PURDUE UNIVERSITY | Agronomy

Indiana CCA Meeting 2025
Indianapolis, Dec 10-11

The Hidden Half:

Root–Soil-Nitrogen Interactions of Short-Stature Corn

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http://purdue.ag/pal

INDIANA CORN Marketing Council

- Assistant Professor at Purdue University (2022-)
- Ph.D. in soil science and microbial ecology
- Has conducted research in multiple states and regions across 3 different countries

Purdue Agroecology Lab (http://purdue.ag/pal)

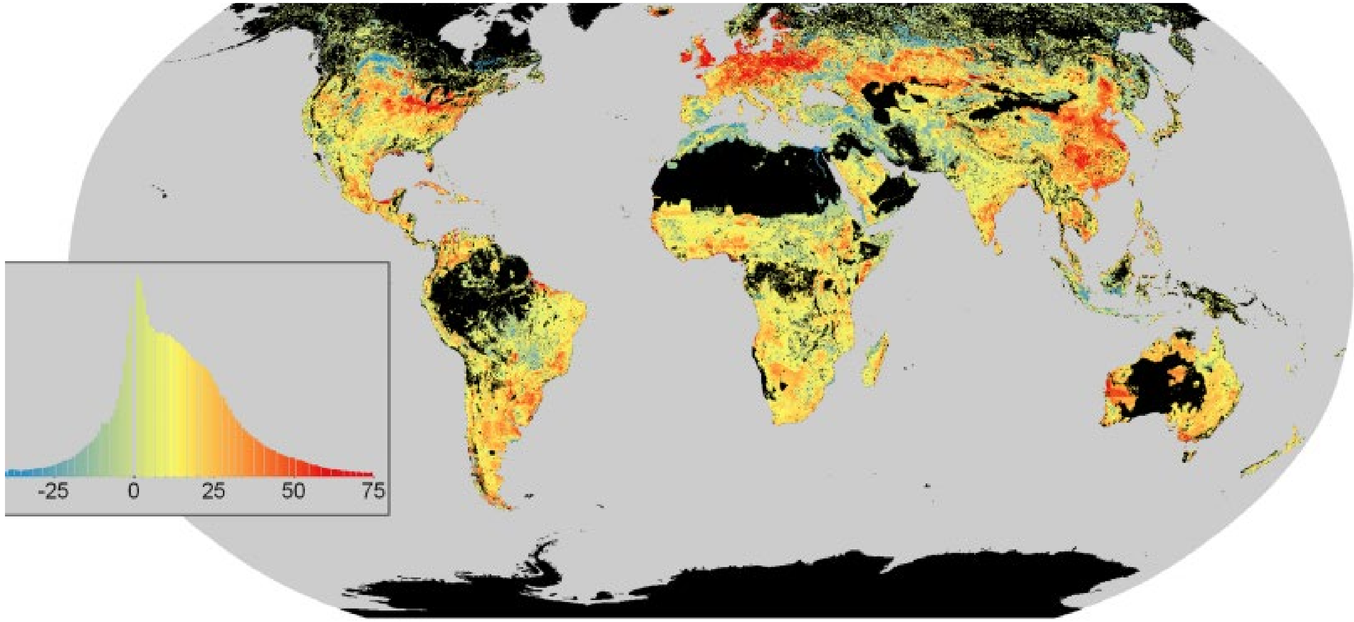
We explore how environmental and management drivers shape soil and ecosystem functions, advancing innovations that foster resilient and sustainable agricultural systems.

Global cropping soils have been massively degraded

PNAS

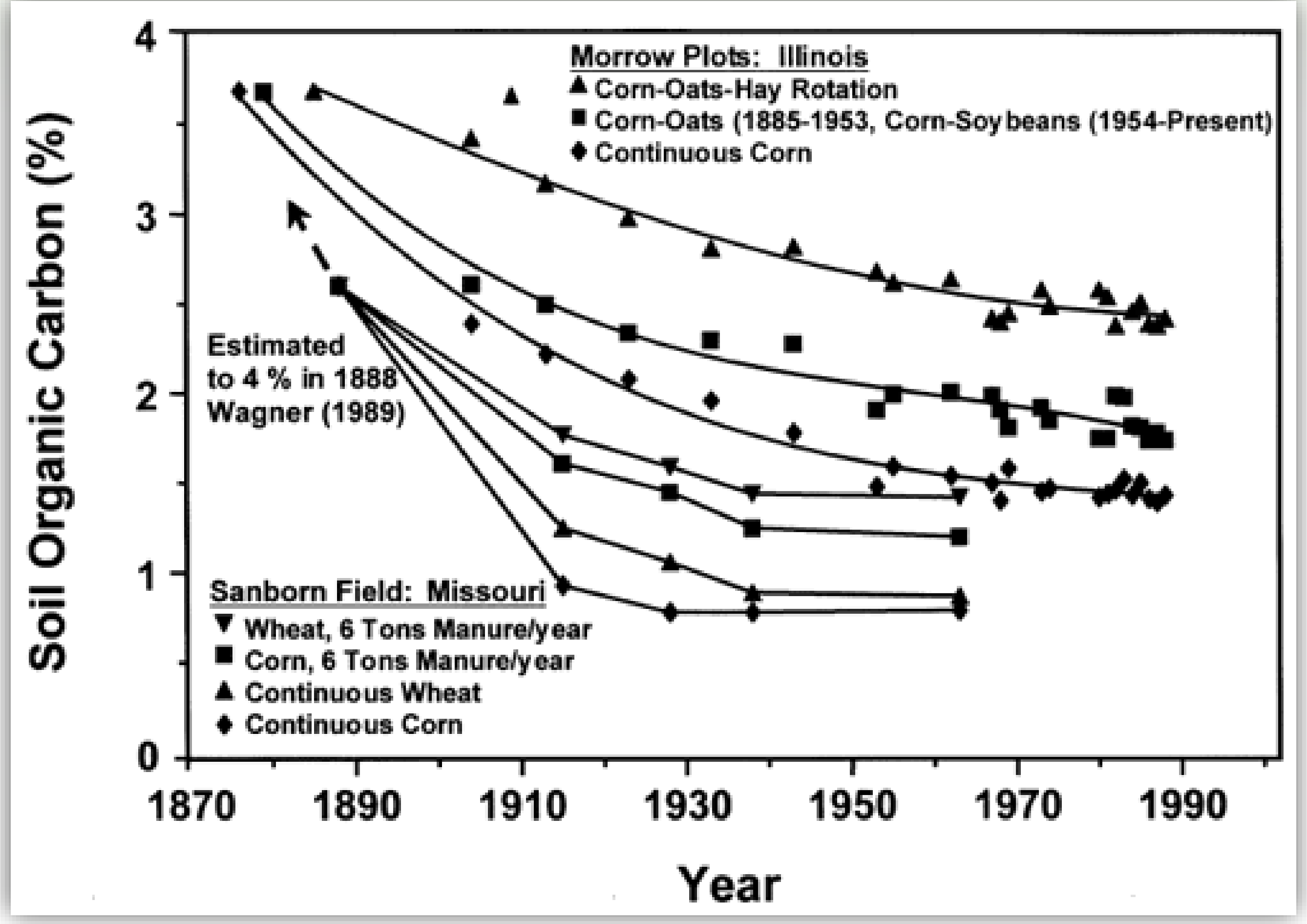
Soil carbon debt of 12,000 years of human land use

Jonathan Sanderman[a,1,2], Tomislav Hengl[b,1], and Gregory J. Fiske[a]



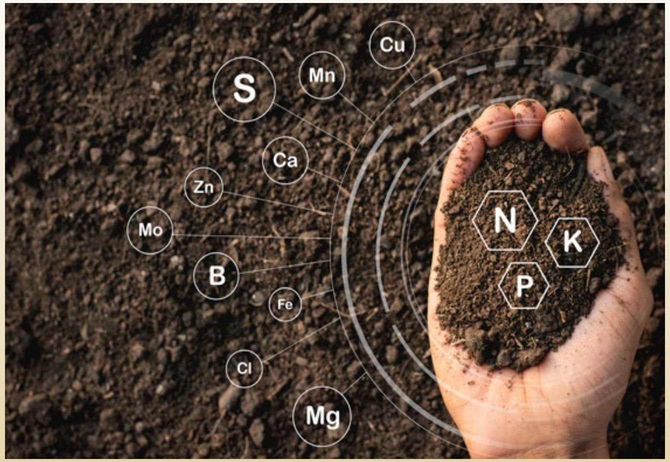
Dr. Jon Sanderman
Woodwell Climate
Research Center

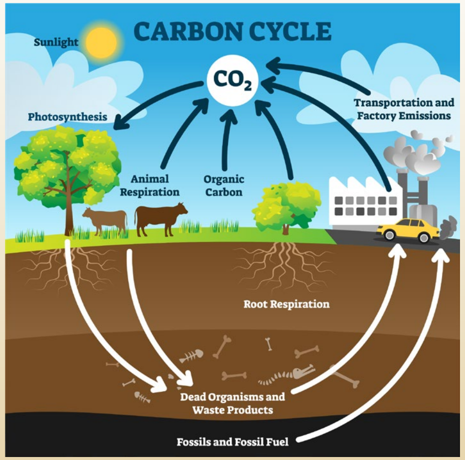
The U.S. Corn Belt Is a Hotspot of Soil Carbon Losses



(Shaxson et al., 2008)

Why is soil carbon/soil organic matter important?



