The Impact of Perennialization and Polyculture on Soil Health

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Introduction

- **PROBLEM:** Farming practices can negatively impact soil health by:
  - Reducing the soil's capacity to aggregate and support plants
  - Reducing soil microbiome biodiversity
  - Increasing vulnerability to erosion
- Illinois "the Prairie State" only has 0.01% of original prairie left
- What do we do with abandoned agricultural sites? Can they be converted to restored prairies?
- **We are exploring restoration** via **perennials** and **polyculture.** This approach can positively impact soil health by:
  - **Improving soil stability:** plants form dense root systems that anchor soil particles;
  - **Reducing disturbance:** plants persist for multiple growing seasons;
  - **Enhancing the soil microbiome:** promoting the diversity of soil microbes and their functions such as enzymes for plant decomposition and nutrient cycling

Research Question

Which row cropping treatment, be it monoculture or polyculture, produces a soil microbiome which best supports the growth of prairie plants?

Hypothesis

Due to the observed effects of perennialization and polyculture on soil microbiome health, we hypothesized that prairie plants grown with soil inoculum from **Kernza-Alfalfa biculture plots** will perform better than those grown in soil inoculated by monoculture row-crops or control treatments.

Results

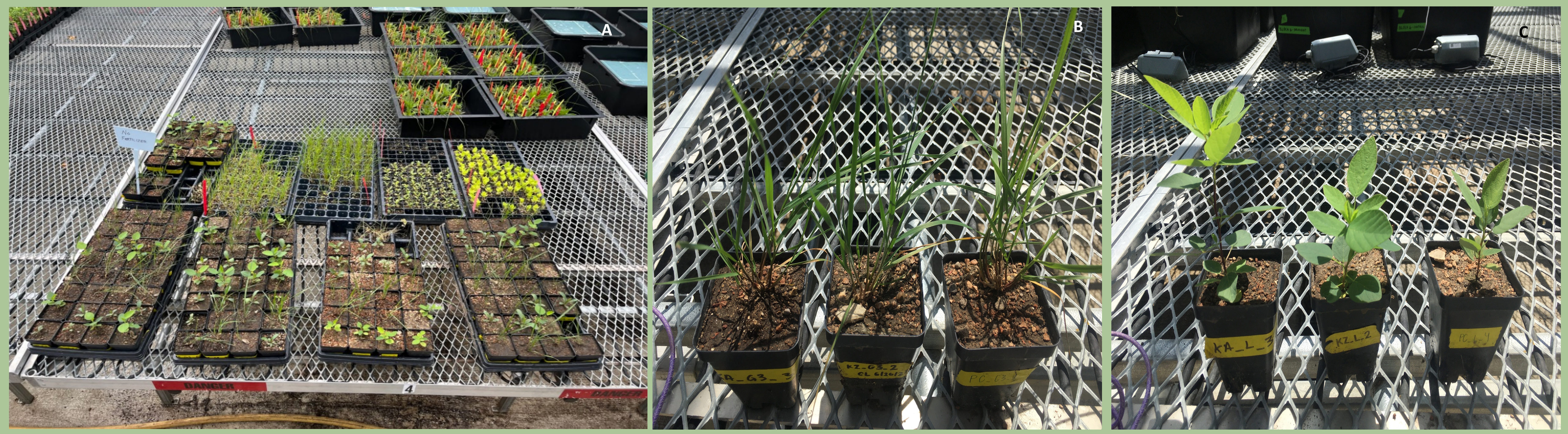

Figure 1. A) Seedlings in greenhouse setting, B) C3 grasses showing similar responses to inoculation, C) Legume seedlings showing greatest growth responses to biculture (KA, Kernza + Alfalfa) inoculum and smallest in positive control (PC, prairie) with monoculture inoculum producing intermediate growth responses (KZ, Kernza).

