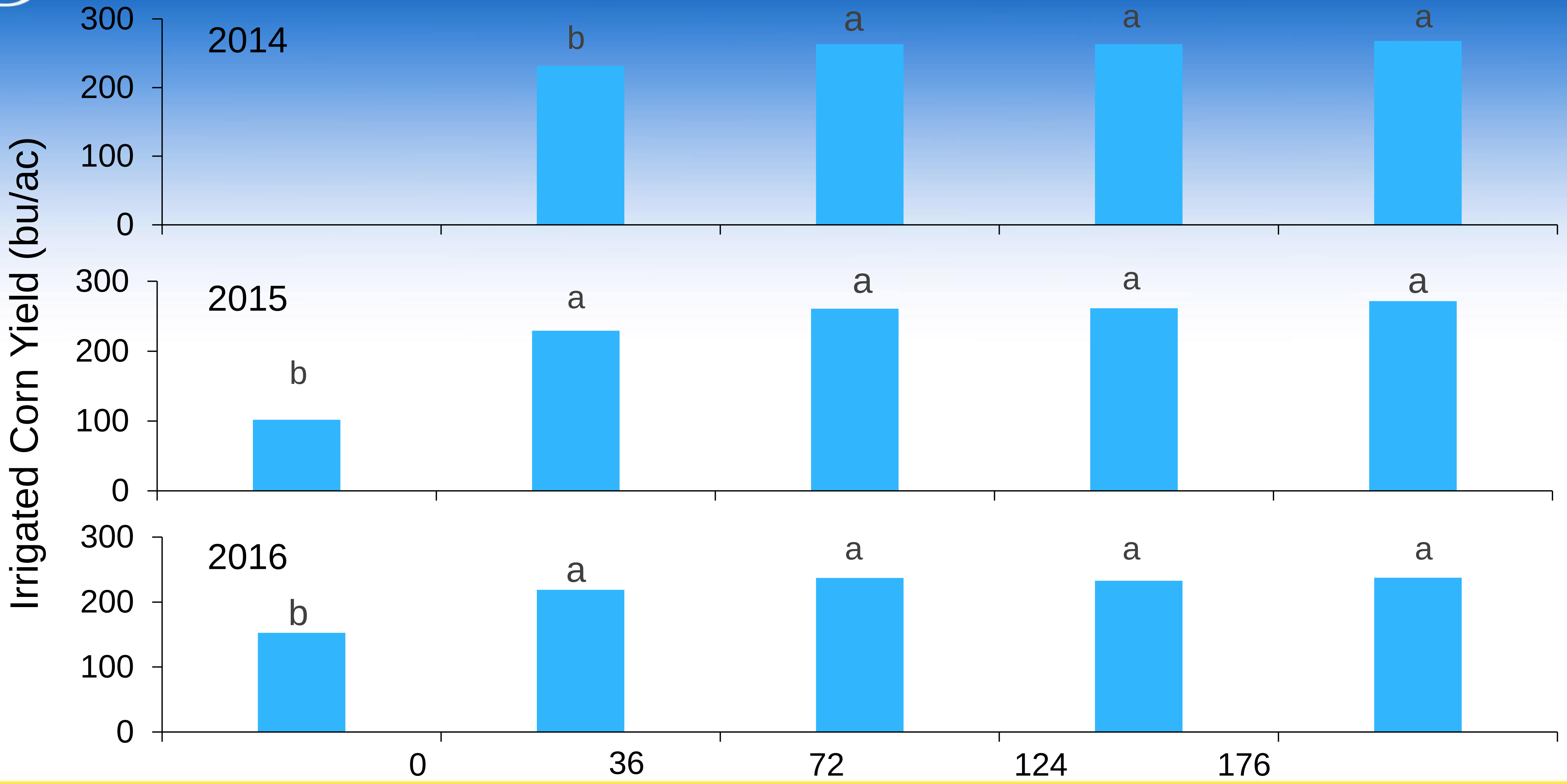
Irrigation Affected WUE in Two of Four Years



