Is Deficit Irrigation to Conserve Water Sustainable for Commercial Agriculture in the Desert?

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Why This Study?

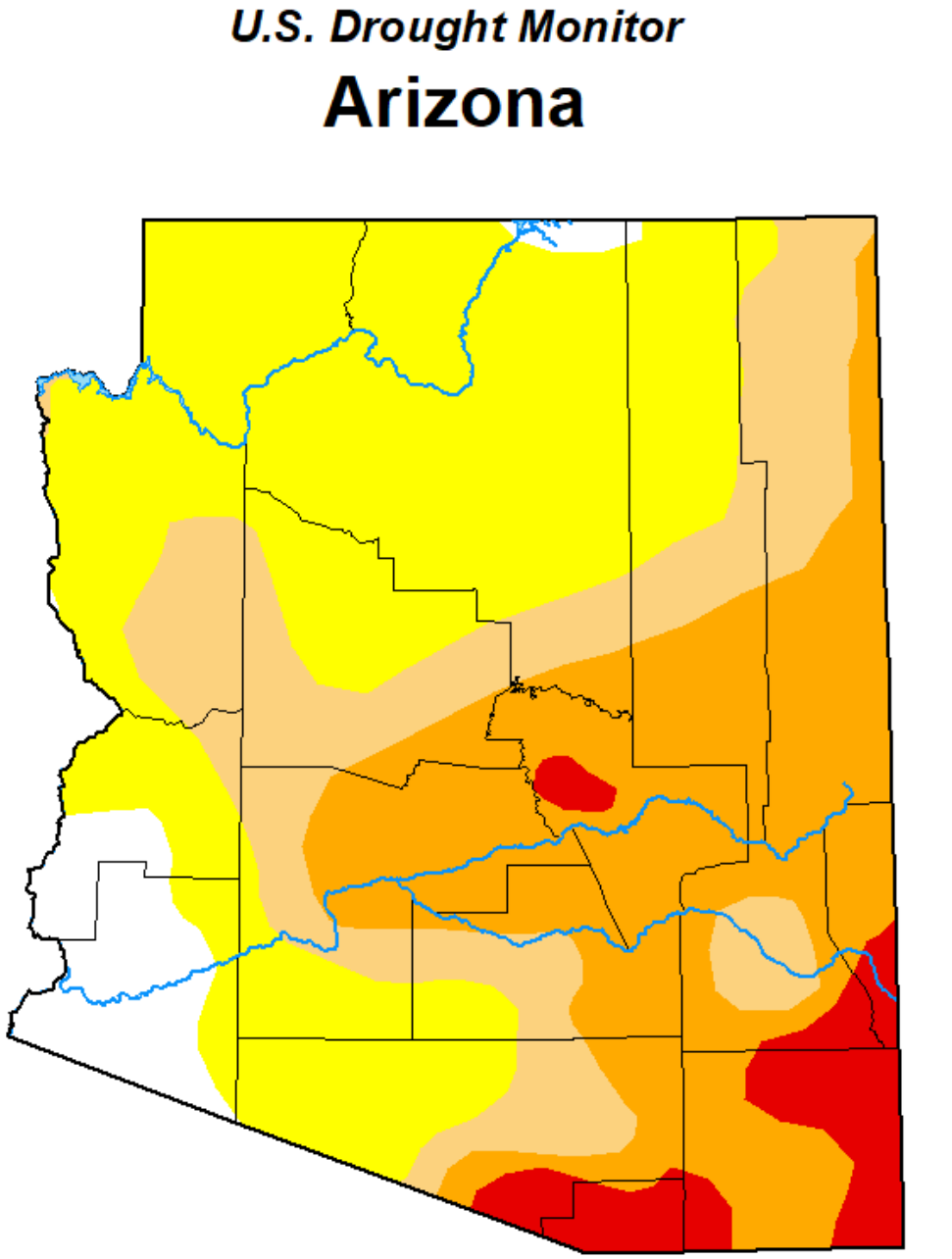
- Deficit irrigation on small grain crops in the US desert SW, knowledge gap
- Small grain crops reported to improve soil health, lack of information
- Improved soil health can facilitate freshwater savings
- Can help inform industry on agronomic management

What is Deficit Irrigation?

- Irrigation water is applied at a lower volume
- Provides growers with the most yield for the least amount of water

The Need for Effective Irrigation Management

- More crop per drop
- Novel irrigation methodology
- Less fallow, more water for other purposes



