Soil-mediated effects on weed-crop competition

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Background

- Diversity can reduce competition through niche partitioning (Trenbath 1974; Harper 1977; Smith et al. 2009)

- Microbial-mediated resource hypothesis (Reynolds et al. 2003)
  1. Rhizosphere soil microorganism activity differs by plant species
  2. Diverse microbe-plant relationships mediate niche partitioning

- Resource pool diversity hypothesis (Smith et al. 2009)
  1. Agricultural practices such as cropping system diversity and fertilization strategy can influence soil resources
  2. Systems with more diverse resources can reduce crop weed competition

- Similar organic and conventional yields despite more weeds in organic systems (Ryan et al. 2010)

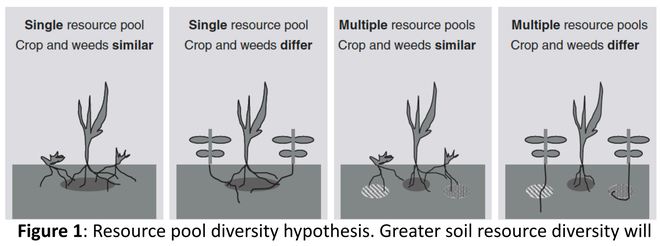

Figure 1: Resource pool diversity hypothesis. Greater soil resource diversity will drive niche partitioning and subsequent reductions in weed-crop competition [Figure from Smith et al. (2009)].

Questions and hypotheses

Does cropping system diversity influence weed-crop competition?

a. Does cropping system diversity affect soil physical, chemical, and biological properties?
   - ↳ Varied soil inputs in high-diversity systems will improve soil health

b. Do crops from more diverse cropping legacies have greater tolerance to weed density?
   - ↳ Greater niche partitioning in high diversity systems will reduce weed-crop competition

c. To what degree do soil microbe communities explain weed-crop competition trends?
   - ↳ Microbially-mediated resource pool partitioning will cause weed-crop competition trends to be maintained in "microbe-only" soils.

Experimental design

Field treatments (2016-2018)

- Four diversity treatments in annual and perennial systems

Treatment	**Low** 1 species 1 variety	**Conspecific** 1 species 4 varieties	**Heterospecific** 4 species 1 variety	**High** 4 species 4 varieties
Perennials	Alfalfa	Alfalfas	Alfalfa Orchardgrass Timothy White clover	Alfalfas Orchardgrasses Timothy White clovers
Winter annuals	Triticale	Triticales	Triticale Cereal rye Winter pea Red clover	Triticales Cereal ryes Winter peas Red clovers
Summer annuals	Sudangrass	Sudangrasses	Sudangrass Pearl millet Sorghum sudangrass Ryegrass	Sudangrasses Pearl millets Sorghum sudangrasses Ryegrasses

Figure 2: Field diversity and systems treatments. Figure modified from Bybee-Finley et al.'s (2018) poster: Double-Cropping & Intercropping in Northeastern Forage Cropping Systems to Enhance Resilience.

Field design

- Split-plot design with system as main plot and four experimental replicates

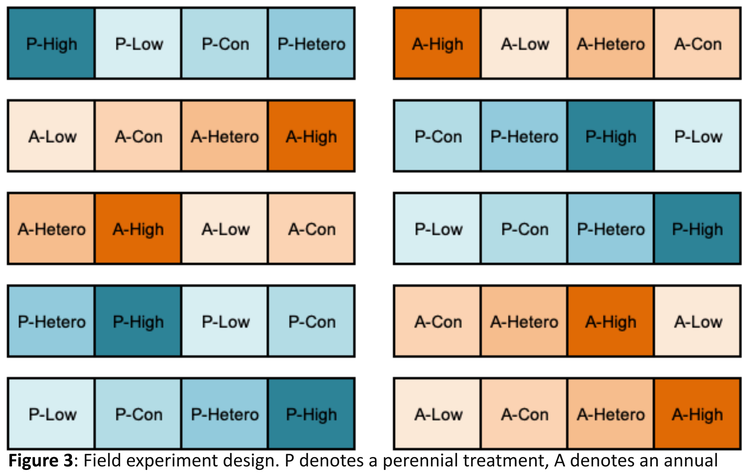

Figure 3: Field experiment design. P denotes a perennial treatment, A denotes an annual treatment.

Greenhouse weed-crop competition

- Split-split-plot design with system as main plot, diversity as subplot, and weed density as sub-sub plot
- All pots seeded with 1 sudangrass (*Sorghum* × *drummondi)* "crop" and 0, 1, 3, or 6 common lambsquarters *(Chenopodium album* L.*)* ("weed" at low to high densities)
- Competition gradient replicated in 50:50 field to sterile sand-vermiculite mix (nutrient and microbes: NM) and 5:95 field to sterile sand-vermiculite mix (microbes: M) for 272 total pots

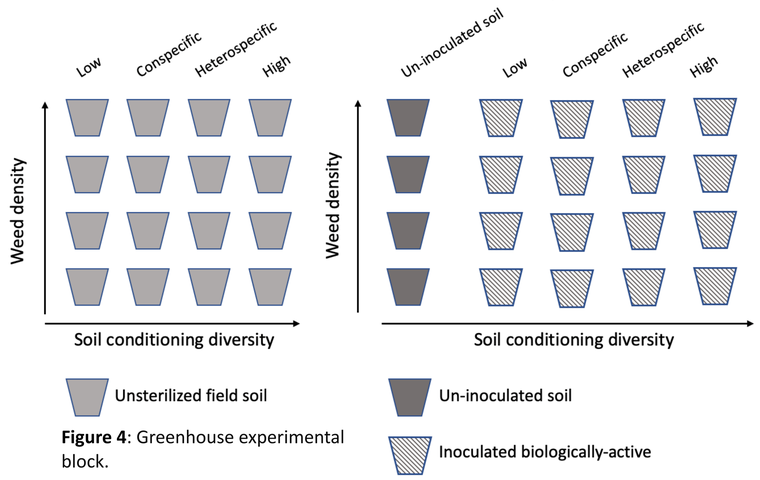

Figure 4: Greenhouse experimental block.

