Resuscitate Soil Health: Cover Crops and Nitrogen Management in Michigan Corn Production

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Introduction

- Increased weather variability may require improved nitrogen (N) management strategies that emphasize cropping system resilience in combination with reduced opportunities for N loss.
- Nitrogen cycling relies on microbial activity yet few data exist regarding how N management and cultural factors impact soil bacterial communities.
- Critical need to investigate alternative strategies that maximize plant genetic potential through incremental changes in soil health.

Objective

Determine the effect of cover crops individually and in combination with N placement and timing on temporal changes in soil health, soil and rhizosphere microbial community composition, and corn yield.

Materials and Methods

- Field studies conducted in Lansing, MI, 2014 to 2016.
- Conv. tillage following wheat.
- Split-plot RCB design with 4 replications (18 total treatments).
- Treatments are combinations of cover x N management strategy

Whole plot factor - Cover

- No Cover
- "The Buster" daikon radish (seeded 11.2 kg ha^{-1})
- "Magnum" forage oats (seeded 28.0 kg ha^{-1})

Sub plot factor – N strategy

- Zero N
- Pre-plant incorporated urea or poultry manure (4-3-2; 2.2 Mg ha^{-1}) (PM) followed by V11 SD.
- Subsurface starter (45 kg N ha^{-1}) placed 5-cm to the side and 5-cm below seed furrow (5x5) followed by V4, V11, or 50/50 V4/V11 split SD

- Total N rates equalized to maximum return to N (MRTN) rate of 179 kg N ha^{-1}.
- Corn (98-d relative maturity) was seeded in 0.76-m rows at 84,510 seeds ha^{-1}.
- Soils sampled on 4 dates from bulk soils and corn rhizospheres.
- Dual-index sequencing of soil 16S rRNA gene using Illumina MiSeq platform and MOTHUR curation pipeline.

Table 1. Cover crop quantity†, quality‡, and impact on soil respiration and soil labile amino-N content (SLAN) after 74 to 81 d of growth.

	Biomass	N content	SLAN	Respiration
	kg ha^{-1}	kg N ha^{-1}		mg CO_2 kg^{-1}
No Cover	--	--	121.3 b	15.2 b
Radish	9,959 a	189 a	126.5 ab	21.7 a
Oat	5,930 b	121 b	135.8 a	19.6 a
P>F	0.0002	0.0069	0.0623	0.0565

†Oat biomass included aboveground canopy only.
‡At March biomass harvest only oat residues were present (2922 and 46 kg ha^{-1} biomass and N content, respectively).

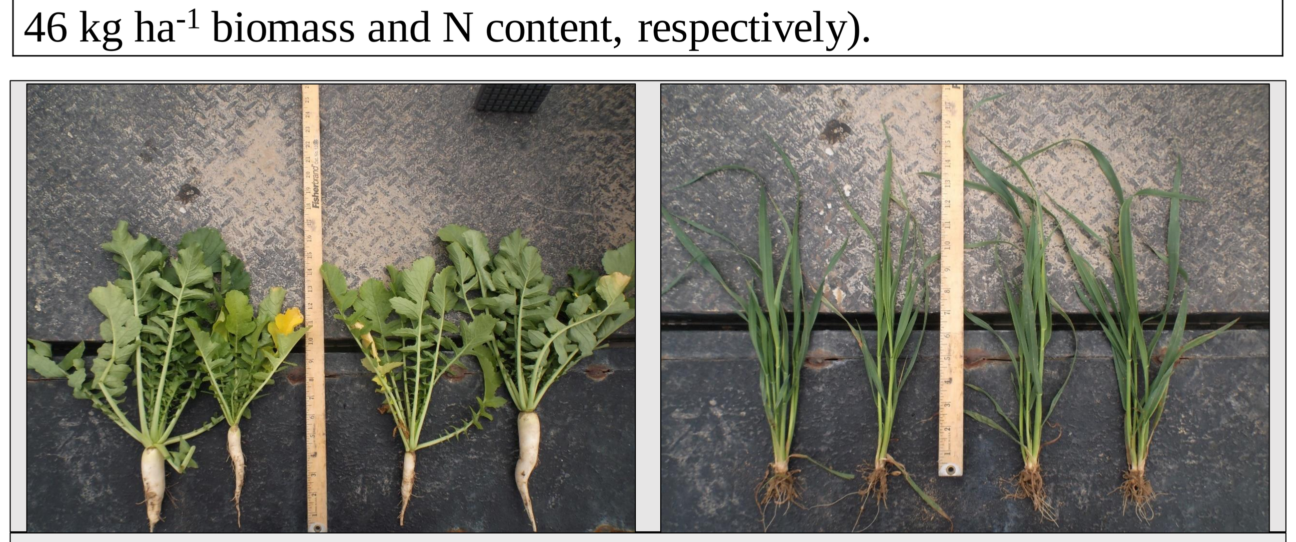

Figure 1. Cover biomass accumulation after 74 to 81 days of growth at autumn termination.

