The Interdependence of Soil Function and Biological Diversity: Lessons from an 8-year Cover Crop Study in Semi-Arid Montana, USA

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Fig. 1: Crop field

INTRODUCTION

Measuring soil biological diversity is a significant task, but even more challenging is interpreting what that diversity means in terms of ecological function. We provide an example in a study on the effects of cover crop mixtures (CCM) on soil properties in a semi-arid system. Dryland wheat farming in the northern Great Plains (USA) occurs in climates with just enough precipitation to grow wheat profitably. Summer fallow has been widely practiced for decades as a way to store part of one year's precipitation for the next year's crop. While effective as a way to increase crop yield, the fallow year impacts soil quality as a result of reduced organic matter inputs and increased erodibility (1,2). We measured the effects of cover crop mixtures relative to fallow or a single-species pea cover crop on soil biological, chemical and physical parameters, along with yield and protein content of the subsequent year's wheat crop. Our questions:

1) Can CCMs change soil biological parameters compared to summer fallow?
2) Does functional group composition of the cover crop affect soil biological parameters?

METHODS

Our study took place in Montana, with two sites seeded to cover crops in 2012, and two additional sites seeded to cover crops in 2013. After 4 years, we continued with just two sites for an additional 4 years. Treatments were established in 10x12 m plots, randomly assigned within 4 blocks.

Table 1: Types of crops by year

Year	Amsterdam, Conrad	Bozeman, Dutton
2012	cover crop	--
2013	wheat	cover crop
2014	cover crop	wheat
2015	wheat	cover crop
2016	cover crop	wheat
2017	wheat	--
2018	cover crop	--
2019	wheat	--

Table 2: Treatments and response variables measured

Treatments	Response variables measured
1. Fallow (SF)	Soil enzyme activity (3,9)
2. Pea (PEA)	Potentially mineralizable N (PMN) (6)
3. Full mix (FULL)	Microbial biomass (4)
4. Nitrogen fixers	Mycorrhizal colonization (7)
5. Fibrous roots	Soil compaction
6. Tap roots	Soil water and N
7. Brassicas	Cover crop biomass
8. Full mix minus N- fixers	Wheat yield and grain protein
9. Full mix minus fibrous roots	
10. Full mix minus tap roots	
11. Full mix minus brassicas	

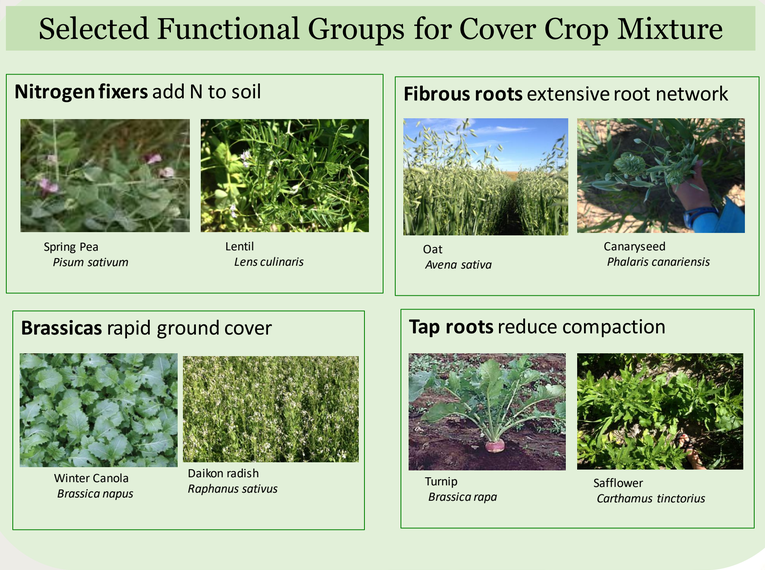

Fig. 2: Selected functional groups for cover crop mixture

RESULTS

Soil Enzymes

- After 2 CCM cycles, soil response to cover crops relative to fallow appeared cumulative, with greater differences after 2 rotations than 1 rotation.
- After 4 rotations, the increase in soil enzyme activity persisted at one of the two sites. Additionally, the amount of biomass produced by the cover crop mixture was more important than plant functional group identity.