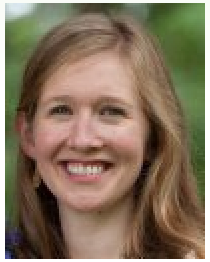


Soil organic matter (SOM) contains N, P, S, and other nutrients, thereby supporting crop production

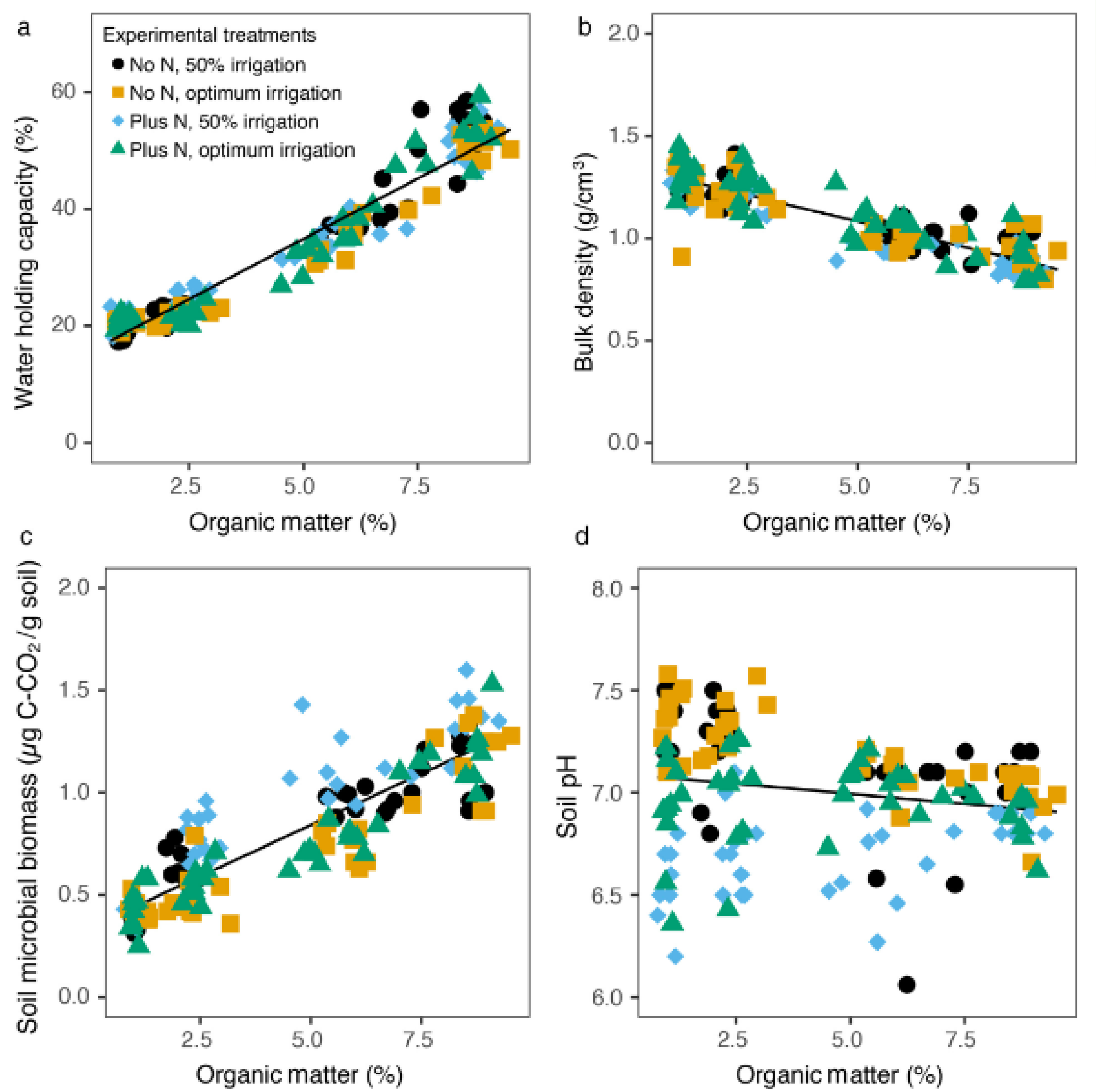
SOM supports the soil food web and enhances biodiversity