Fertilizer Method Did Not Affect Irrigated Corn Yields

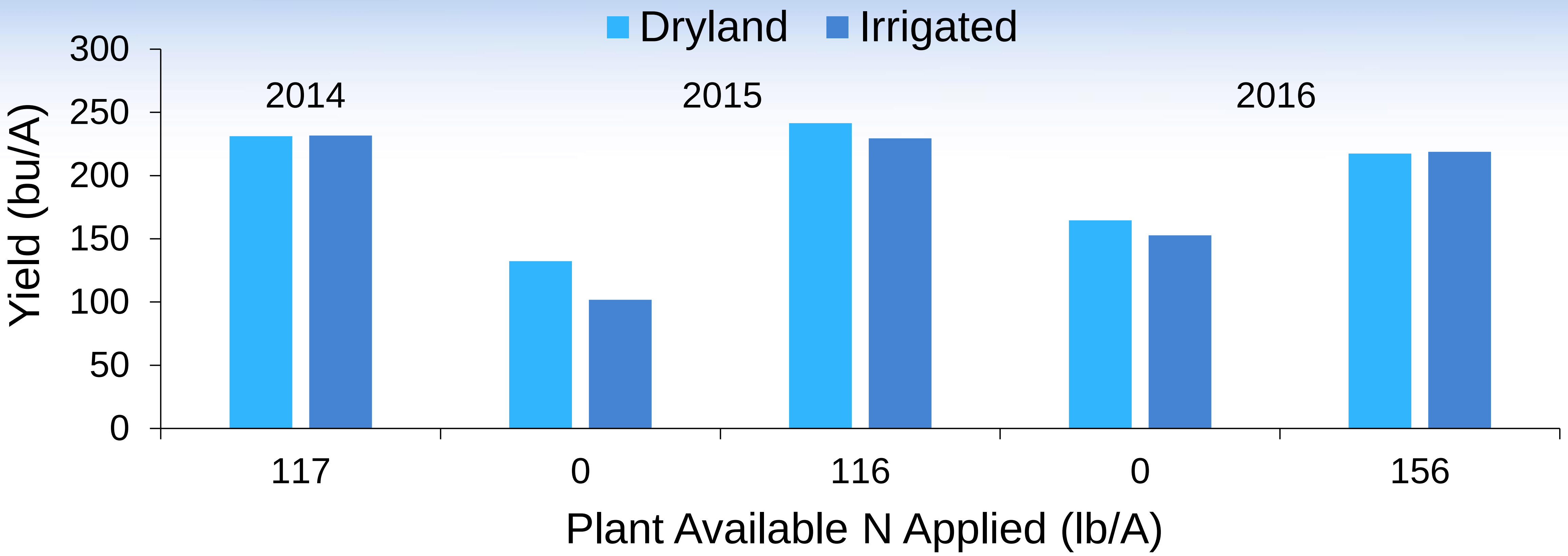


In-Season N Boosts Yield



In-season Plant Available N Applied (lb/A)