https://www.azwater.gov/drought/drought-status

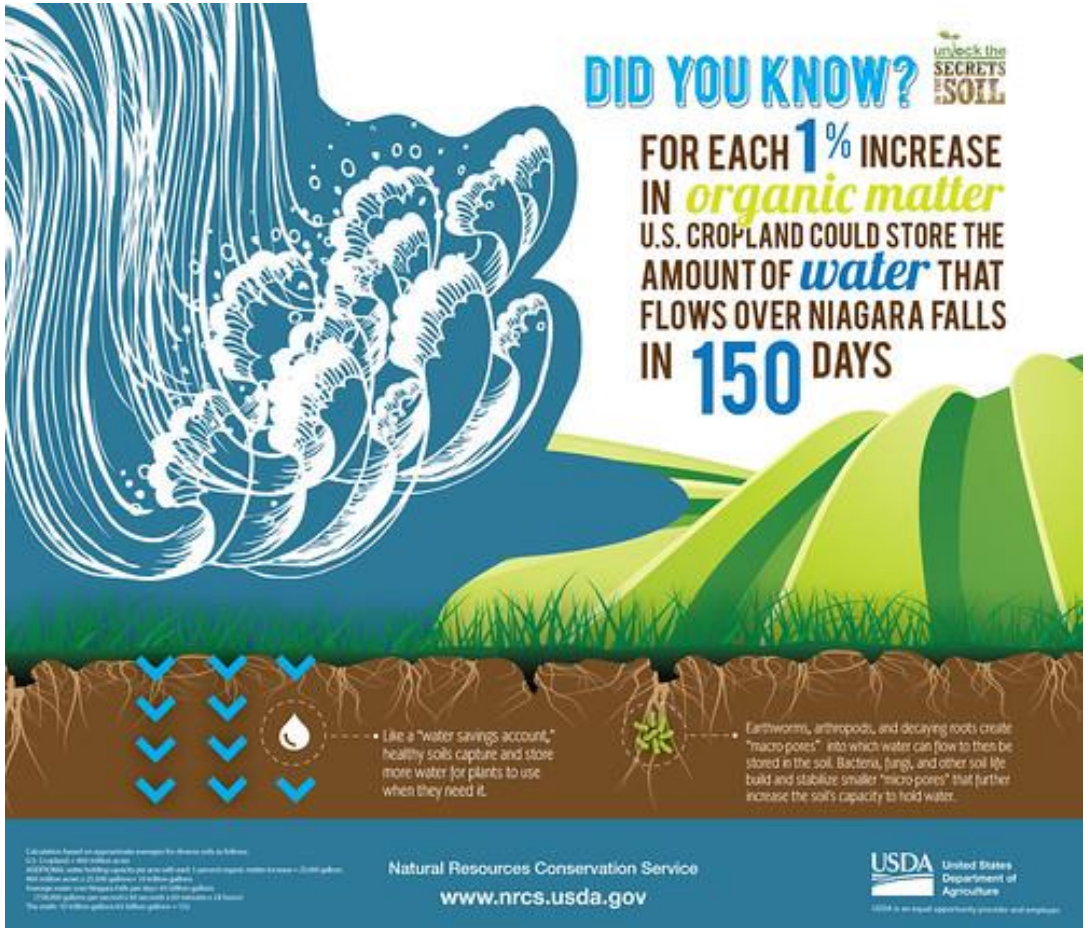
Project Objectives

To compare yield of two major winter small grain crops in Arizona, **barley** and **durum wheat**, under flood irrigation at varied deficits

To generate baseline information on crop performance and soil health parameters under **deficit irrigation** regimes as a climate-smart practice

Soil Health Impacts Water Savings

- More organic matter in the soil, more water holding capacity
- More water retained, less water wasted



https://www.usda.gov/media/blog/2015/05/12/hedge-against-drought-why-healthy-soil-water-bank

Small Grains May Improve Soil Health

- More carbon input
- Fibrous roots: soil aggregation
- Better ground cover
- Easily established, fast growth
- More stress tolerance

Experiment Location

- University of Arizona Maricopa Agricultural Center (MAC)
- Spring of 2023
- Delayed planting, on 14th February due to wet winter season

Methodology

Utilized 2-acre plot following a randomized complete block design

Conducted a randomized replicated research trial

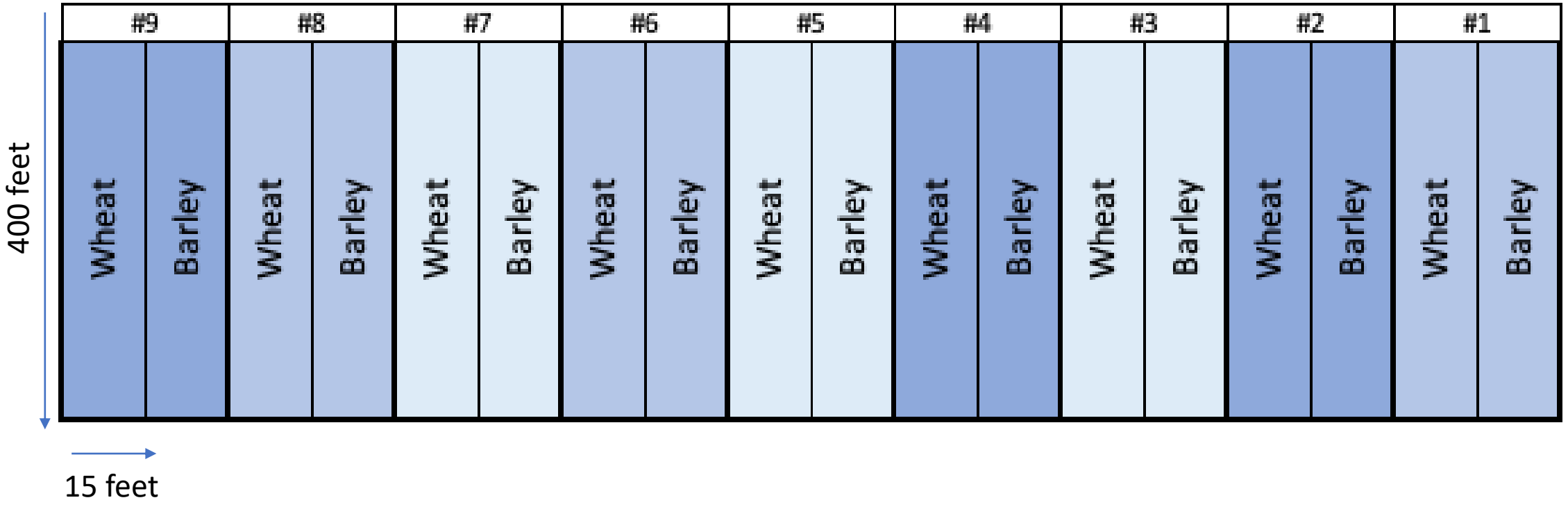
Implemented 2 levels of deficit irrigation, 12.5% and 25% deficits were applied

Methodology– Crop Planting

- Planted barley (Baretta) & durum wheat (Tiburon) at rates of 150 lbs./acre and 170 lbs./acre, respectively
- Pesticides and herbicides were sprayed as needed

Plot Layout

Map of the wheat and barley plots grown at Maricopa Agricultural Center (MAC).