SOM regulates global carbon and water cycle

SOM/Soil carbon is central to soil health

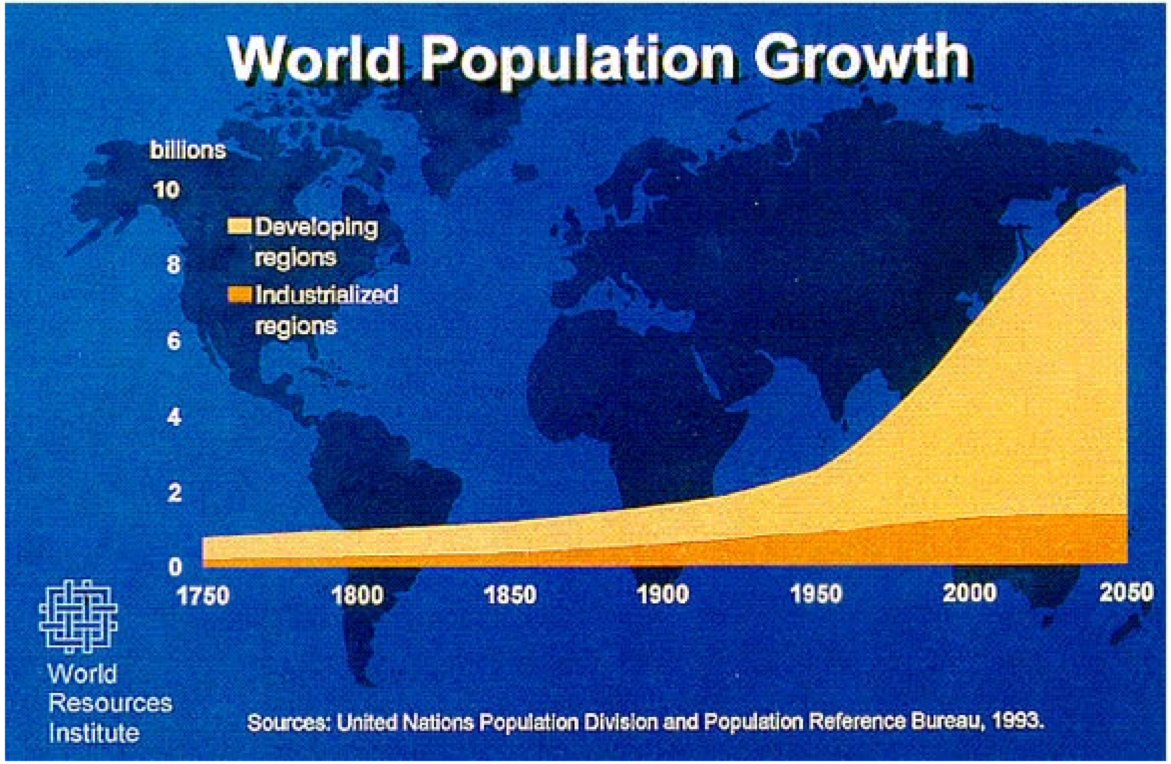


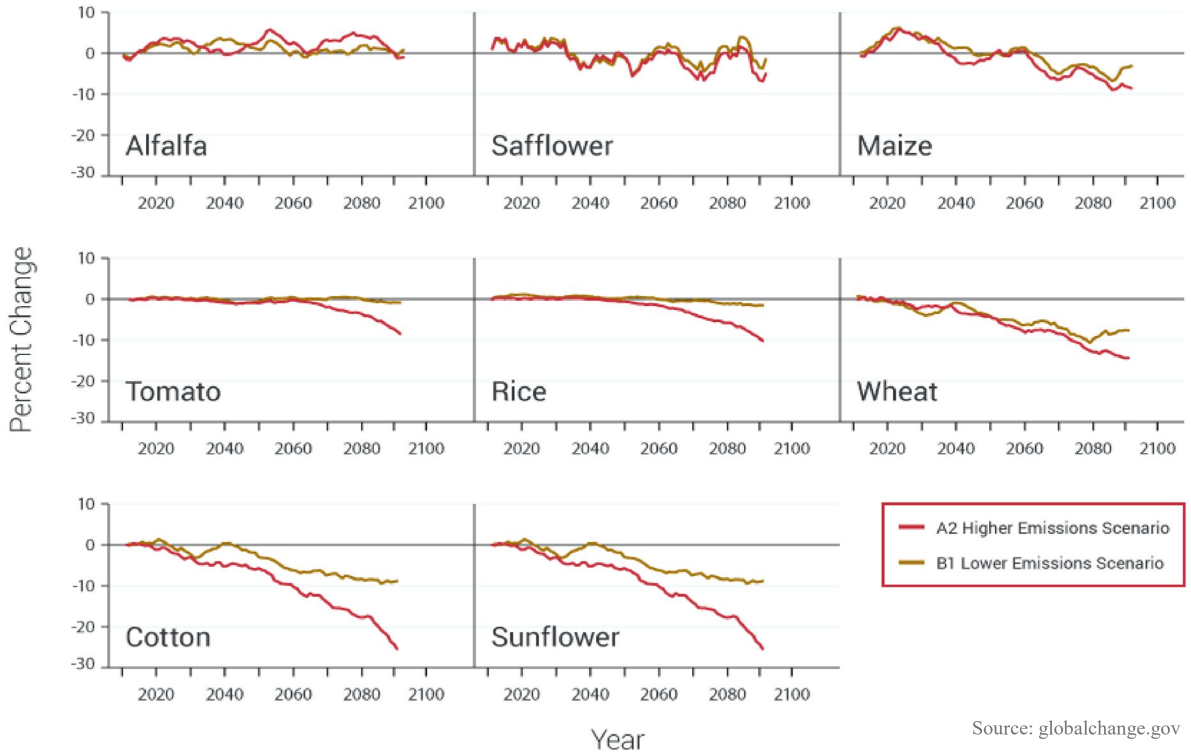
Dr. Emily Oldfield
Environmental Defense Fund



Oldfield et al., 2020

Our Grand Challenge: Feeding and Meeting the Needs of a Growing Population

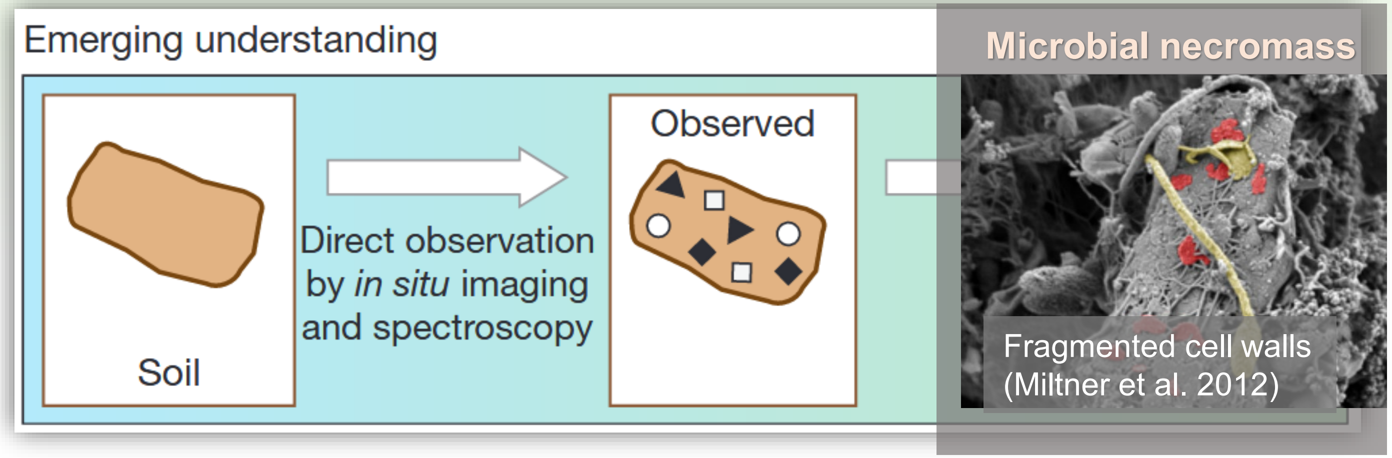




Source: globalchange.gov

Question:

Soil Carbon Formation – Evolving Understanding



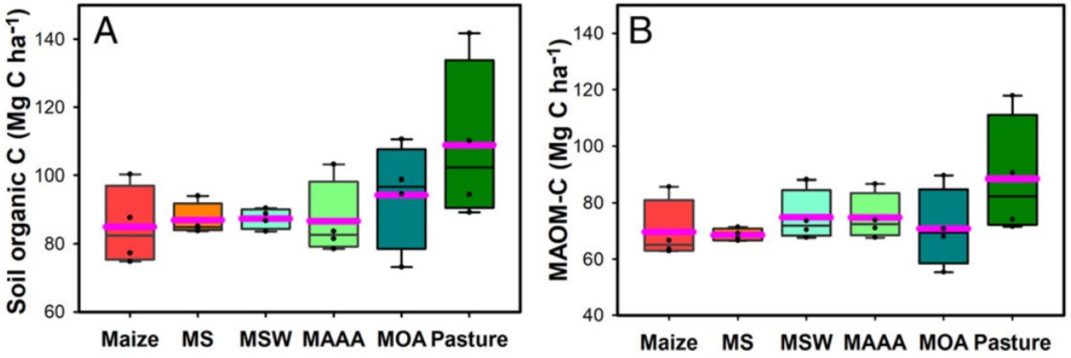
(Schmidt et al., 2011)

- <u>Simple-structured C compounds</u> contribute to stable soil C formation.
- *Root exudates* and *microbially-derived C* (microbial necromass & microbial byproducts) form associations with **soil minerals** (silt & clay).

PNAS

Persistent soil carbon enhanced in Mollisols by well-managed grasslands but not annual grain or dairy forage cropping systems

Yichao Rui, Randall D. Jackson, M. Francesca Cotrufo, Gregg R. Sanford, Brian J. Spiesman, Leonardo Deiss, Steven W. Culman, Chao Liang, and Matthew D. Ruark