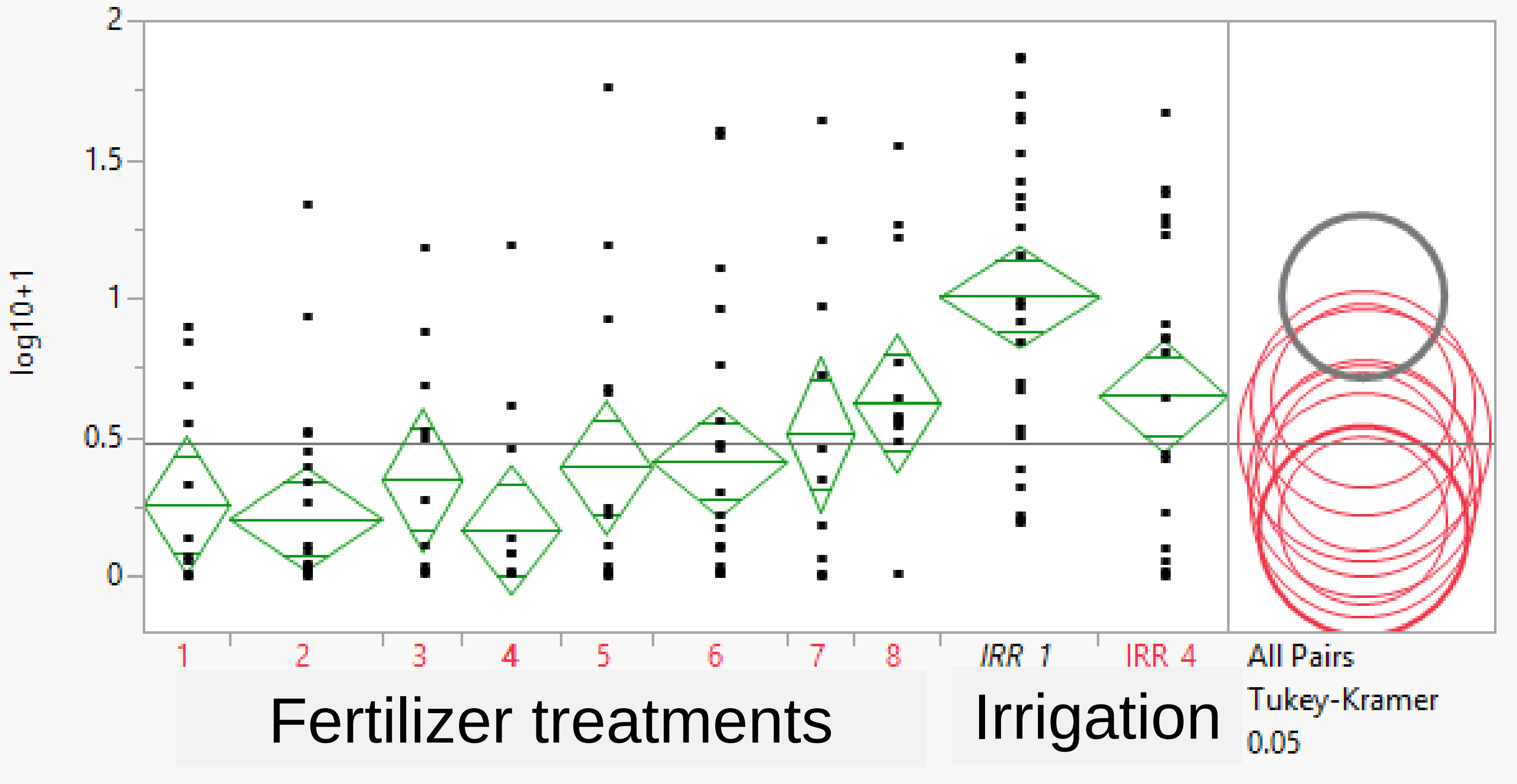
No Yield Bump From Irrigation



Nitrogen Use Efficiency

- In general, PFP_N declined as in-season N rate increased
- Yet, in-season N had no effect on e_f, except in 2014 when low N rate had higher e_f
- UA_N high in-season N > medium > low
- Manure + Starter plots had higher NUE and lower UA_N in all years than plots receiving in-season N

High Irrigation Increased N in Leachate



Objective 2

COMPARISON OF WUE AND NUE ON-FARM

Paired Farmer-Managed Corn Fields 2015

Parameter	Dryland Field	Irrigated Field
Yield Goal, lb/ac	160	245
Poultry litter, ton/ac	2	2
Yield, bu/ac	164	238
PFP_N, lb/bu	1.03	0.97
e_f	0.79	0.61
UA_N, lb/ac	34	95