Deficit Irrigation Regimes

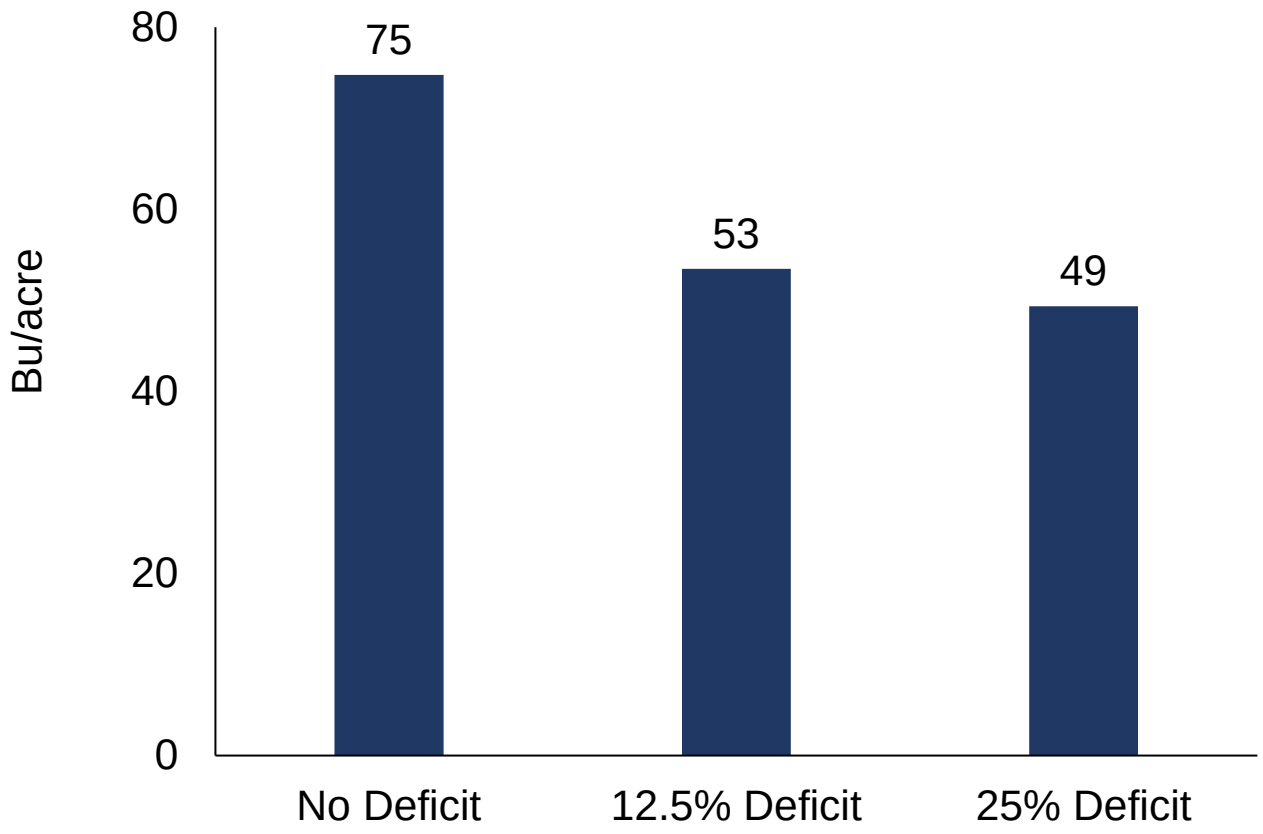
- Total of 8 irrigations to control plots; 7 and 6 irrigations were applied to deficit regimes
- Deficit was applied by skipping a flood irrigation event, though the irrigation strategy was otherwise similar
- Control crops received 107 cm (3.5 acre-feet) of water during the growing season

Fertilizer Application

- Initial soil test N content was 28 lbs./a
- Total of 200 lbs./a of N was applied to the experimental plots
- Applied as Urea Ammonium Nitrate (32-0-0) over four applications:
  - 75 lbs./a at planting
  - 50 lbs./a on 4 April and 26 April
  - 25 lbs./a on 19 May
- Applied through irrigation (fertigation)

Crop Harvest and Tissue Sampling

- Harvested on June 22, 2023
- 5 random microplots harvested inside each treatment plot
- Microplot dimensions: 1 m x 1 m
- Plant samples collected at physiological maturity; sent to a commercial lab for nutritional analyses



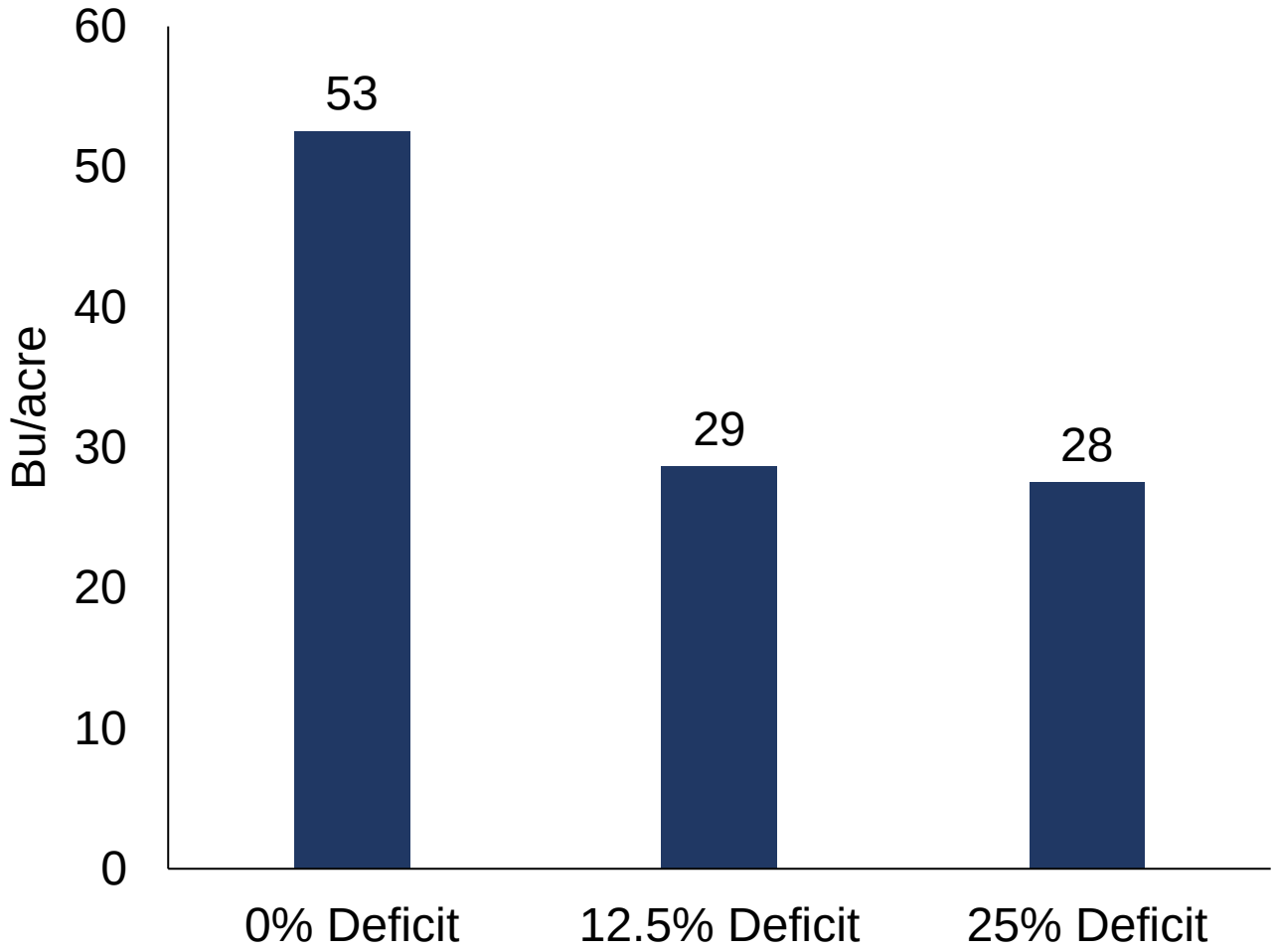
Durum wheat yields (Bu/acre) under deficit flood irrigation regimes