Table 2. Microbial respiration and corn grain yield as affected by cover crop and N management strategy, Lansing, MI, combined across years 2015-16.

Treatment	Respiration R1	Respiration R6	Grain Yield
	mg CO_2 kg^{-1}		Mg ha^{-1}
Cover Crop	--	--	--
No Cover	17.9 b†	20.4 a	14.7
Radish	21.2 a	20.9 a	14.5
Oat	20.3 a	20.3 a	14.2
N Strategy	--	--	--
Zero-N	19.5 b	21.9 a	11.6
Urea PPI	19.8 b	20.6 a	15.0
PM+ V11 SD	21.9 a	20.7 a	15.1
5x5 N + V4 SD	19.4 b	20.7 a	15.0
5x5 N + V11 SD	19.4 b	21.7 a	15.0
5x5 N + split SD	18.6 b	21.4 a	15.1
Source of Variation (*P*>F)	--	--	--
Cover Treatment (C)	0.0239	0.2130	0.0349
N Strategy (N)	0.0763	0.9120	<.0001
C x N	0.2885	0.4782	0.0712§

†Column values with the same lower case letter are not sig. different at α=0.10.
§Significant cover x N strategy interaction due to cover x zero N strategy (*P*=.0245). Significant grain yield means contrasting cover x zero N strategy presented below.