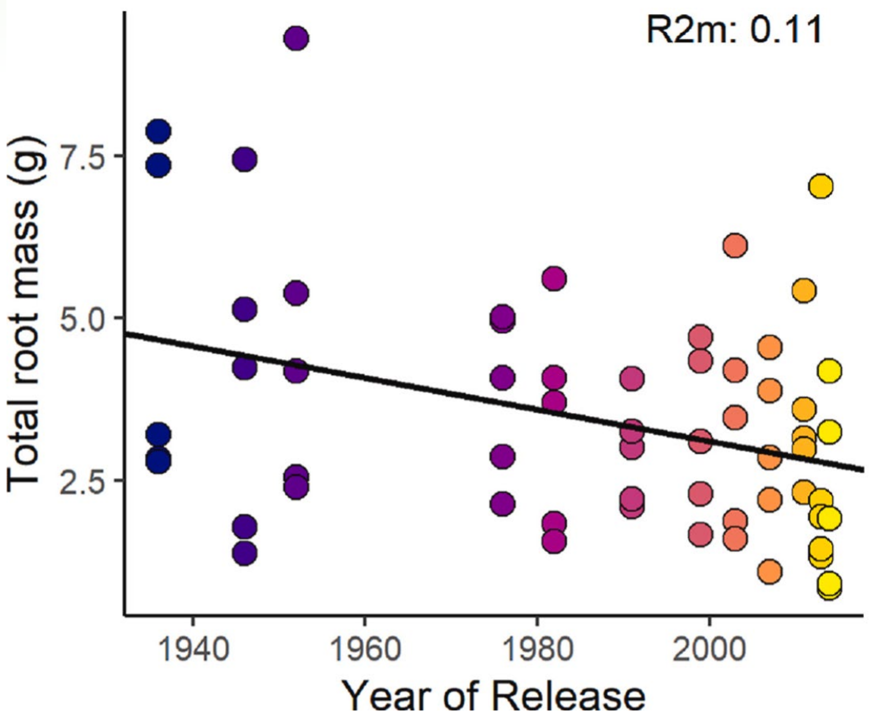


Corn is here to stay

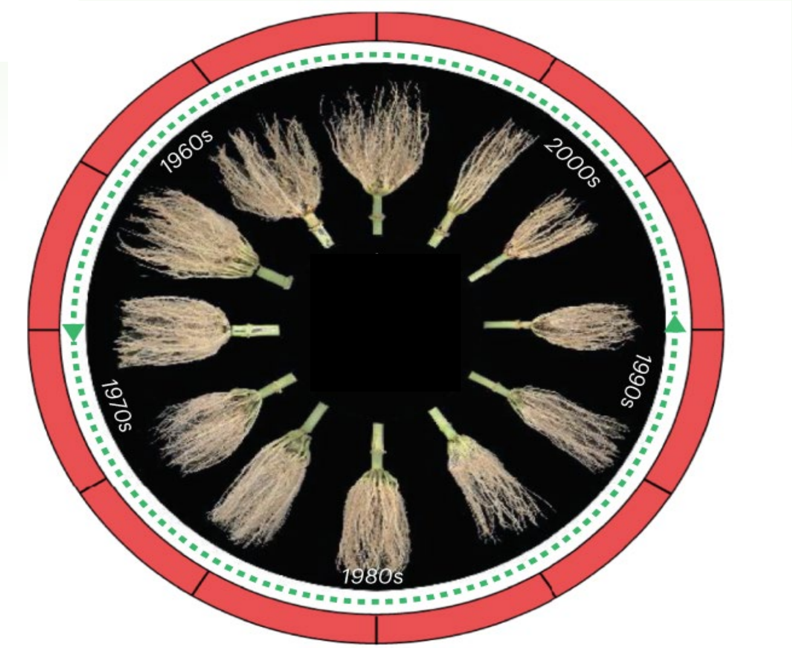
- High productivity and strong adaptation to Midwest climate and soils
- Unmatched versatility, economic value, and consistent market demand
- Well-established infrastructure and supply chains that support large-scale production
- Ongoing genetic and technology innovations that further boost yields and efficiency

Grow corn in innovative ways to achieve both productivity and sustainability

Modern Corn Systems: Have We Ignored the Belowground?



(Ren et al., 2022)



ELSEVIER

Rhizosphere
Volume 30, June 2024, 100915

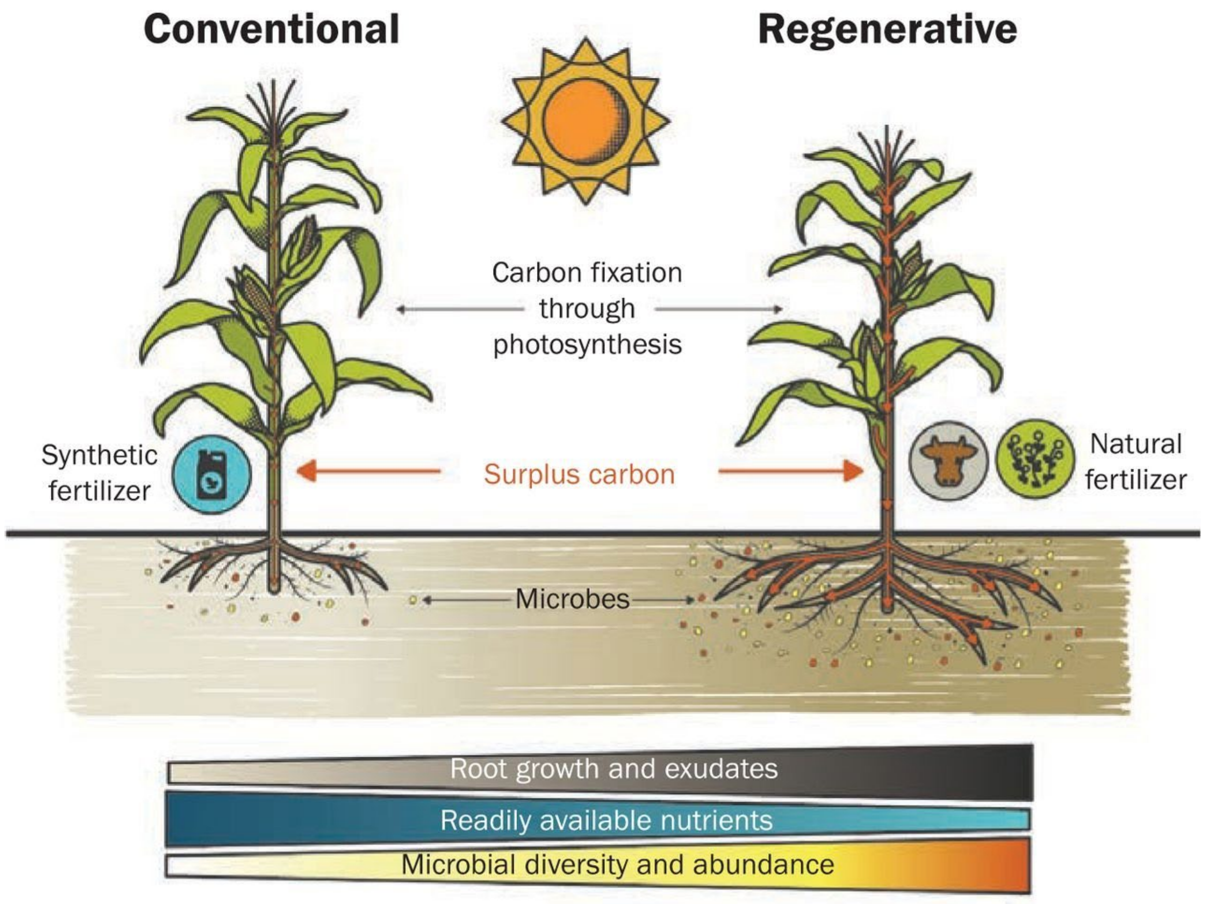
Commercial maize hybrids have smaller root systems after 80 Years of breeding

B. Rinehart [a d], L. Borras [b], M. Salmeron [c], D.H. McNear Jr. [d], H. Poffenbarger [a]

“Surplus Plant Carbon” Theory

Managing plant surplus carbon to generate soil organic matter in regenerative agriculture