Results: Wheat Yield

- The highest durum grain yield in our experimental plots was 85 Bu/a (Wheat Bushel = 60 lbs.)
- 30% decline in grain yield for durum wheat under 12.5% deficit

Results: Barley Yield

- Our average yield was 53 Bu/a. (Barley Bushel = 48 lbs.)
- The highest barley grain yield we recorded in our experimental plots was 64 Bu/a
- 45% decline in grain yield for barley under 12.5% deficit



Barley grain yields (Bu/acre) under deficit flood irrigation regimes

Results: Wheat and Barley Grain Quality

- No significant difference in grain protein content
- The protein content was 18% (control), 19% (12.5% deficit), 19% (25% deficit) for durum wheat
- The grain protein content was 15% (control), 17% (12.5% deficit), 16% (20% deficit) for barley

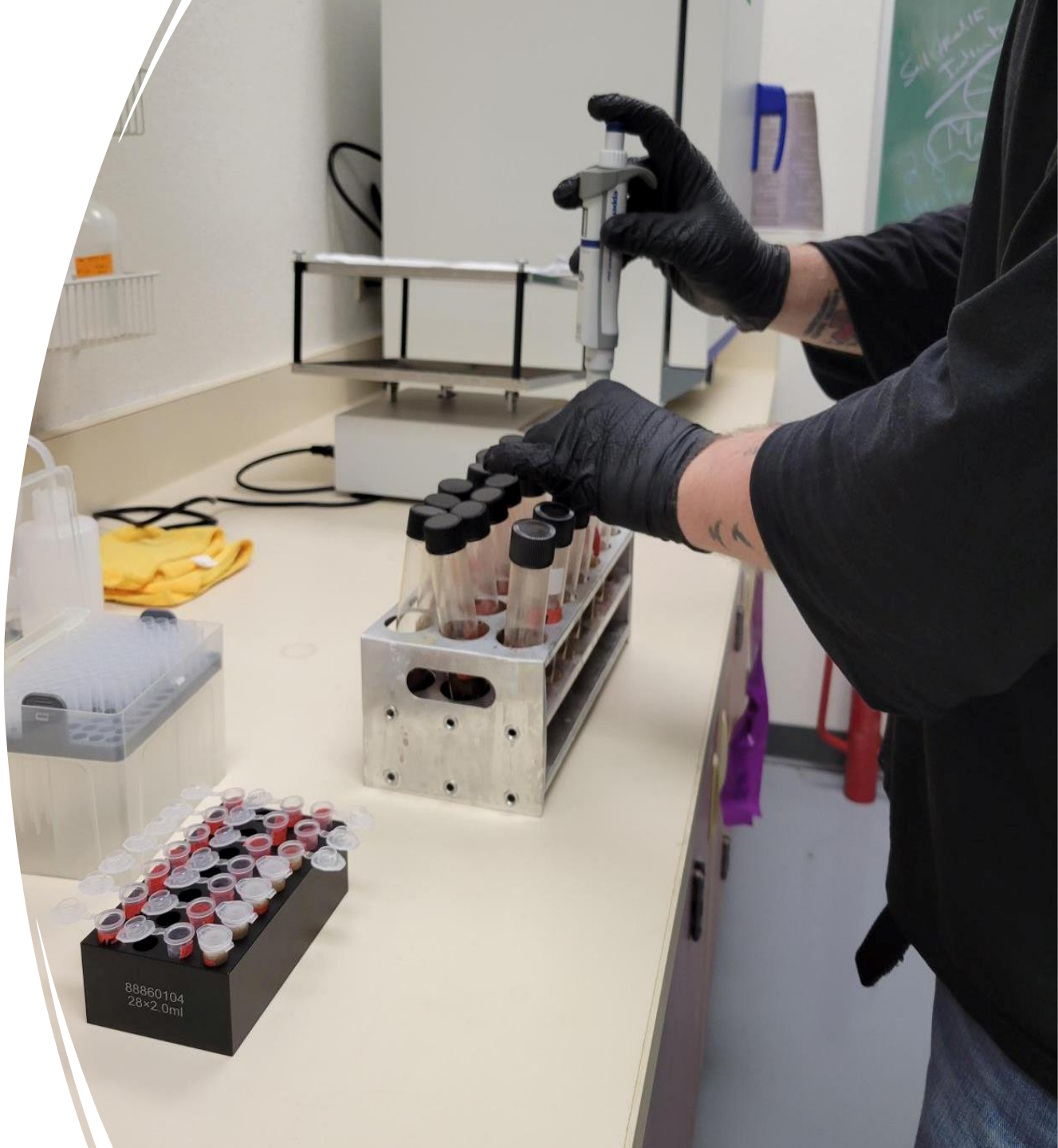
Soil Sampling

- Soil samples were collected from the top 0-6” soil profile and then processed

- Analyses performed at Sanyal Lab and samples sent to additional commercial lab for further chemical analysis

Soil Health Parameters Tested

- Potentially mineralizable nitrogen
- Permanganate oxidizable carbon
- Soil respiration
- Soil protein
- pH and electrical conductivity
- Soil nitrate-ammonium
- Nutrient content

