Contribution of no-till cover cropping to greenhouse gas remediation: Can nematodes tell the tale?

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Climate change, mostly drought, is already affecting the global agricultural supply. Global food experts warned that climate change could double grain prices by 2050 (United Nation, 2014).
Conservation Agriculture (CA)

- An approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment (FAO; Friedrich et al., 2012).

- 3 principles:
  1) planting with minimum soil disturbance,
  2) permanent soil cover (crop residues, cover crops),
  3) crop rotation.

http://www.fao.org/ag/ca/
Cover the soil at all time

Reduce soil disturbance

Grow a living root 24/7

Synergize with diversity: Crop rotation/Cover crop

2015 International Year of Soils
Types of Conservation Tillage

- Reduced/minimum/zero/No-tillage
- Direct drilling
- Ridge till
- Strip-till

Strip-till

Ridge-Till

Flail mower

After flail mowing

Roller crimper/ No-till drill
Overall Goals of Project

Evaluate the influences of conventional and conservational tillage systems in the transitioning organic vegetable production on N availability, pest dynamics, soil health, greenhouse gas emissions, and crop performance.
Questions to be addressed

- Can conservation tillage practice mitigate greenhouse gas emission in organic vegetable cropping systems in the Northeast of U.S.?
- Does the use of nematodes as soil health indicators correspond to GHG mitigation?
- Does improving soil health mean improved crop yield (food security)?
How Does Conservation Tillage Mitigate Greenhouse Gas (GHG) emission?

- decrease use of fossil fuels in field preparation
- increase carbon sequestration in soil
- increased CH₄ uptake

Impacts of Agriculture to GHGs Emission

- Globally, agriculture accounts for 10–12% of total anthropogenic emissions of greenhouse gases (GHGs), ~ 5.1–6.1 Gt CO₂-eq yr⁻¹ in 2005 (Smith et al., 2007)
- In recent decades, widespread adoption of no-till has occurred over approximately 125 million hectares, equivalent to 9% of global arable land (FAO, 2011).
Tilled soil produced 26% greater global warming potential (GWP) than zero tilled soil ($P < 0.05$).
Field Trials at the University of Maryland, Upper Malboro

- Four tillage treatments:
  - Conventional tillage
    1) Bare ground – BG
    2) Black plastic mulch - BP
  - Conservational tillage
    3) Strip tillage - ST
    4) No-tillage – NT
- RCBD, 4 replications, 3 trials

Vegetables (MD)
2012 2013 2014

- Winter cover crop mix in all treatments: forage radish (*Raphanus sativus*), crimson clover (*Trifolium incarnatum*) and rye (*Secale cereale*)
- Cover crop was flail-mowed in all plots.
- Conventional tilled: rototilled/chisel plowed followed by diskng.
- Seedlings were transplanted.
- Same amount of organic fertilizer (140 kg N ha⁻¹) for all plots either soil incorporate or as side dressing.
Total $N_2O$ –N emission

- No difference in $CO_2$ emission.
- BP emitted the most $N_2O$.
- Difference among NT, ST and BG was not clear.
Total $N_2O$ –N emission
(2012 data could not be properly estimated with repeated measure)

- BP heat up the soil, enhanced more denitrification of nitrate, thus more $N_2O$ released.
- Lack of $N_2O$ mitigation by NT in 2014 was possibly due to a wet season and over irrigated field.
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Covering soil with black plastic increased $N_2O$ emission.
Nematodes as Indicators of Soil Health

Bacterivore  Fungivore  Herbivore  Omnivore  Predator

El=Enrichment index
Cl=Channel index

SI=Structure index
+ richness, diversity

Till in organic matters
Reduce tillage
Low CI in BP indicating bacteria-dominated decomposition, that could lead to more denitrification.
BG=Bare Ground
BP=Black plastic
NT=No till
ST=Strip till

Significant Contrast ($P < 0.05$) by dates:
M = Mulched vs no-mulch
T = Till vs conservation till
ST = Strip-till vs No-till

- NT continued to increase SI, and gradually enhanced EI.
- BP heat up the soil, increased bacterial decomposition, lead to lowest CI.
NOAA National climate data recorded that summer of 2014 in NE of the U.S. was much wetter and warmer than average.

Lack of tillage effect on nematode community indices over time, except that tillage consistently reduced Structure Index (SI) early in the season.

BG=Bare Ground
BP=Black plastic
NT=No till
ST=Strip till
Scatter Plot of Environmental Variables and Nematode Trophic Groups

- Bare ground (BG)
- Black plastic (BP)
- No-till (NT)
- Strip-till (ST)

2012
Scatter Plot of Environmental Variables and Nematode Trophic Groups

- □ = Bare ground (BG)
- ◆ = Black plastic (BP)
- ▼ = No-till (NT)
- ○ = Strip-till (ST)

2013
Scatter Plot of Environmental Variables and Nematode Trophic Groups

Effects of conservation tillage on soil health could be affected by climate. Three years might be too short to see a clear trend on its impact on soil health.
Canonical Correlation Analysis b/t Abundance of Nematode Trophic Groups and Environmental Data

First & second axes accounted for 90.4%, 88.1% and 86.0% of the cumulative variance of CCA in 2012, 2013, and 2014, respectively.
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\[ \text{N}_2\text{O} \text{ emission was negatively correlated to SI and CI consistently over the 3 years, but positively correlated to EI especially in 2012.} \]
Eggplant Yield in 2012 and 2014

 Marketable yield:

A. Jul. 16 to Aug. 21, 2012

B. Jul. 25 to Sep. 12, 2014

- Plant growth in NT plots was relatively slower, extending harvest period could achieve full benefit;
- Cooler temperature may reduce yield regardless of tillage treatments.
**Sweet Corn Yield in 2013**

Sweet corn yield: quantity and quality in 2013

- ST had the highest plant population and most ears;
- BP had the lowest marketable yield due to the combination of higher insect damage and fewer ears;
- NT had the least insect damage.
Nature (Pittelkow et al., 2014): No till reduce 5-6% yield based on one of the largest meta-analysis conducted in agriculture (5000 side-by-side observations from 610 studies of 48 crops in 63 countries).

But yield losses were not as severe when the three principles of CA (no-till, residue retention and crop rotation) were practiced together.

In fact, NT increased yield in drought conditions.
Summary

- This experiment did not provide clear evidence that conservation tillage (NT, ST) reduced N$_2$O, but covering soil with BP after tilling increased N$_2$O emission.

- Although nematode community structure varied within each growing season, NT and ST maintained higher SI, whereas BP or BG supported higher EI (more bacteria decomposition) early in each growing season.

- Whereas effects of tillage on N$_2$O emission and nematode community structure were not consistent, maintaining higher SI followed by CI were corresponding to lower N$_2$O emission.

- NT only reduced eggplant yield in the first year, ST increased corn yield in 2013. Other ecosystem services provided by NT resulted in lowest insect damage on corn.
Acknowledgement

- This research was supported, in part, by USDA NIFA ORG Program (2011-51106-31203) and in part by USDA NRCS CIG (69-3A75-14-231).
- Magaret MacDonald and Dr. Susan Meyer for processing and shipping nematode samples to Hawaii.