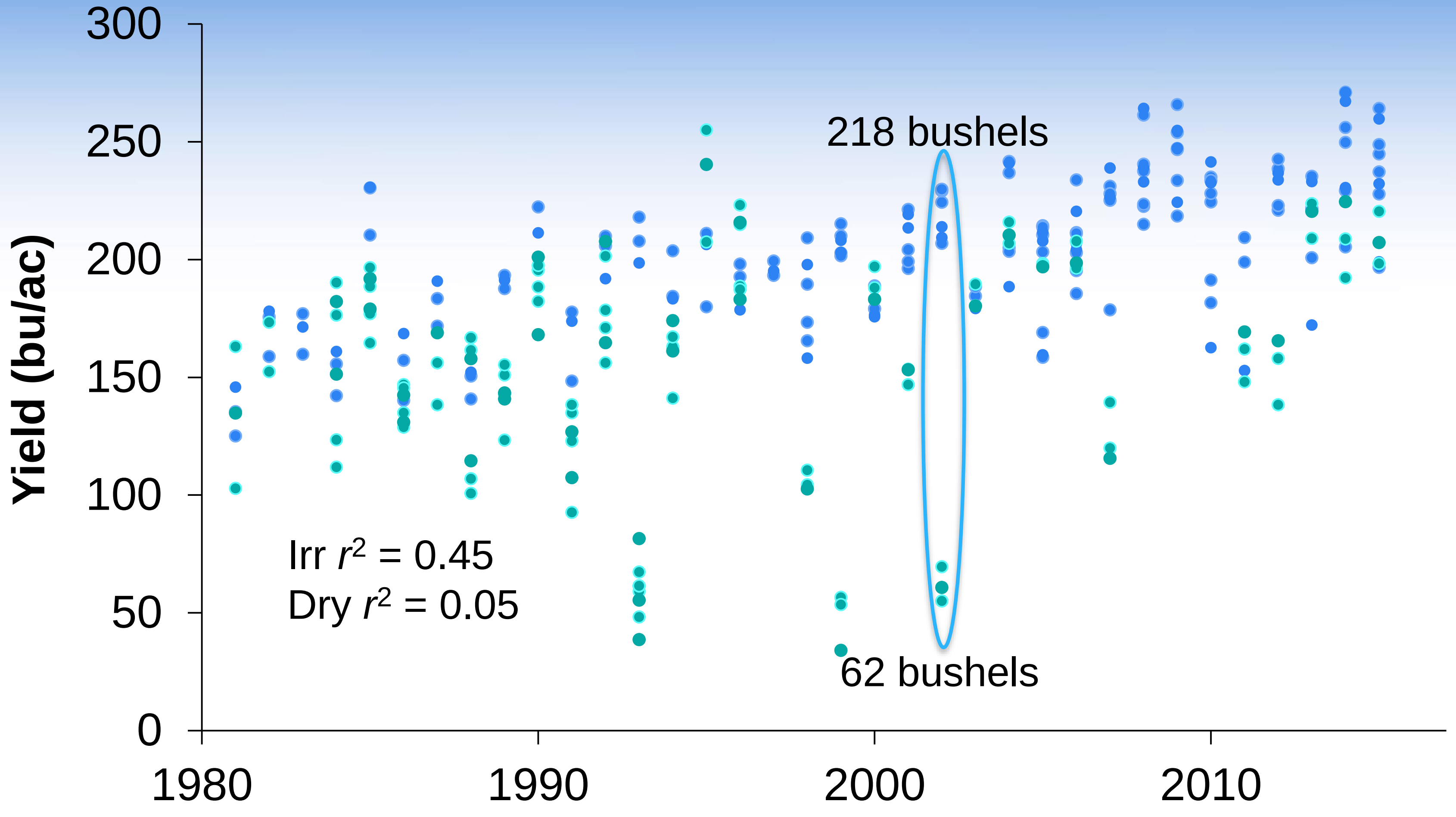
Differences in NUE were due to lower N application rates to the dryland field, significant applications of irrigation water N, and differences in estimated soil N mineralization potential between the two fields.

Objective 3

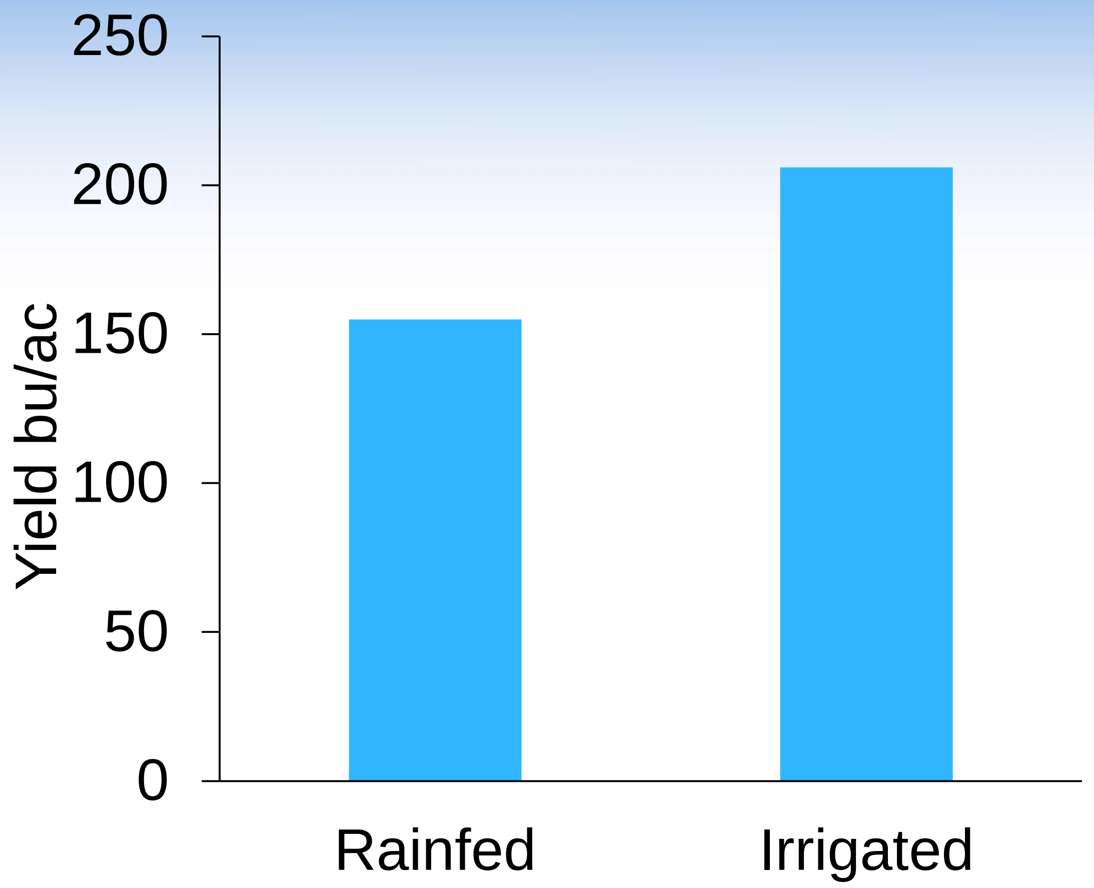
EVALUATE LONG-TERM NUE IN UD VARIETY TRIALS