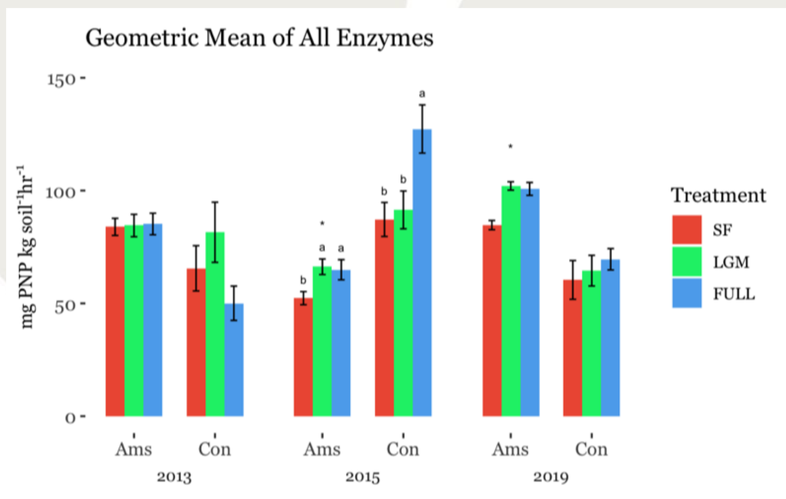

Fig. 3: Geometric mean of all enzymes

Potentially Mineralizable Nitrogen (PMN)

- We predicted that cover crops should increase PMN relative to fallow. This was true after 2 CCM cycles in 4 of the 8 site-years. (Just 2 sites shown on right)
- After 4 rotations, across two sites, the pattern of higher rates of PMN after cover crops than fallow was consistent at one site only.

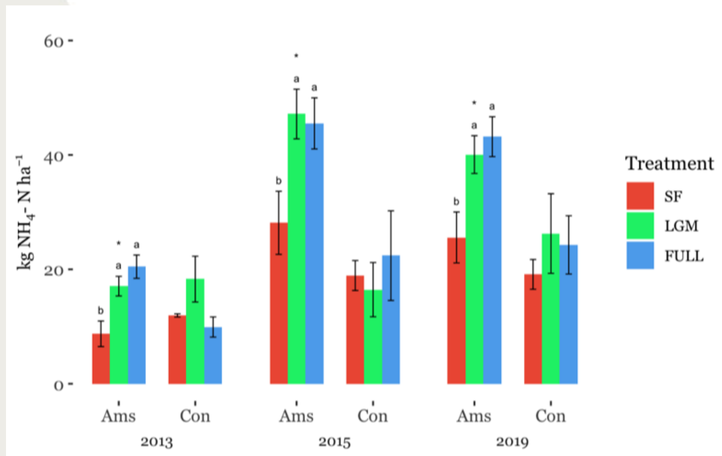

Fig. 4: Potentially mineralizable nitrogen

DISCUSSION

We did not measure differences in soil biological parameters between the single functional group treatments, suggesting that the diversity of cover crops is not as important as we expected. PMN and other responses were correlated to cover crop biomass and not species diversity. Additionally, in semi-arid systems, with a short period of cover crop growth between alternate year crops, soil biological traits increased in response to cover crops relative to fallow only during years with average or above average rainfall (5). These findings are complementary to studies that document shifts in biological communities with cropping intensification (8).

Acknowledgements

Funding was provided by Western SARE (Sustainable Agriculture, Research & Education), Montana Fertilizer Advisory Committee, USDA NIFA MONB00397. Thanks to producer partners Eric and Chad Doheny, Carl Vandermolen, and Herb Oehlke.