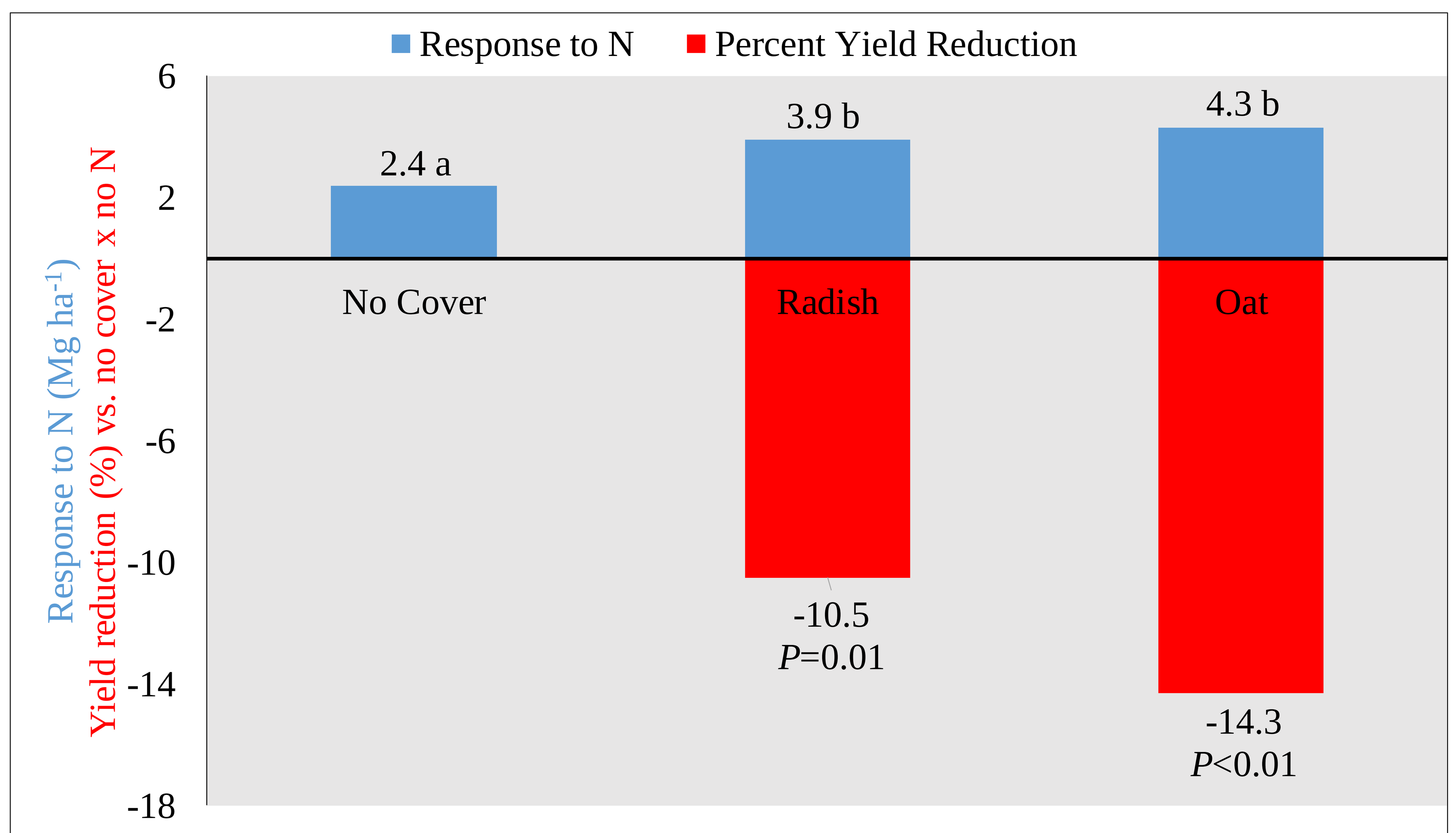

Figure 2. Impact of cover treatment on response to N fertilizer (mean yield from plots receiving N minus yield from zero N plots within each respective cover) and percent change in mean grain yield vs. no cover x zero N control using single *df* contrasts applying Dunnett's test to control Type I error rate, Lansing, MI, 2015-16.

