Perennial agriculture as a tool for regenerating soil health in degraded lands

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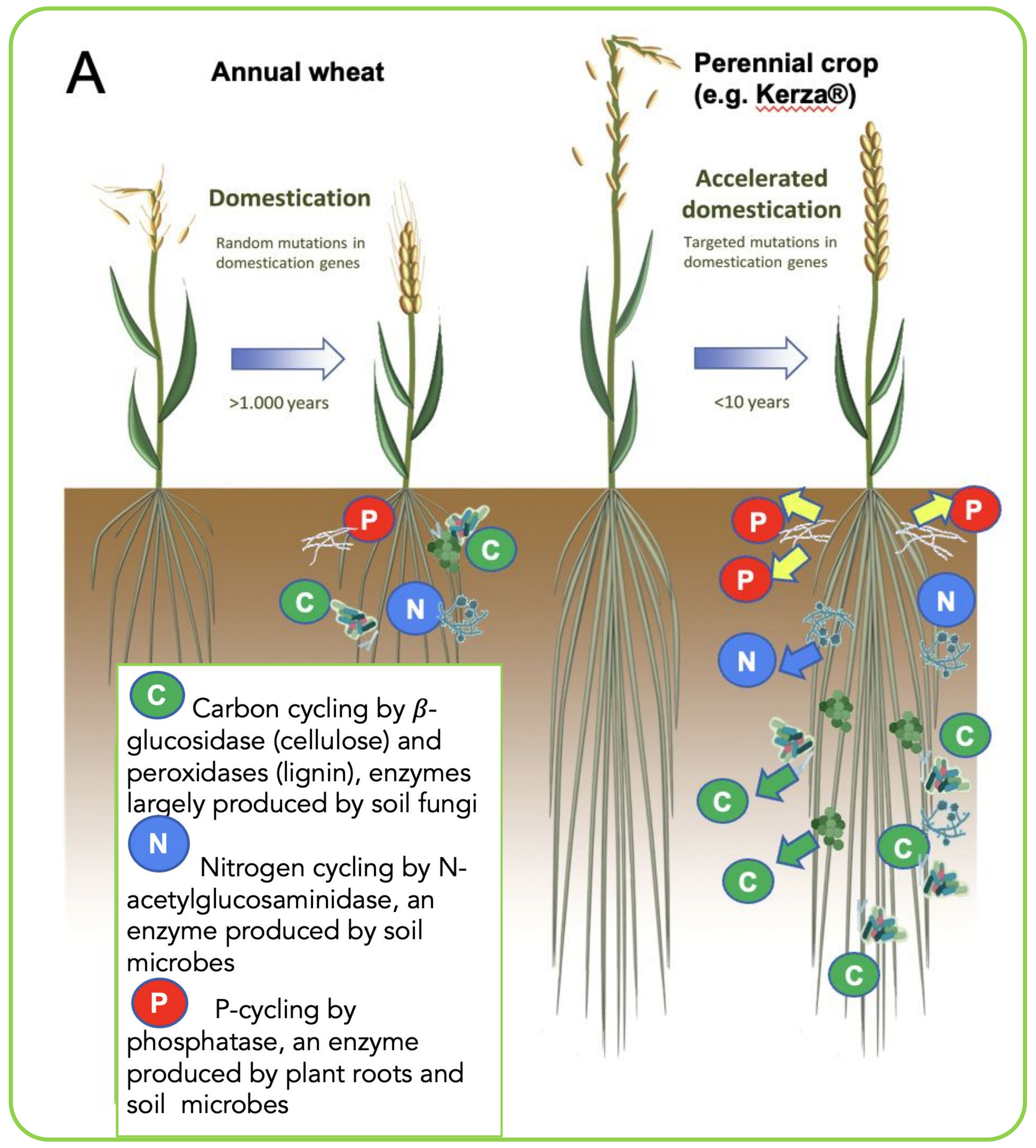
INTRODUCTION