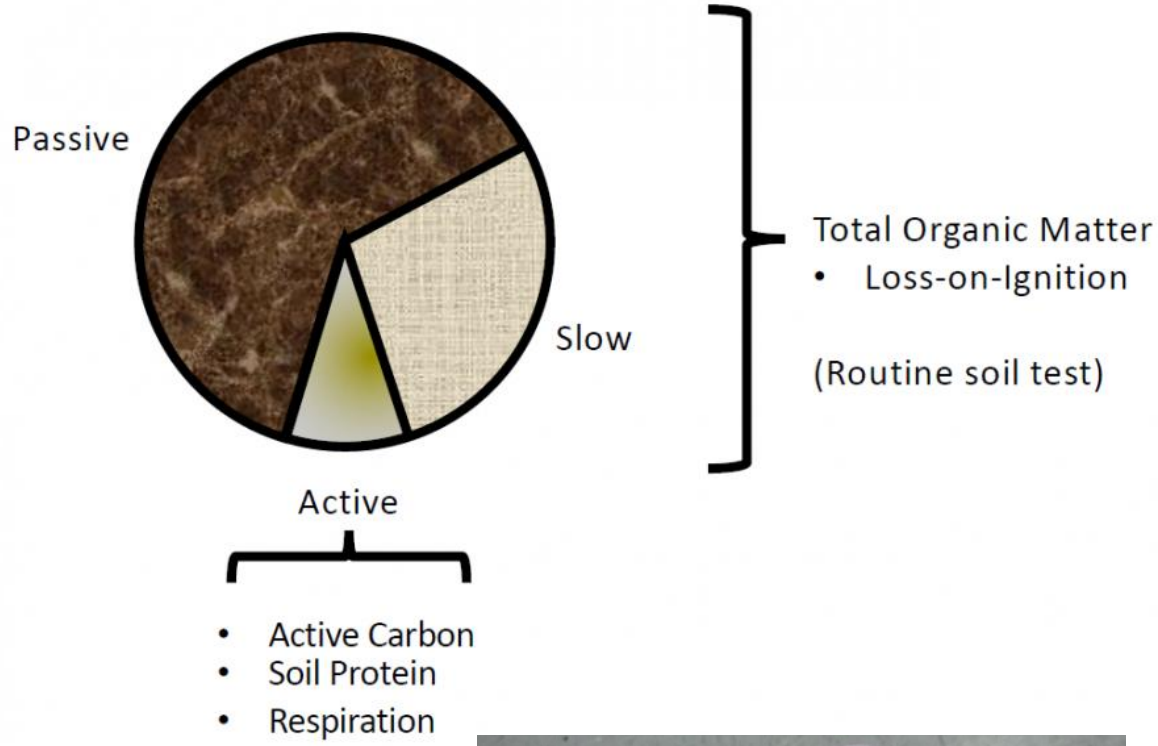


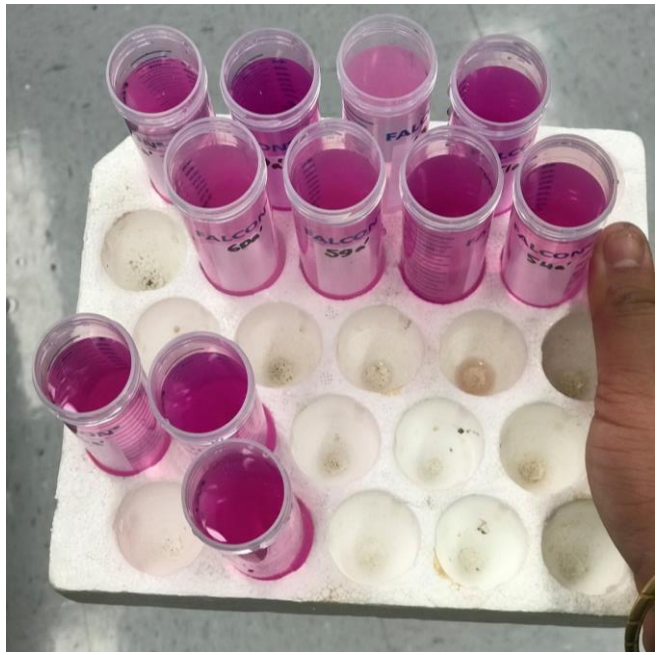
Soil Health Parameters: PMN

Potentially Mineralizable Nitrogen: An indicator of the capacity of the soil microbial communities to mineralize nitrogen (N) tied up in complex organic residues into the plant-available forms of N.

Soil Health Parameters: POXC

Permanganate Oxidizable Organic Carbon: An indicator of the small fraction of SOM that can serve as a readily available food and energy source for the soil microbial community, thus helping to maintain a healthy soil food web to support optimum microbial activity.



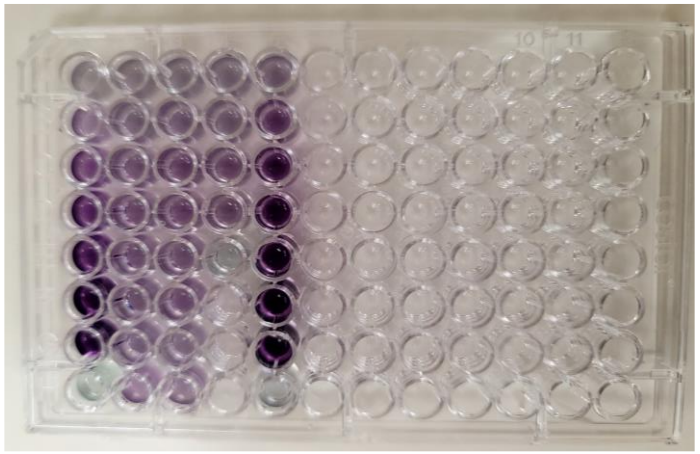


Soil Health Parameters: Soil Respiration

A measure of the metabolic activity of the soil microbial community. As the microbes respire or decompose SOM, CO_2 is evolved, and this test measures CO_2 evolved during microbial metabolism as an indicator for soil microbial activity.

Soil Health Parameters: Soil Protein

Soil protein is an indicator of the quantities of protein-like substances in the soil. It is a large pool of organically bound N in the SOM which soil microbes can mineralize; therefore, protein content is well associated with overall soil health status, especially the N and carbon in the soil.