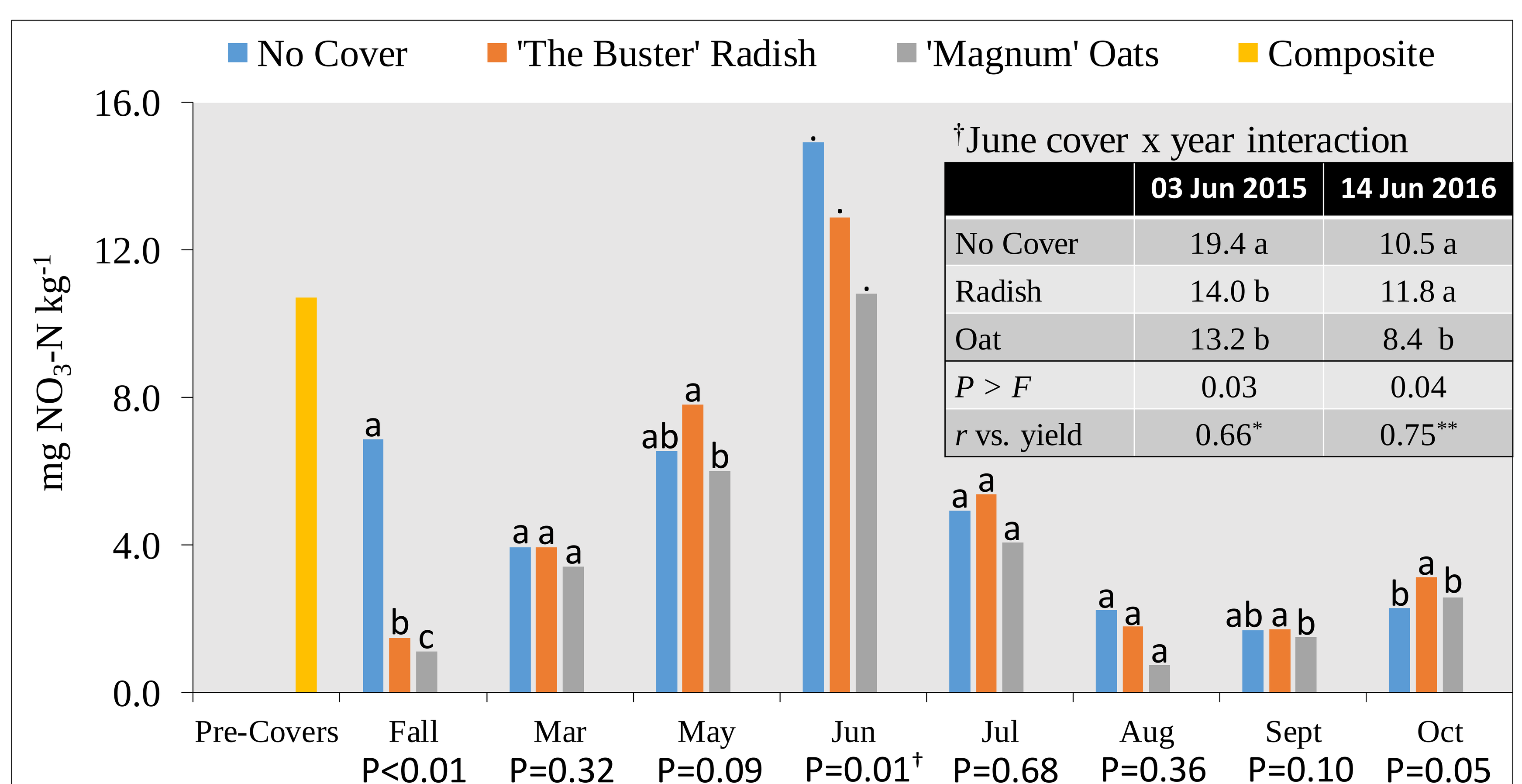

Figure 3. Impact of cover treatment only on monthly soil nitrate levels (0-30 cm depth), Lansing, MI, 2014-16. Bar clusters followed by the same letter are not sig. different at α=0.10.

Table 3. Cover crop and N strategy effects on inverse Simpson's diversity values (0-10 cm) at two soil sampling zones and two timings, 2015-16.

	Bulk Soil R1	Bulk Soil R6	Rhizosphere R1	Rhizosphere R6	*P > F*
2015†	R1	R6	R1	R6	--
No Cover	338 aB	317 bB	335 aB	370 aA	<.01
Radish	341 aA	366 aA	356 aA	354 aA	0.38
Oat	341 aB	353 aB	344 aB	381 aA	0.03
P > F	0.98	0.01	0.42	0.23	--
2016‡					
Zero-N	336 aB	366 aA	304 aC	309 bC	<.01
Urea PPI	342 aB	353 aAB	280 aC	371 aA	<.01
PM + V11 SD	320 aB	359 aA	288 aC	366 aA	<.01
5x5 N + V4 SD	310 aC	344 aB	199 cD	385 aA	<.01
5x5 N + V11 SD	344 aB	358 aB	225 bC	391 aA	<.01
5x5 N + split SD	317 aB	356 aA	221 bcC	381 aA	<.01
P > F	0.16	0.81	<.01	<.01	--

†In 2015 a sig. cover x soil sampling location x timing interaction (*P*=0.0091) was observed.
‡In 2016 a sig. N strategy x soil sampling location x timing interaction (*P*<.0001) was observed.
Means followed by the same lower case letter within a column and by the same upper case letter within a row are not sig. different at α=0.10.

Table 4. Pearson correlation coefficients relating Inverse Simpson's Diversity indices to grain yield at selected observation timings and soil sampling zones.

Soil Sampling Time – Zone	N Fertilizer - NO		N Fertilizer - YES	
(Soils 0 – 10 cm depth)	2015	2016	2015	2016
	r-value			
Cover harvest – bulk soil	0.38	-0.35	--	--
Corn planting – bulk soil	-0.29	0.67*	--	--
Corn R1 – bulk soil	-0.44	-0.35	-0.00	-0.45***
Corn R1 – rhizosphere	-0.63*	-0.53$^{0.08}$	0.05	-0.10
Corn R6 – bulk soil	-0.40	-0.72**	0.02	-0.42***
Corn R6 – rhizosphere	0.04	-0.34	0.13	-0.15

Results and Discussion

Lansing, Michigan

- In both years a radish cover crop produced 68% more biomass than an oat cover crop corresponding to a 56% increase in total N uptake. Oat cover increased SLAN 12% from a no cover while cover crops increased CO_2 respiration 29 – 43% indicating biological activity (Table 1, Fig. 1).
- At autumn termination, radish and oat cover crops reduced soil nitrate levels 78% and 84%, respectively, suggesting that a portion of total N taken up by oats remained in the roots since total N uptake observed was greater with radish (Table 1, Fig. 3).
- A cover crop x N strategy interaction was observed for corn grain yield (*P*=0.0245). Unfertilized radish and oat covers sig. reduced grain yield 10.5 and 14.3%, respectively, and increased yield response to N 63 to 79% from the no cover x no N control. This indicates fall N removed from the soil by the covers may not have been available during critical periods of rapid corn N uptake the following June (Table 2, Figs. 1 to 3).
- A three-way interaction which included soil sample zone and timing occurred for inverse Simpson's diversity index each year. Sample zone and timing had greater impact on overall community diversity than main factors. Negative correlation coefficients indicated increased community diversity often did not correspond to increased yield and inconsistent yearly trends suggest bacteria relative abundance may be more important than diversity for crop yield (Tables 3 and 4).