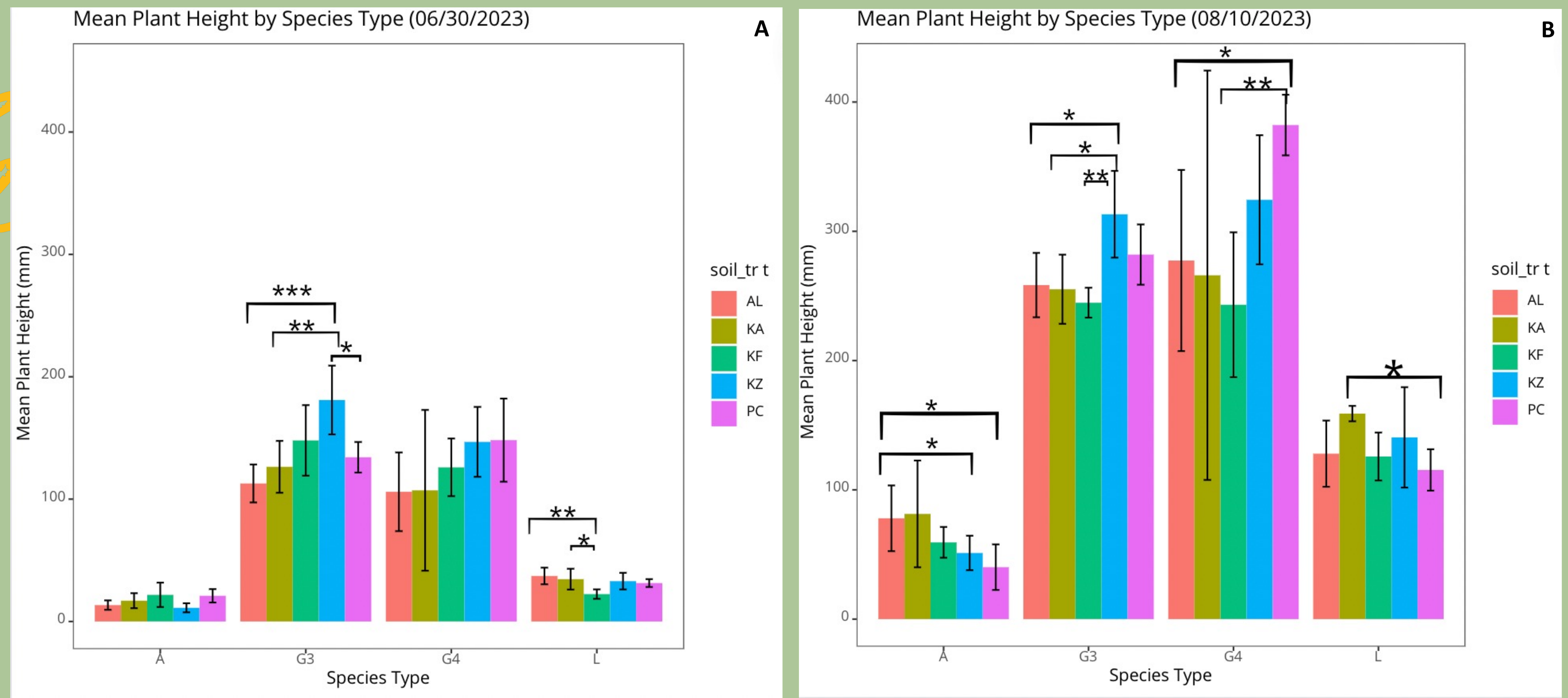

Figure 2. Mean height of prairie plants grown in various soil treatments. Height of each bar corresponds to mean plant height at week 1 (A) and week 8 (B), with plant species indicated along the x-axis, and height in mm along the y-axis. Bar color corresponds to soil treatment, AL = alfalfa, KA = Kernza-Alfalfa biculture, KF = Kernza + fertilizer, PC = positive control. Bars connects by a bracket were found to have statistically significant differences according to an ANOVA with Tukey Post-hoc, and asterisks indicate significance level (* = p < 0.05, ** = p < 0.01, *** = p < 0.001.)