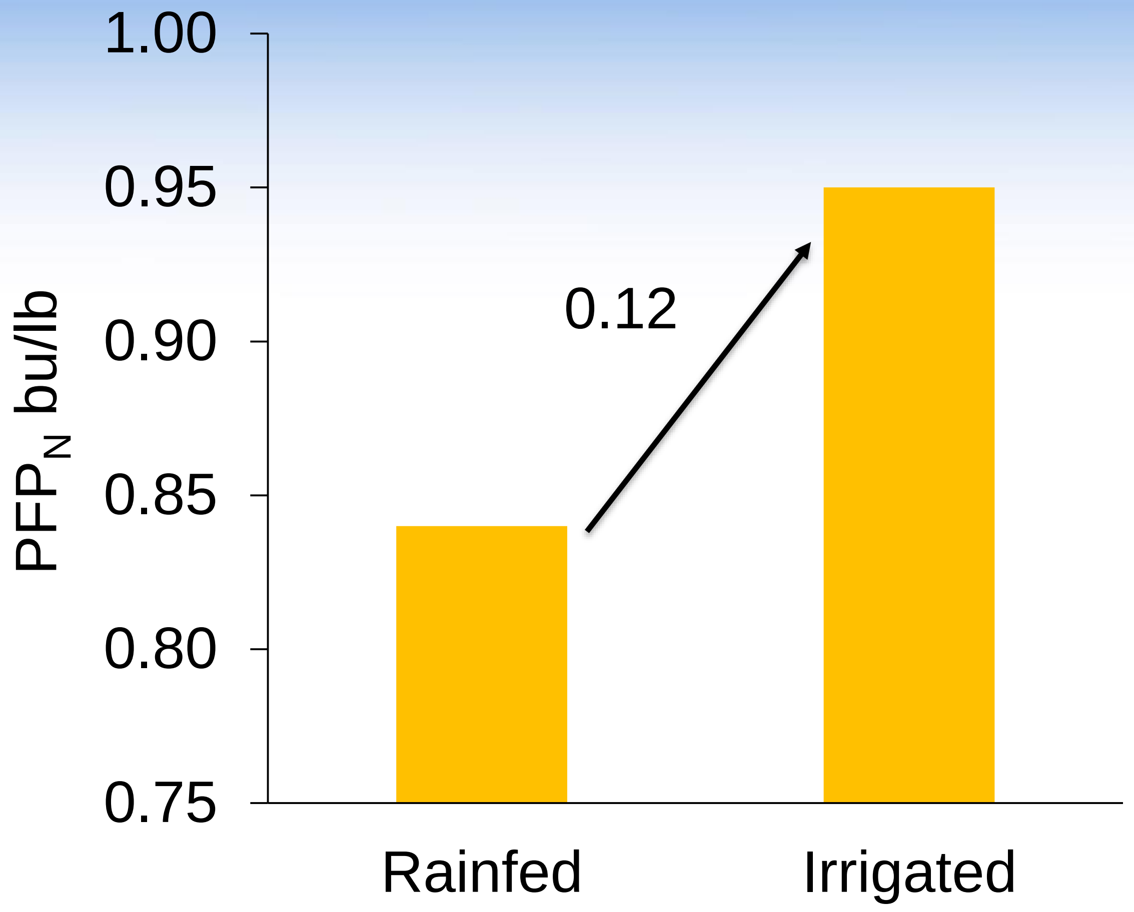
Historical Hybrid Variety Yields

UD Variety Trials

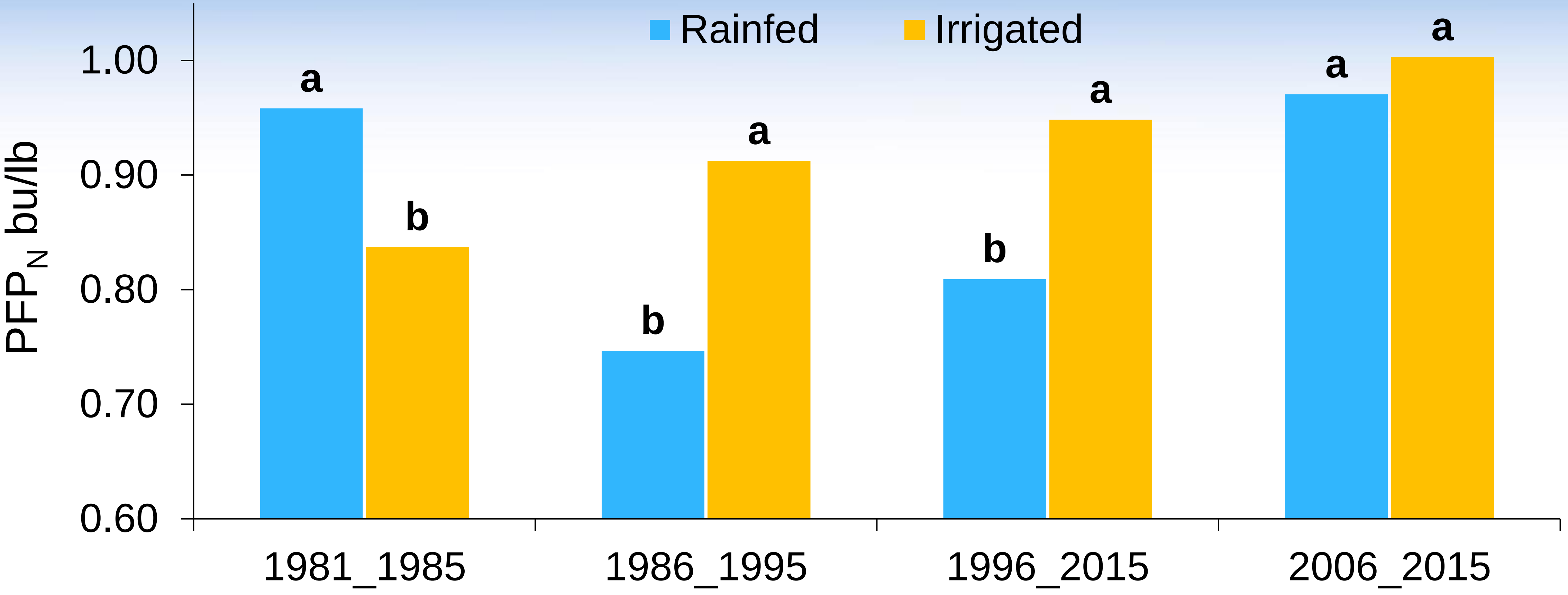


Irrigation Raises Yield and NUE





NUE By Decade – UD Variety Trials



Irrigation Raised NUE in UD Variety Trials

- Irrigation had higher efficiency and yield stability over a 35 year period

- Decade-scale yield summaries were affected by meteorology

- Irrigation has far higher PFPN in dry years

Key Points From Our Work

- When we measured NUE based on fertilizer inputs only (PFPN), we saw generally good efficiencies
- Mass balance approach gave much lower NUE
- It is difficult to accurately estimate ancillary sources of N (e.g. atmospheric, soil, and irrigation)
- The ability to accurately estimate these “other” N inputs is key to increasing NUE

Key Points From Our Work

- Because we received adequate to excessive rainfall, we are not able to make definitive claims about the benefits of irrigation on WUE and NUE
- Historic UD Variety Trial data suggests that irrigation can significantly improve NUE
- We recommend expanding WUE and NUE trials to additional farms, with differing soils and larger scale production.

Key Points From Our Work

- In the future, data should be collected:
  - From paired fields (dryland and irrigated) at each site
  - Over multiple years
  - During periods with intensive rainfall and extended dry periods
- Improvements in NUE with irrigation are expected to be best in drought years

Questions?

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