Results: Soil Health Parameters

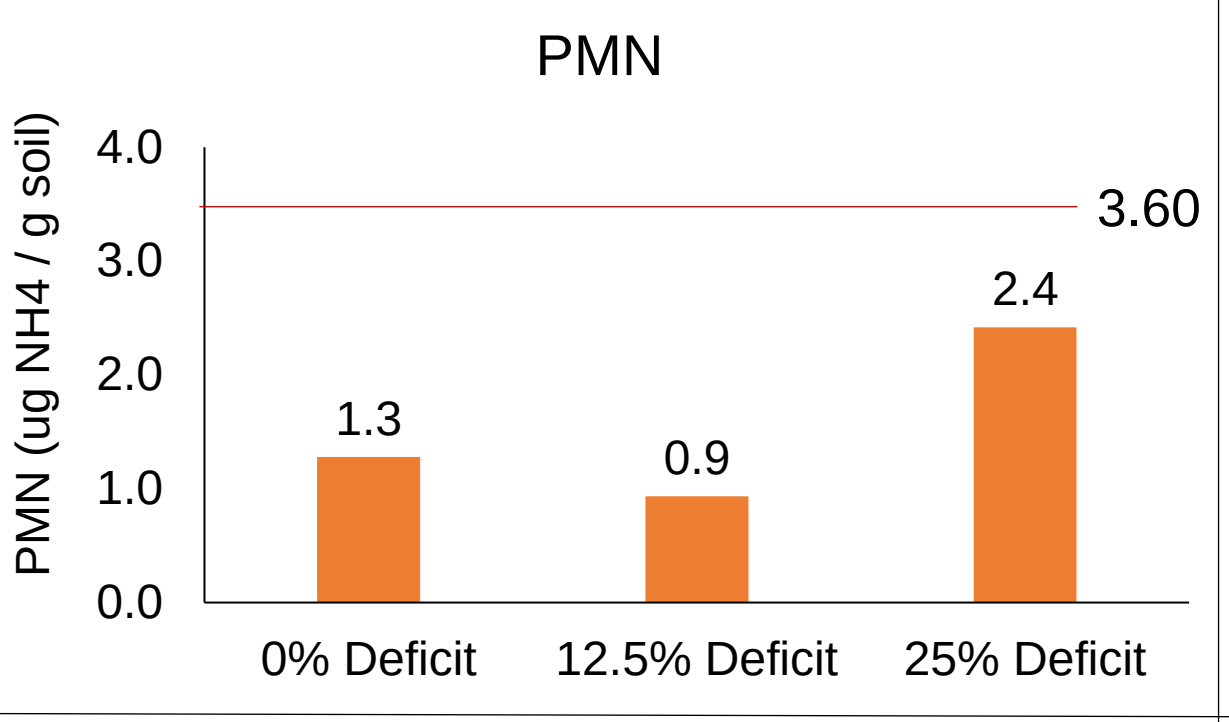
Soil Parameters	Initial	Reproductive Stage			Post-harvest		
		Control	12.5% Deficit	25% Deficit	Control	12.5% Deficit	25% Deficit
PMN ($\mu g\ NH_4$ /g soil)	3.60	2.2	1.8	1.3	1.3	0.9	2.4
POXC (mg C/kg)	251	211	219	174	230	309	368
Soil Respiration (mg CO_2/g/4d)	1.23	1.01	1.01	1.38	1.06	1.07	1.00
Soil Protein (g/kg soil)	0.45	0.29	0.24	0.15	0.16	0.27	0.37

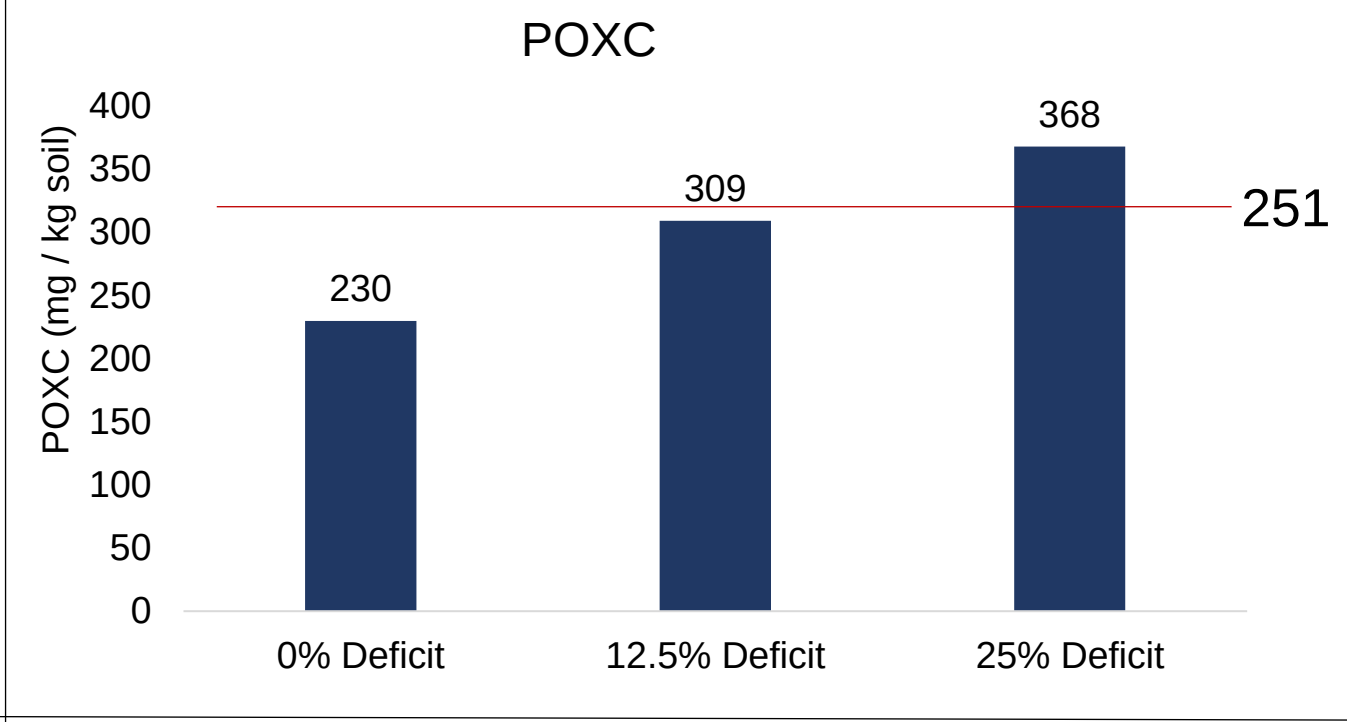
Mean values of potentially mineralizable nitrogen (PMN), permanganate oxidizable carbon (POXC), soil respiration, and soil protein before the experimentation, at the reproductive growth stage, and after the small grain crop harvest