Cindy E. Prescott, Yichao Rui, M.Francesca Cotrufo, and Sue J. Grayston



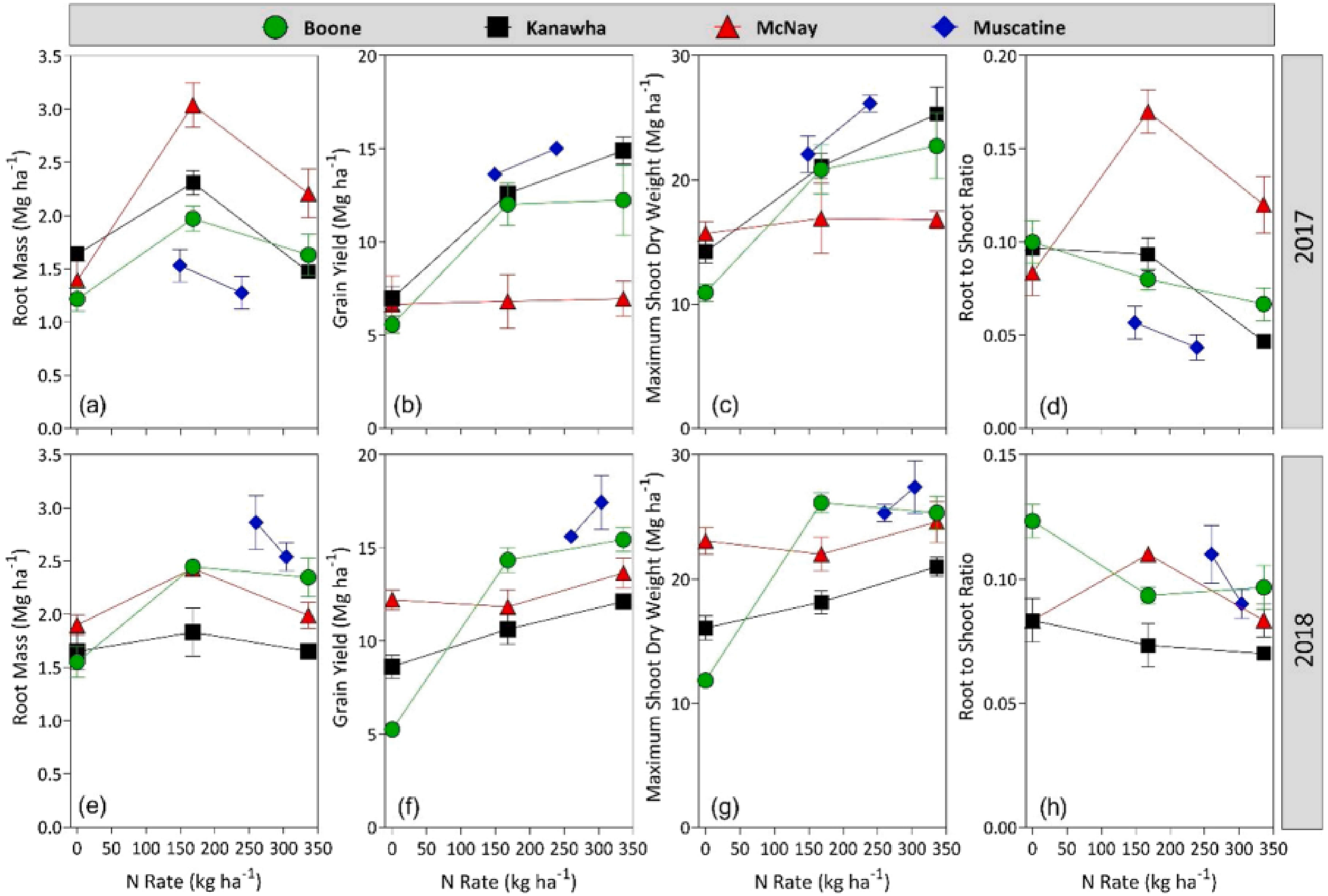
Cindy Prescott
(University of British Columbia)

Raziel Ordóñez, Ph.D.

Insufficient and excessive N fertilizer input reduces maize root mass across soil types

Raziel A. Ordóñez[a,b,*], Michael J. Castellano[a], Gerasimos N. Danalatos[a], Emily E. Wright[a], Jerry L. Hatfield[a], Lee Burras[a], Sotirios V. Archontoulis[a,*]

[a] Department of Agronomy, Iowa State University, Agronomy Hall, Ames, IA, 5 0011-1010, USA
[b] Department of Plant Science, The Pennsylvania State University, University Park, PA, 16802, USA



Knowledge Gap:

Can we optimize **fertilization** and **crop genotypes** to boost **surplus plant carbon** and **soil carbon generation**?

set the stage for short-stature corn

Recently introduced by Bayer to address lodging issues of corn.

Field Study

Greenhouse Study

Genotype
(Corn Hybrids)

Environment
(Soils)

Management
(N Rates)

Field Study

- **Treatments:**
  - Corn hybrids (Tall and Short corn hybrids)
  - N rates (0, 100, 200, and 300 kg/ha)

- **Research Sites:**
  - **ACRE** (Agronomy Center For Research and Education)
  - **SEPAC** (Southeast Purdue Ag Center)

- **Plot Size:** 15 by 40 feet
- **Fertilizer:** UAN (28% N)
- **Seeding rate:** 32K seeds/ac

4% OM
(Mollisol)

1% OM
(Alfisol)

Dr. Dan Quinn
Purdue Extension Corn Specialist

Dr. Raziel Ordóñez
“Dr. Roots”

Binod Joshi
(PhD student)

- Root sample extraction: **Gidding’s Probe** (6.8 cm diameter).
- Root sample collection: **R2 growth stage of corn** (Maximum root biomass).
- Each core was cut at five different depths: 0-15, 15-30, 30-60, 60-90, and 90-120 cm**.**

Root Data

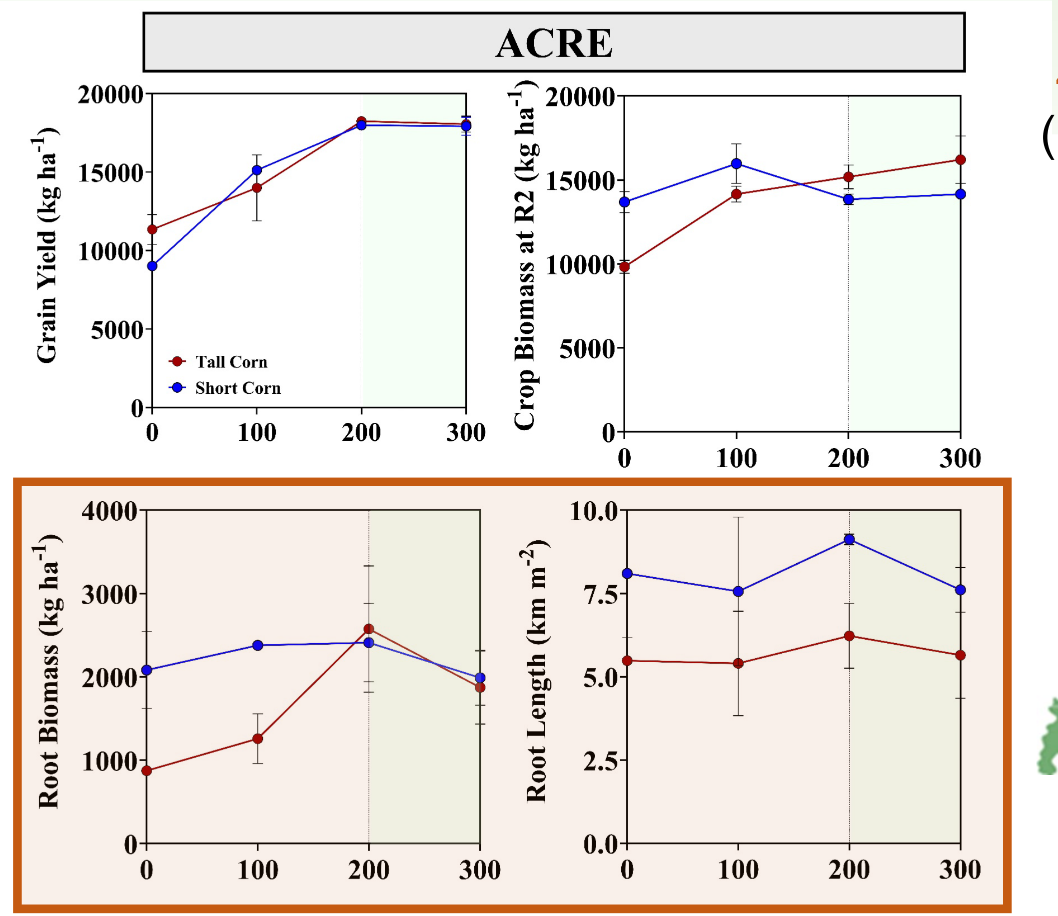
- Root Biomass
- Root Length
- Root Length Density
- Specific Root Length
- Root C:N