- Land-use conversion for agriculture has impacted over 75% of lands globally, resulting in extensive soil degradation and the loss of soil health [1].
- Perennial crop plants with deep, extensive root systems and large microbial communities could enable the restoration of degraded lands in natural and agricultural systems (Fig.1A). One potential crop is Kernza® (*Thinopyrum intermedium*), a perennial wheatgrass developed by The Land Institute (Fig. 1B).
- Compared to annual wheat, Kernza develops deep root systems (Fig. 1C) that may promote soil health via greater soil stabilization, carbon sequestration, and microbial nutrient cycling.
- Although these effects are expected to be greatest in highly degraded soils, our understanding of plant and microbial traits that facilitate a regenerative system is very limited.
- *We hypothesized that Kernza would promote ecosystem health by enhancing soil microbial activity and soil respiration more than annual crop (wheat) and forage species.*



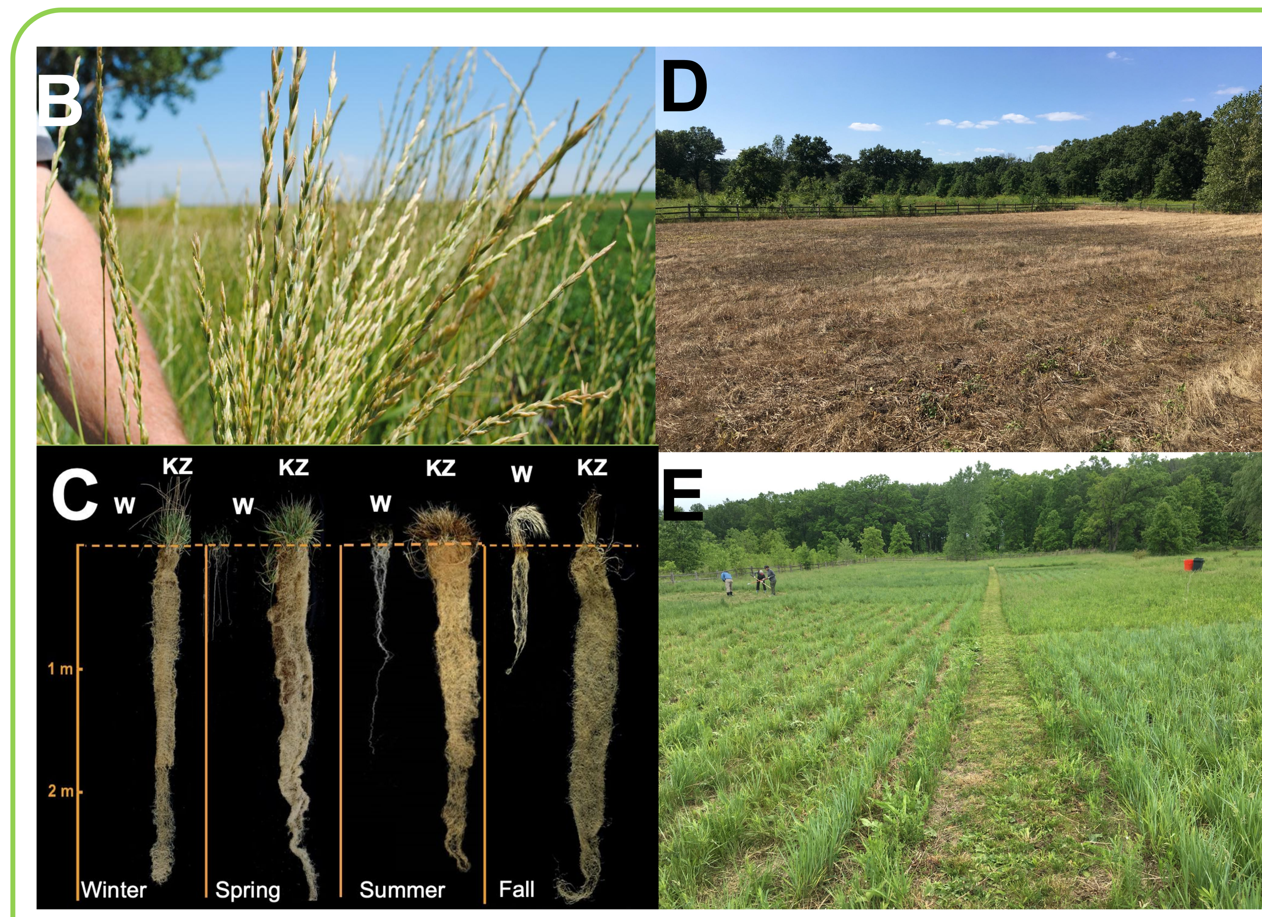


Figure 1. A) Conceptual diagram of annual wheat and kernza rooting patterns and nutrient cycling capacities; B) Kernza grain; C) temporal patterns of root distribution in annual wheat (W) and Kernza (KZ); D) experimental site before crop treatments were installed (2018); E) experimental site showing crops after three years of growth (2021).

Credits: A, Adapted from DeHaan et al. (2020); B, C, The Land Institute; D, E, the authors.

METHODS

Our study site was established in 2018 in a degraded agricultural field in Mettawa, IL (42°14'N 87°55' W) and contains replicated plots of Kernza, Kernza biculture (Kernza- alfalfa), annual wheat, forage grass (pasture), prairie, and fallow (Fig.1 D, E). In May, June, and July 2021, soil samples (10 cm deep, ~4 cm diam.) were collected in each plot and analyzed for microbial biomass (as substrate induced respiration, SIR [2]), and four soil microbial enzymes associated with carbon, nitrogen and phosphorus cycling [3] (Table 1). Data were analyzed using a repeated-measures analysis of variance and post-hoc Tukey HSD tests using R v.1.2.5001 and the *vegan* and *Hmisc* packages.

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TABLE 1: Enzymes assayed, the nutrient cycle in which they participate, and target substrate for enzyme activity.

Enzyme	Nutrient	Target
β-glucosidase (BG)	Carbon	Cellulose
Phenol oxidase (PPO)	Carbon	Lignin
N-acetyl-glucosaminidase (NAG)	Nitrogen	Organic-bound N
Acid phosphatase (AP)	Phosphorus	Mineral- or organic-bound P