Sampling and analysis

Soil health

- We sampled 4 cores/plot 20 cm deep (128 samples) in fall 2018. Soils were sent to DaryOne and Cornell soil health for standard soil testing; microbial enzyme analysis was done at the Neher lab in UVM.
- Linear mixed effect models tested treatment for a diversity and system interaction while fitting field block as a random effect.

Weed-crop competition

- Plants were grown for 11 weeks (25°C for a 16 hr. photoperiod) after which we measured the biomass of each plant.
- Spitters (1983) competition model was fit using a non-linear mixed effects model with greenhouse block as a random effect.

$$Crop\ biomass = \frac{\frac{1}{a_0}31.8}{1+iW(Weed\ biomass)}$$ (Spitters, 1983)

a_0: Weed-free biomass; iW: fractional crop biomass loss per unit of weed biomass; N_c=31.8: Crop density

- Crop and weed biomass plotted and compared through F-tests

Results

Table 1. 2016 and 2018 soil health results. D: diversity effect (low, conspecific, heterospecific, or high), S: system effect (annual or perennial), and D*S: the diversity-system interaction. Treatments P, K, Mg, and Ca denote phosphorous, potassium, magnesium, and calcium. Treatment BG is β-glucosidase, LUC is L-leucine aminopeptidase, and NAG is β-1, 4-N-acetylglucosaminidase. All 2018 treatment effects were at the system level.

2016 P-values

	SOM %	bulk density	pH	aggregate stability %	gravametric moisture	respiration (mgC/g)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	BG	LUC	NAG
S	0.96	0.09	0.73	***0.05***	***0.01***	***0.01***	0.70	0.80	0.14	0.29	0.98	0.05	***0.01***
D	0.95	0.71	0.51	0.51	0.26	0.56	0.70	0.23	0.44	0.92	0.86	0.63	0.94
D*S	0.99	0.29	***0.01***	0.55	0.90	0.75	0.46	***0.03***	0.70	0.28	0.80	***0.01***	0.17

2018 P-values

	SOM %	bulk density	pH	aggregate stability %	gravametric moisture	respiration (mgC/g)	Log P (ppm)	Log K (ppm)	Mg (ppm)	Ca (ppm)	BG	LUC	NAG
S	0.96	***0.01***	***0.01***	0.40	***0.01***	0.45	***0.01***	***0.01***	0.30	***0.04***	0.95	0.59	0.72
D	0.74	0.08	0.45	0.40	0.52	0.92	0.68	0.65	0.63	0.76	0.33	0.49	0.30
D*S	0.94	0.50	0.47	0.52	0.91	0.96	0.43	0.26	0.70	0.38	0.23	0.82	0.24

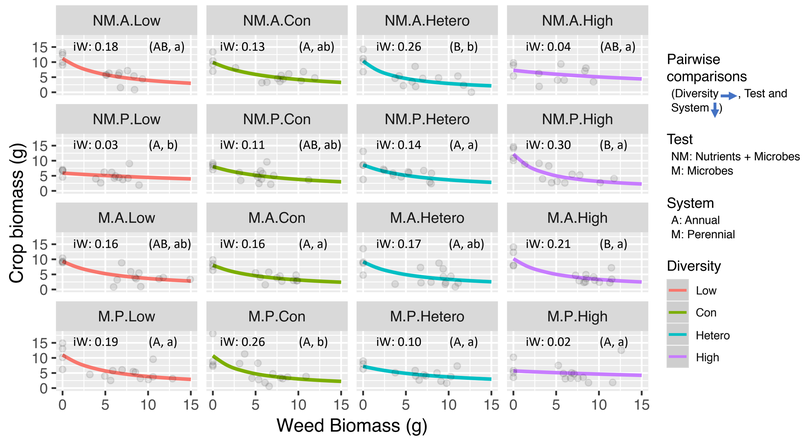

Figure 5. Crop tolerance to weed density. Pairwise comparisons between diversity (rows), system (columns), and nutrient-microbe treatments (columns). Crop tolerance differed with five diversity, three system, one test, and one system and test treatment change ($p<0.05$). Of the five diversity-induced pairwise differences in crop tolerance to weed density, 80% included the high diversity treatment. In 2/3 of system differences, the perennial system had lower competition (iW value). The nutrient microbe treatment had lower competition (iW value) than the microbe only treatment.

Conclusions

a. Most soil differences were at the cropping system level. Fertilization differences between systems might have driven the observed soil changes.

b. Weed-crop competition trends differed in annual and perennial cropping systems.

c. Competition trends were the same in all but one nutrient microbe vs. microbe treatment pair suggesting that microbe communities can replicate weed-crop competition trends.

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