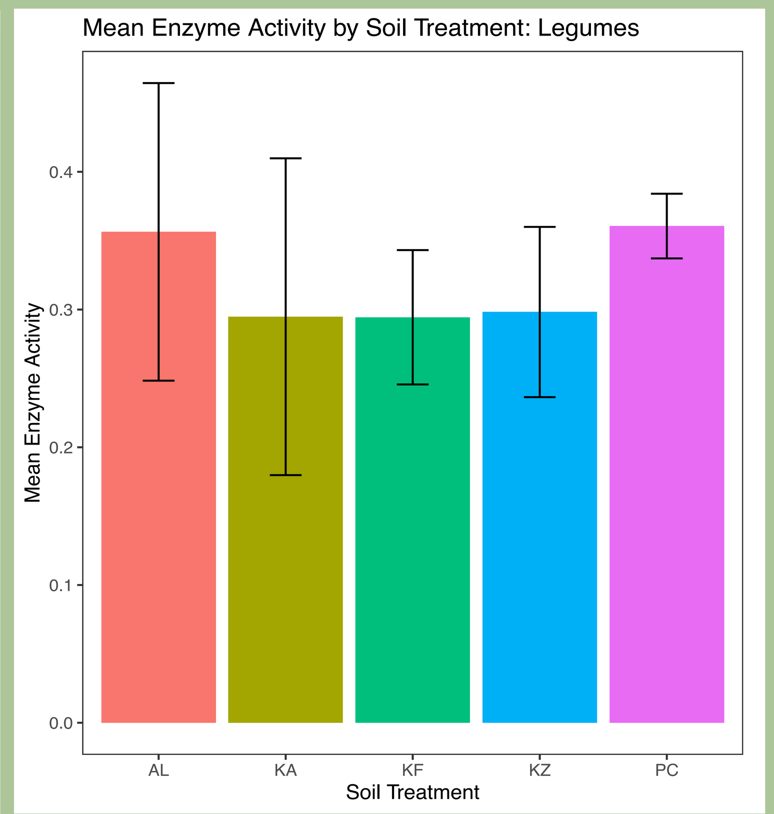

Figure 3. Mean enzyme activity by soil treatment for the legumes. Height of each bar corresponds to mean enzyme at week 6, with soil treatment indicated along the x-axis, and enzyme activity along the y-axis. Bar color corresponds to soil treatment (AL = alfalfa, KA = Kernza-Alfalfa biculture, KF = Kernza + fertilizer, PC = positive control).

- Each plant species demonstrated greatest growth responses to different soil treatments (Figs 2A,B).
  - Forbs and legumes responded best to the biculture inoculum while the grasses preferred the monoculture inoculum.
- The prairie control treatment did not necessarily result in the greatest plant growth.
  - In this treatment, forbs and legumes had the lowest mean plant height, but the C4 grasses had the greatest mean plant height.
- No significant difference was detected in enzyme activity of legumes in response to each inoculum treatment (Fig 3).

Methodology

Soil Inoculum Sources
- Kernza Monoculture
- Kernza monoculture + N fertilizer
- Kernza/ Alfalfa Biculture
- Alfalfa monoculture

Control treatments
+ Prairie (restored) soil
- Sterilized soil

Setting: Greenhouse

Into each soil inoculum source, we planted four species (Fig 1) that represented different functional groups within prairie ecosystem:
- C3 grass (*Elymus* sp.)
- C4 grass (*Bouteloua gracilis*)
- Forb (*Solidago* sp.)
- Legume (*Desmodium* sp.)

with **5 replicates** for each soil-plant combination

Metrics Used
- Plant survival
- Plant height (biomass proxy)
- Number of leaves (life stage proxy)
- Soil enzyme activity (microbiome abundance and activity);, phosphatase activity, with a focus on legume plants

Discussion

We found that:

- Inoculum from the Kernza-Alfalfa biculture was not always the optimal treatment for each plant species, as hypothesized.
- Instead, the various growth responses to inocula suggest that crop species and polycultures generated different microbiomes. Thus, matching plant species to these microbiomes (niches) will be important in restoration efforts, especially for species that performed better with prairie inoculum (C4 grasses).
- Similar levels of phosphatase activity between plant- treatment combinations indicates a degree of functional redundancy in the microbiome for P acquisition. This is also supported by the lack of correlation between plant growth (height) and enzyme activity. Possibly, microbiomes may differ in other functions such as N or water uptake.

Future Directions

Our study results raises a number of questions for future research:

- What are different soil health metrics that can be used to determine how well the plants are being supported by the soil inoculum and microbiome?
- Which species would be best suited for a restoration process at an agricultural field setting as opposed to a greenhouse setting?
- What are the soil-plant feedback mechanisms contributing to the differences in plant performance?
- Why do some plant species respond better to certain treatments than others?

Works Cited

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