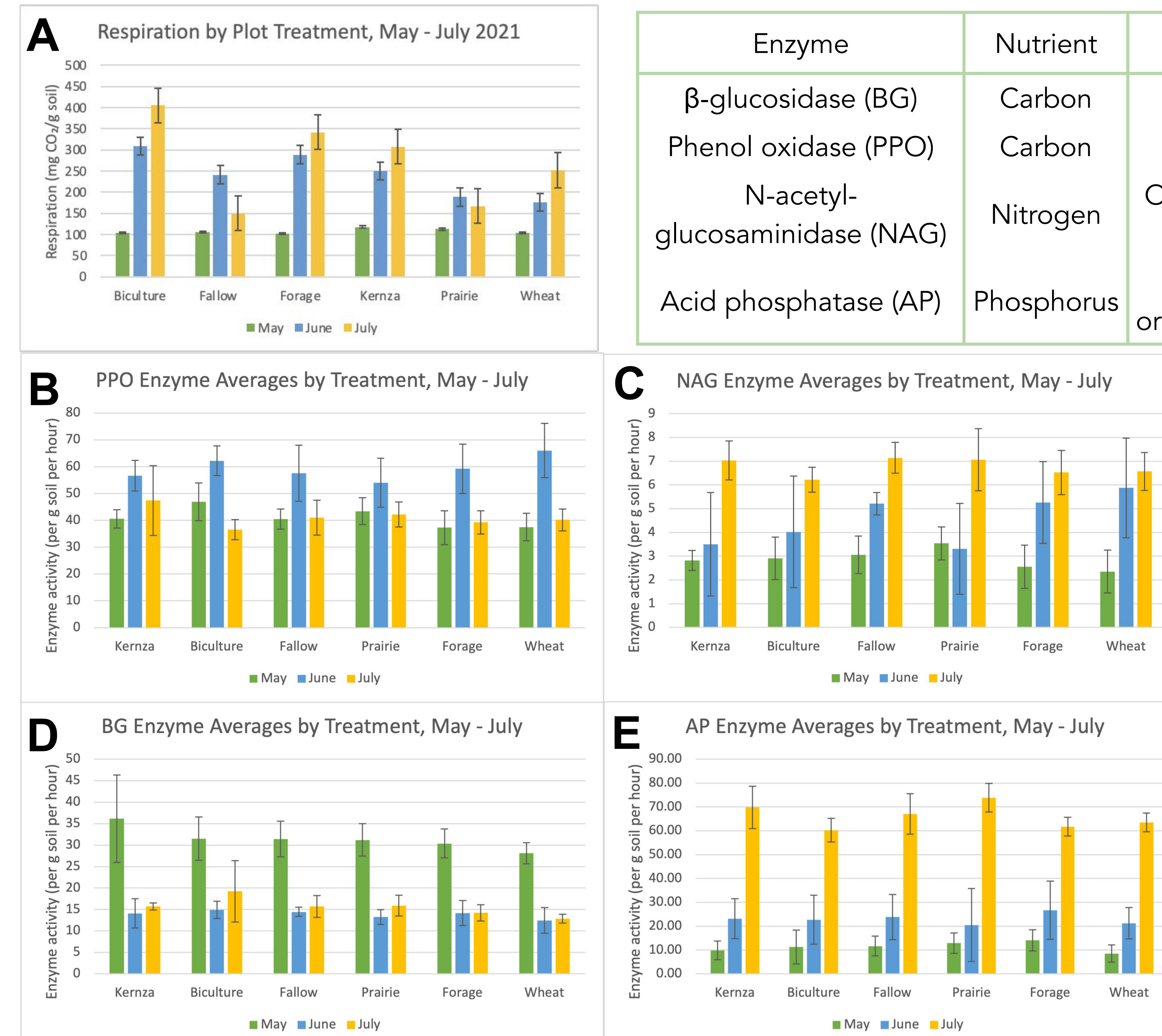

Fig. 2. A) Average SIR and enzyme activities for each crop treatment in May, June, and July 2021. B) Phenol oxidase (PPO); C) n-acetyl-glucosaminidase (NAG); D) β-glucosidase (BG); E) acid phosphatase (AP). Vertical bars indicate the standard deviation (n = 4 per crop).

RESULTS

- Respiration (SIR; Fig. 2A) activity varied significantly between sampling times ($p = 0.006$), but not between crop treatments ($p > 0.05$), and increased throughout the growing season.
- Enzyme activities also showed strong and significant temporal patterns of activity ($p < 0.001$) with no significant difference in enzyme activity between crops ($p > 0.05$).
- β-glucosidase (BG) activity was highest in May (Fig. 2B) and phenol oxidase (PPO) in June (Fig. 2C), with n-acetyl-glucosaminidase (NAG) and acid phosphatase activities highest in July (Figs. 2D, E, respectively). This pattern indicates organic matter (fine root) decomposition (BG, PPO) during a period of relative drought[4] followed by a shift to nutrient cycling (NAG, AP) with a return to average rainfall (July).

CONCLUSIONS

Our results do not provide support for our initial hypothesis. Instead, we found that microbial abundance (SIR) and function (enzyme activity) were more responsive to sampling time than crop treatment. It is possible that analyses of host-specific beneficial and pathogenic microbes may yield different insights of how Kernza may stimulate soil health. Kernza seems to have the potential for soil stability benefits, but this research is not conclusive. However, these plots are only three years old and data from August 2021 has not yet been taken, so ecosystem services might increase over time. Further research is needed at this site to determine Kernza's effect on restoring degraded soils.