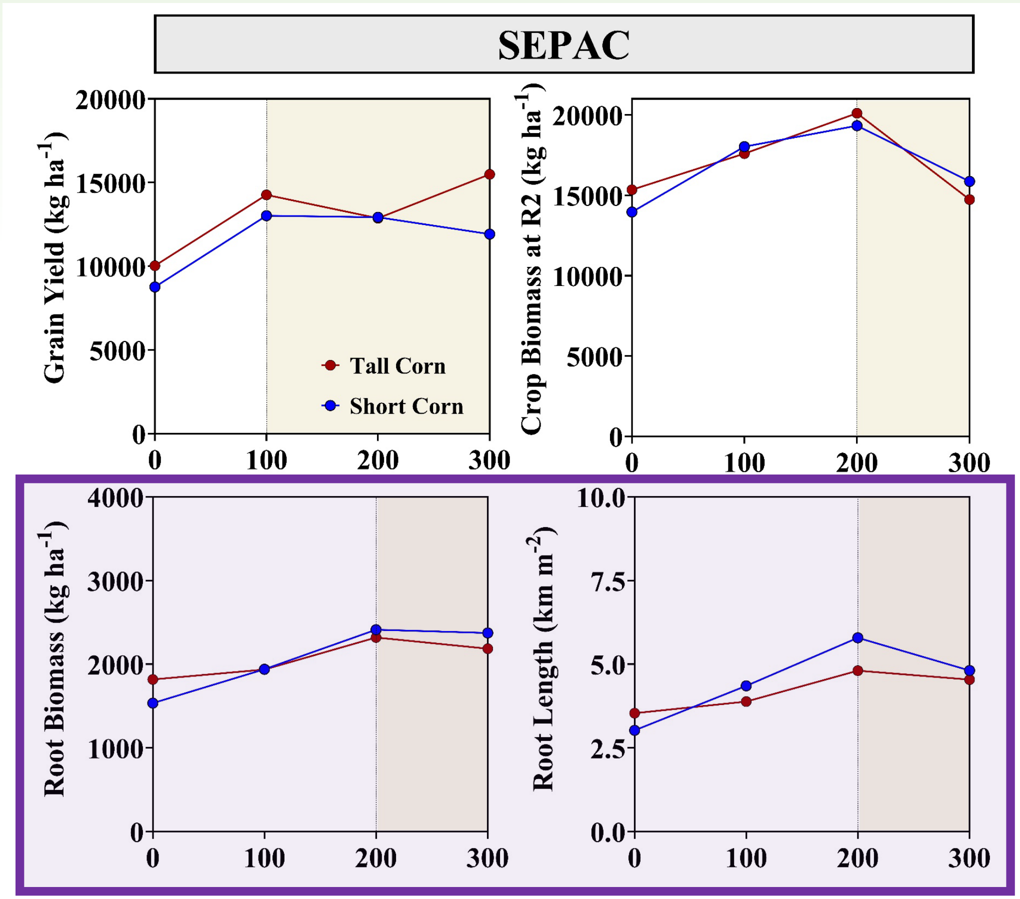
Soil Data

- POXC
- PMC
- SMBC
- Nitrate

Results: Root Biomass and Length

Tall Hybrid
Short Hybrid



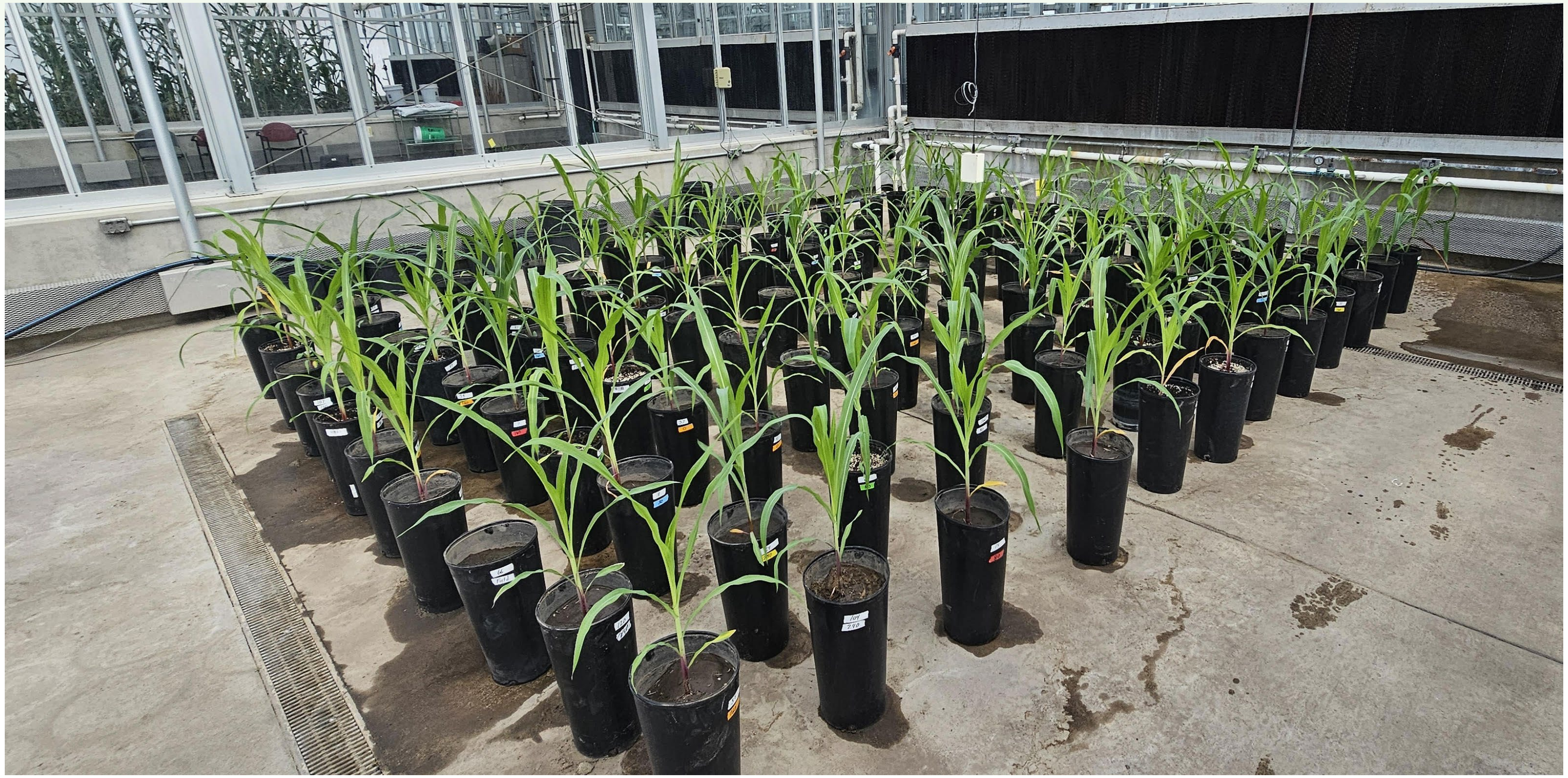


- Short corn produced 35-42% greater root biomass and length than tall-stature hybrids.
- Root responses to a hybrid site were site-specific.
- Root biomass and length were maximized at 200 kg N ha^{-1}.

Soil C Pools: No Immediate Hybrid or N Effects

Source of variation	POXC (mg kg^{-1})	PMC (mg CO_2-C kg^{-1} soil $^{-1}$day)	Nitrate (ug N g^{-1})	SMBC (ug C g^{-1})
Site (S)				
ACRE	842^a	404^a	7.06	579^a
SEPAC	632^b	301^b	5.47	484^b
Hybrid (H)				
Tall	743	377	5.78	527
Short	731	328	6.75	536
N rate (N)				
N0	715	333	5.47	499
N100	779	314	5.46	492
N200	736	339	7.44	537
N300	718	423	6.69	598
Depth (D)				
0-15cm	844^a	377^a	7.21	578^a
15-30cm	630^b	328^b	5.32	485^b

Greenhouse Study



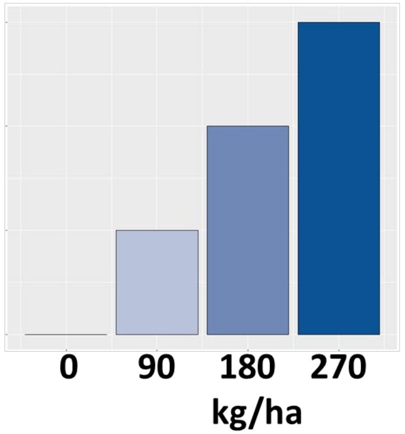
Carson Pearl
(MSc student)

- Corn was grown to the V8 stage for the collection of root exudates and assessment of other root characteristics.