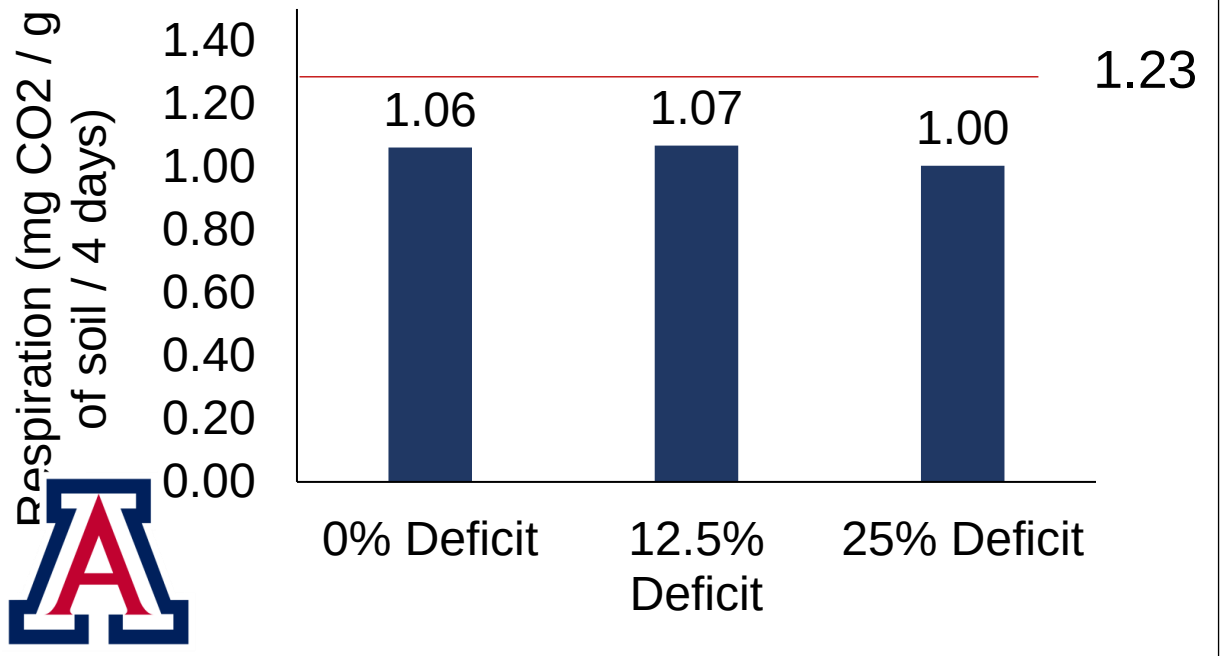
Results: Soil Chemical Parameter

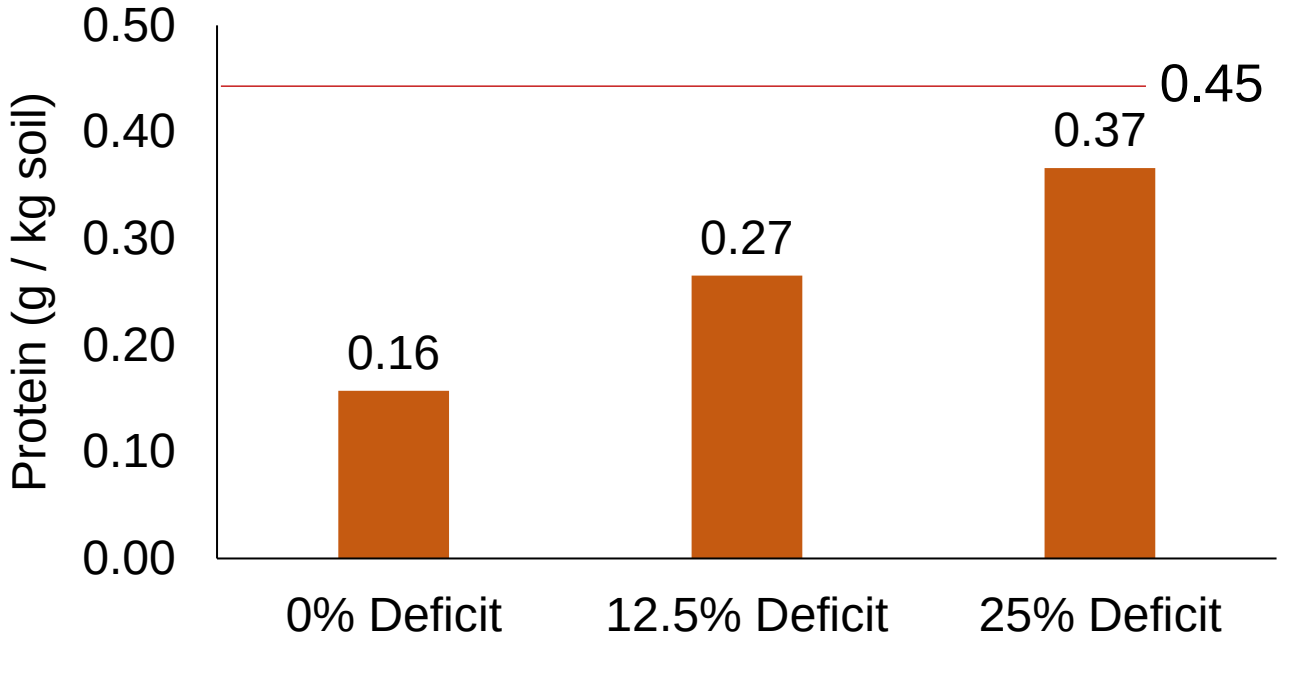
Soil Parameters	Initial	Reproductive Stage			Post-harvest		
		Control	12.5% Deficit	25% Deficit	Control	12.5% Deficit	25% Deficit
Soil pH (1:1)	8.4	8.3	8.3	8.3	8.4	8.4	8.4
Soluble Salts (dS/m)	0.20	0.25	0.24	0.21	0.18	0.20	0.21
Organic Matter (%)	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Nitrate-nitrogen (lbs./a)	28	5.7	5.9	2.6	2.8	2.6	2.9
Olsen P (ppm)	4.5	0.2	1.0	0.8	0.9	0.8	1.3
Potassium (ppm)	313	223	206	210	205	195	204
Sulfate-S (ppm)	21.7	20	21	17	19	17	21
Zinc (ppm)	0.55	0.5	0.5	0.5	0.4	0.4	0.5
Sum of Cations (meq/100g)	28.8	23	22	23	24	24	24