Tall-Statured Short-Statured

Sandy Soil

Loamy Soil

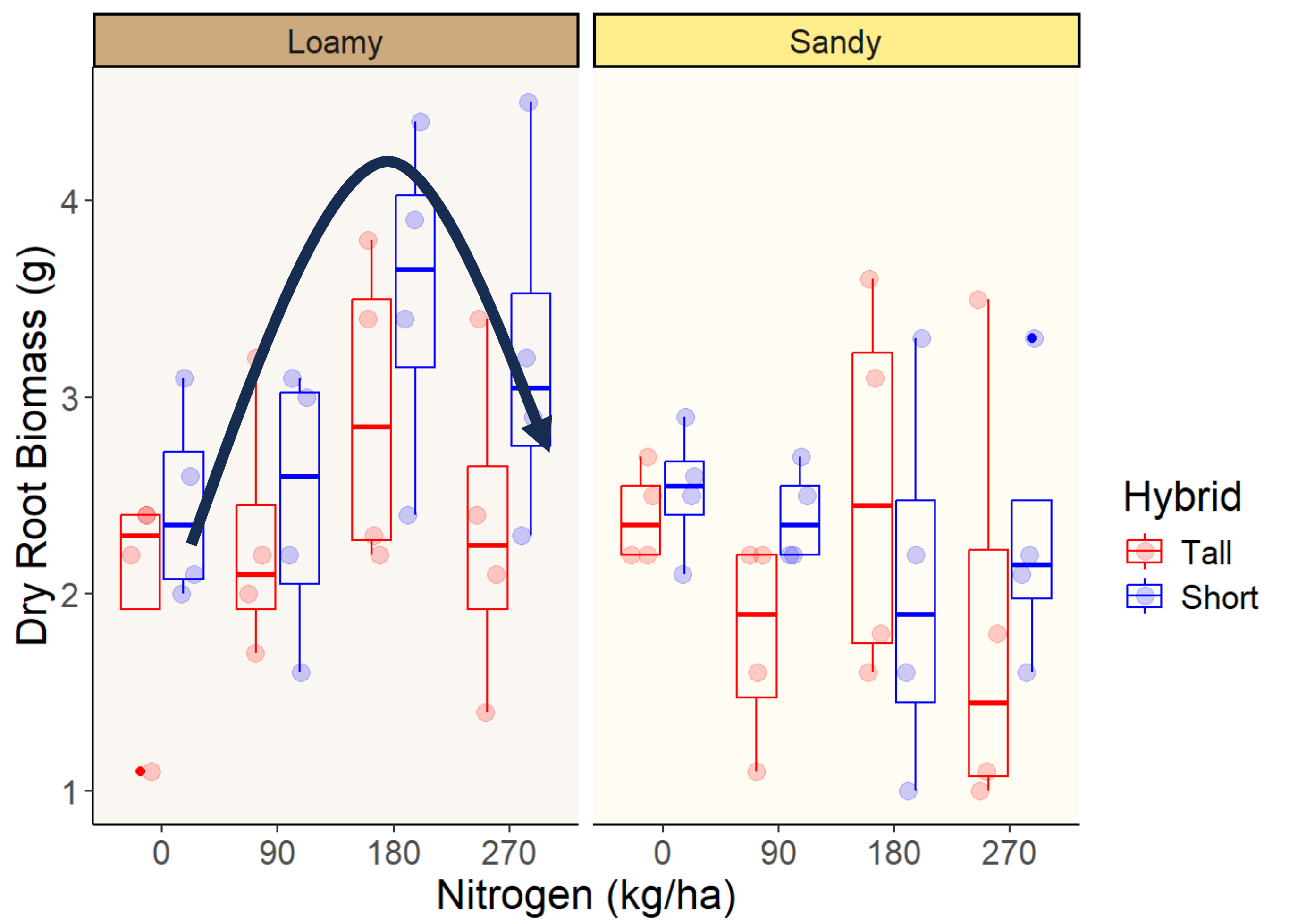


Root Exudate Collection

Pot Leaching

Hydroponic Incubation

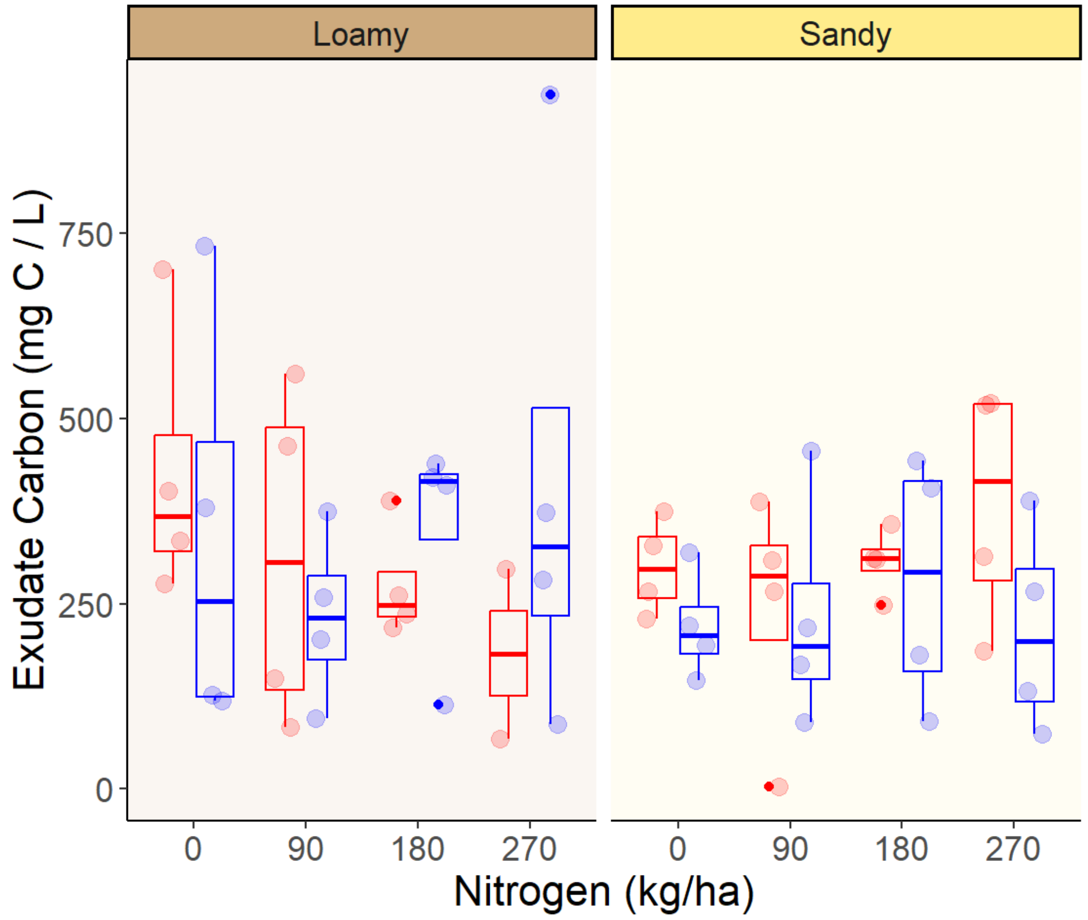
Belowground Biomass



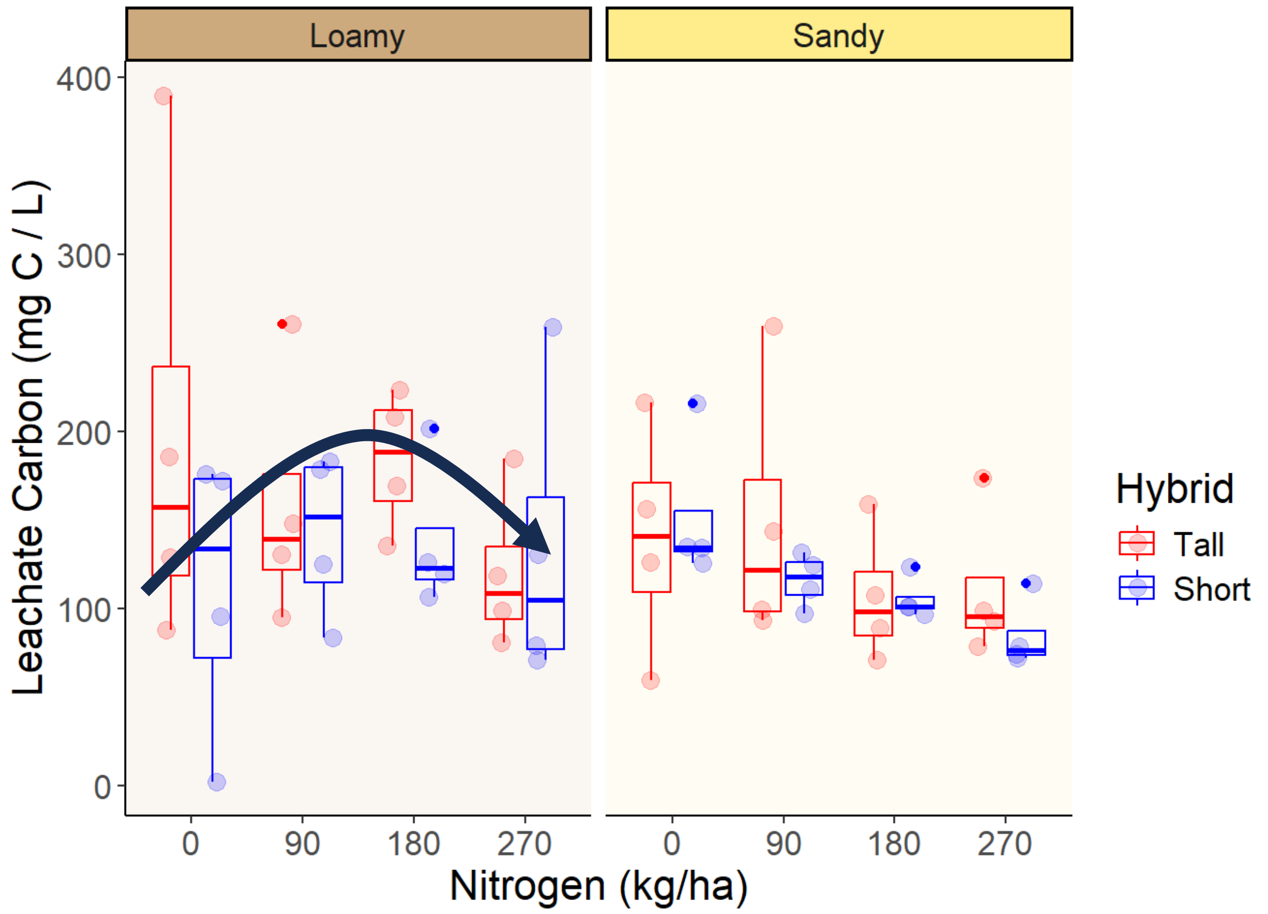
- **Short corn had 22% greater root biomass than tall corn.**
- **Root biomass of both short and tall corn increased with N rate until 180 kg/ha, then decreased in loamy soils.**

Root Exudate

Hydroponic Incubation

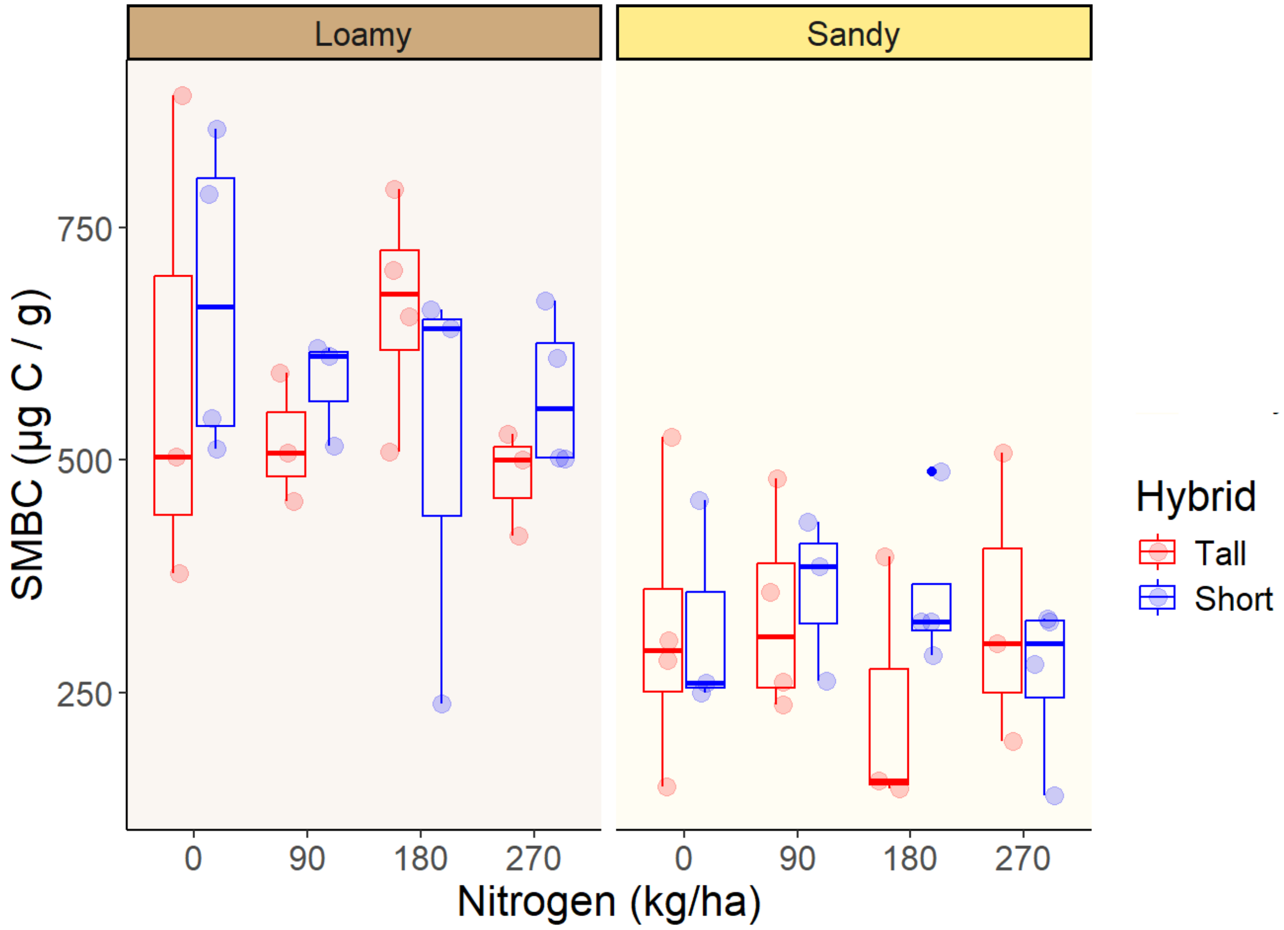


Pot Leaching



- No consistent noticeable trend.
- Leachate C first increased then decreased with N in loamy soils.

Soil Microbial Biomass

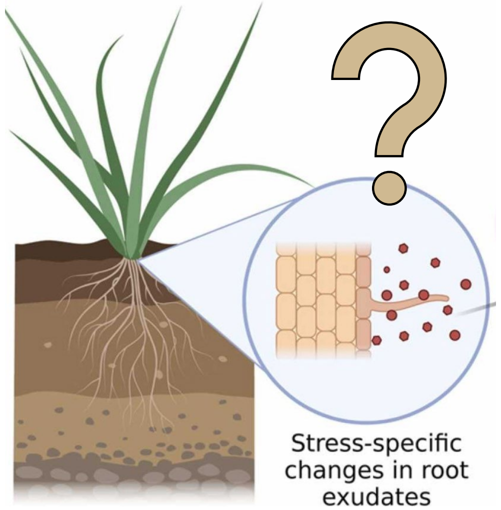


- **Soil microbial biomass was 46% greater in loamy than sandy soils.**
- **Microbial biomass decreased from 180-270 kg/ha N application.**

Do Our Findings Support the "Surplus C Theory"?

- Both short- and tall-stature corn hybrids tended to achieve maximum root biomass at 180-200 kg N ha^{-1}, while excessive N application reduced root performance.

- No consistent trends in root exudates.



(Tiziani et al., 2022)

Does Breeding For Roots and Ecosystem Services Work?

- Short-stature corn hybrids exhibited enhanced root biomass and length, but the response might be site-specific.

- Minimal impact on soil biological indicators in single year studies.

- **Short corn offers a root-system advantage.**

  Its inherently larger and longer root system suggests greater capacity for C input and water and nutrient acquisition.

- **Goldilocks rule of N: not too little, not too much.**

  Both short and tall corn achieve their strongest root growth at mid-range N rates, reminding us that applying more nitrogen beyond this point can actually reduce belowground performance.

- **Soil type matters.**

  Root responses varied across soil types, underscoring that hybrid performance is not universal—soil texture and inherent fertility can amplify or limit root development.

Thank you!

INDIANA CORN Marketing Council

NORTH CENTRAL SARE Sustainable Agriculture Research & Education

- Dr. Dan Quinn
- Dr. Raziel Ordóñez
- Dr. Chad Penn
- All graduate students and researchers at Purdue Agroecology Lab

http://purdue.ag/pal