Soil chemical properties before the experimentation, at the reproductive growth stage, and after the small grain crop harvest


PMN
PMN (ug NH4 / g soil)
4.0
3.0
2.0
1.0
0.0
3.60
1.3
0.9
2.4
0% Deficit
12.5% Deficit
25% Deficit


POXC
POXC (mg / kg soil)
400
350
300
250
200
150
100
50
0
251
230
309
368
0% Deficit
12.5% Deficit
25% Deficit


Respiration (mg CO2 / g of soil / 4 days)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1.23
1.06
1.07
1.00
0% Deficit
12.5% Deficit
25% Deficit


Protein (g / kg soil)
0.50
0.40
0.30
0.20
0.10
0.00
0.45
0.16
0.27
0.37
0% Deficit
12.5% Deficit
25% Deficit

Conclusions

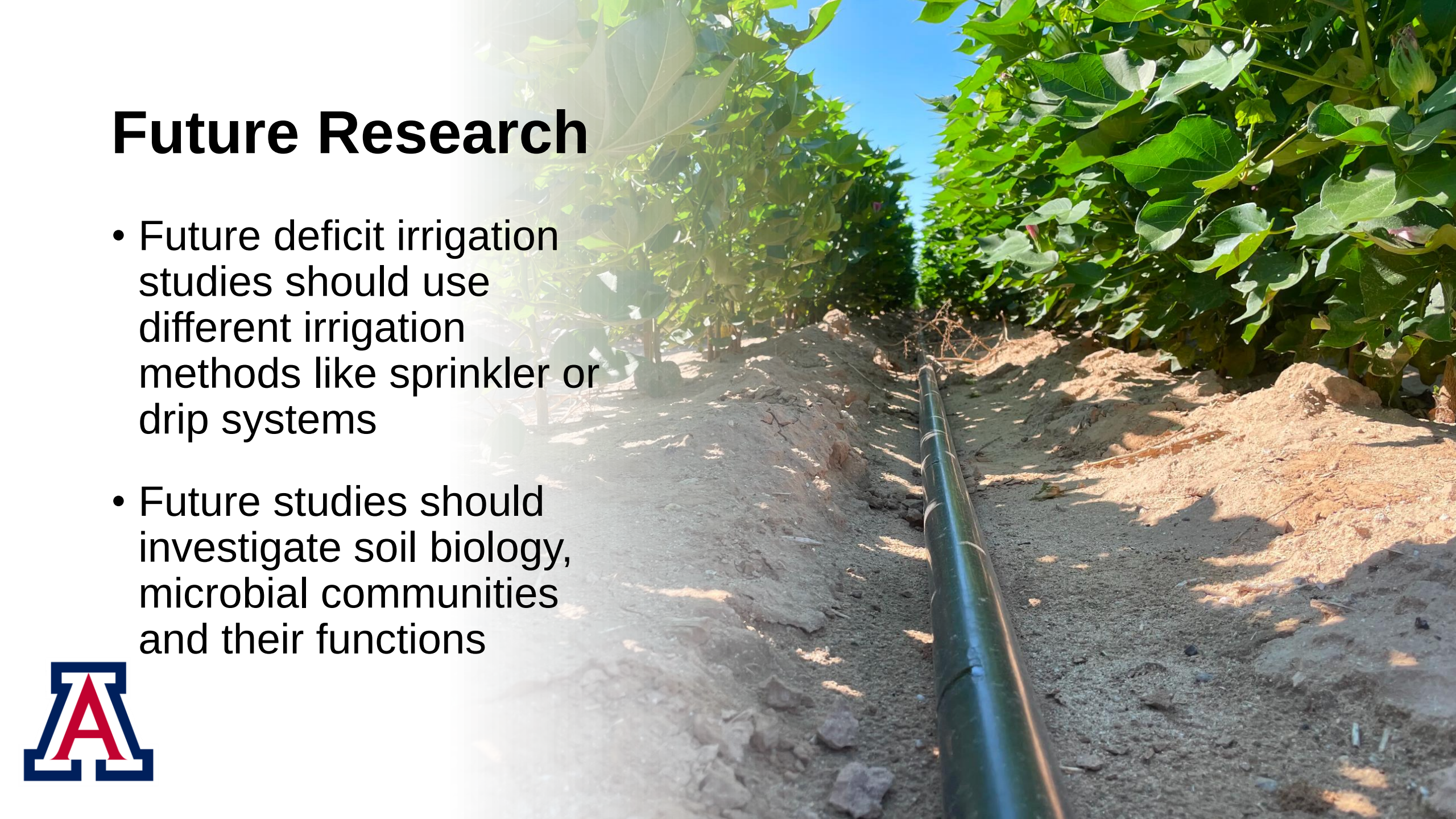
- Significant yield loss even with 12.5% deficit irrigation
- No grain quality benefits from reduced yield
- No effect on soil chemical properties or soil health

Recommendations

- No deficit irrigation if durum wheat and barley are grown for grain yield
- The deficit irrigation strategy under flood irrigation is not sustainable for commercial agriculture
- If it is necessary to use deficit irrigation, a different irrigation method should be applied such as drip irrigation

Future Research

- Future deficit irrigation studies should use different irrigation methods like sprinkler or drip systems
- Future studies should investigate soil biology, microbial communities and their functions



Acknowledgements

Dr. Debankur Sanyal (left) and Charles Stackpole (Right)

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THE UNIVERSITY OF ARIZONA

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COOPERATIVE EXTENSION

Thank you!

- Questions?

- Additional questions can be sent to jasontaylorarp@arizona.edu