College of Tropical Agriculture and Human Resources
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USDA ARS

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

Koon-Hui Wang[1], Guihua Chen[2], Zhiqiang Cheng[1],
Susan L.F. Meyer[3], and Cerruti R.R. Hooks[2]

Climate Change, Ecosystem Sustainability, and Food Security

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/

unlock the SECRETS IN THE SOIL

2015 International Year of Soils

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

Types of Conservation Tillage

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

Strip-till

Ridge-Till

Overall Goals of Project

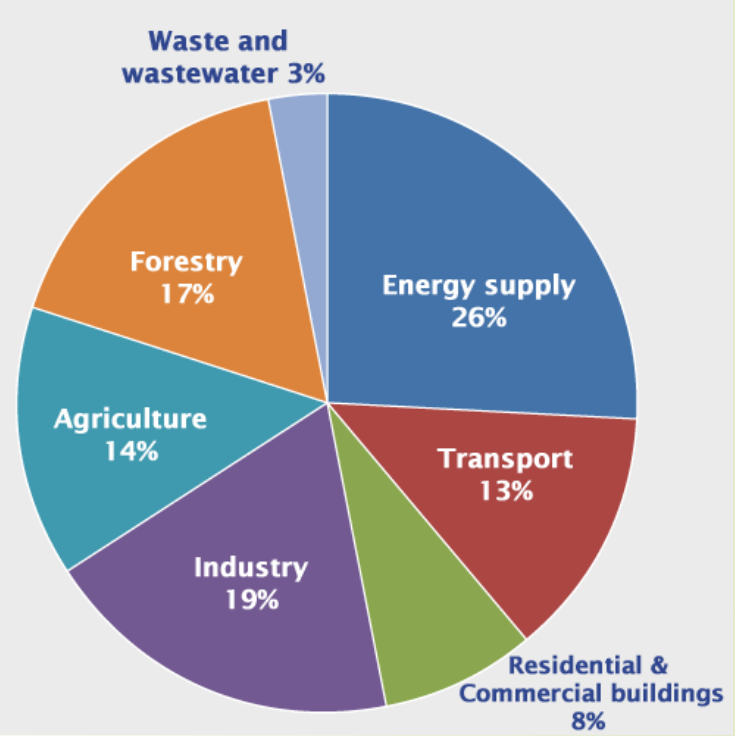
Evaluate the influences of conventional and conservational tillage systems in the transitioning organic vegetable production on N availability, pest dynamics, soil health, greenhouse gas emissions, and crop performance.

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 CH_4 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 CO_2-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).

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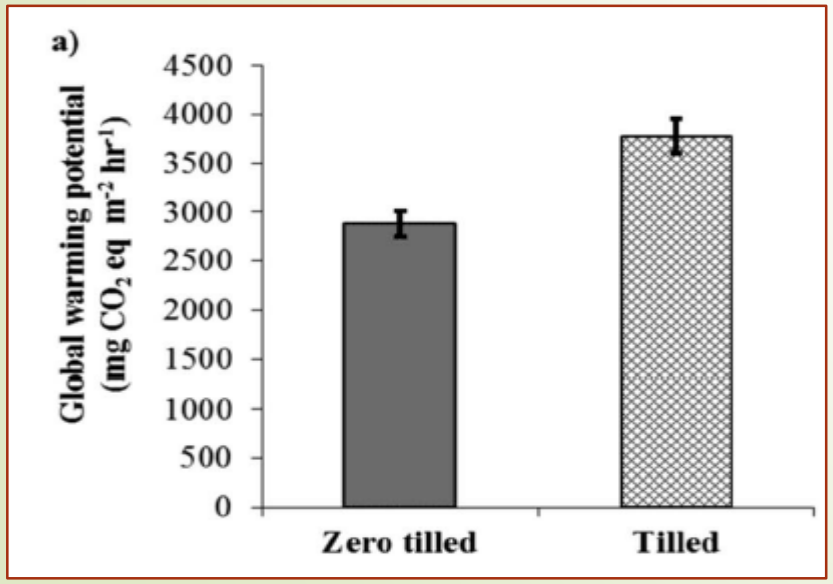
SCIENTIFIC REPORTS | ARTICLE OPEN

To what extent can zero tillage lead to a reduction in greenhouse gas emissions from temperate soils?

Shamsudheen Mangalassery, Sofie Sjögersten, Debbie L. Sparkes, Craig J. Sturrock, Craigon & Sacha J. Mooney

CO_2, CH^4
N_2O



Tilled soil produced 26% greater global warming potential (GWP) than zero tilled soil ($P < 0.05$).

(Nature Scientific Reports 4 (2014): article 4586)

Field Trials at the University of Maryland, Upper Malboro

- **Four tillage treatments:**

Conventional tillage

1) Bare ground – **BG**
2) Black plastic mulch -**BP**

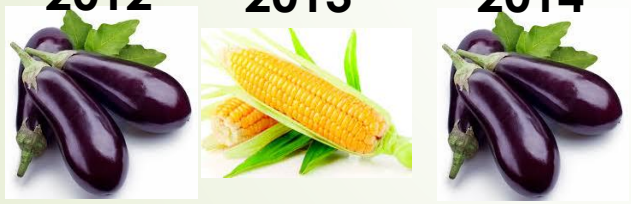
Conservational tillage

3) Strip tillage -**ST**
4) No-tillage – **NT**

- **RCBD, 4 replications, 3 trials**

Vegetables (MD)

2012 **2013** **2014**



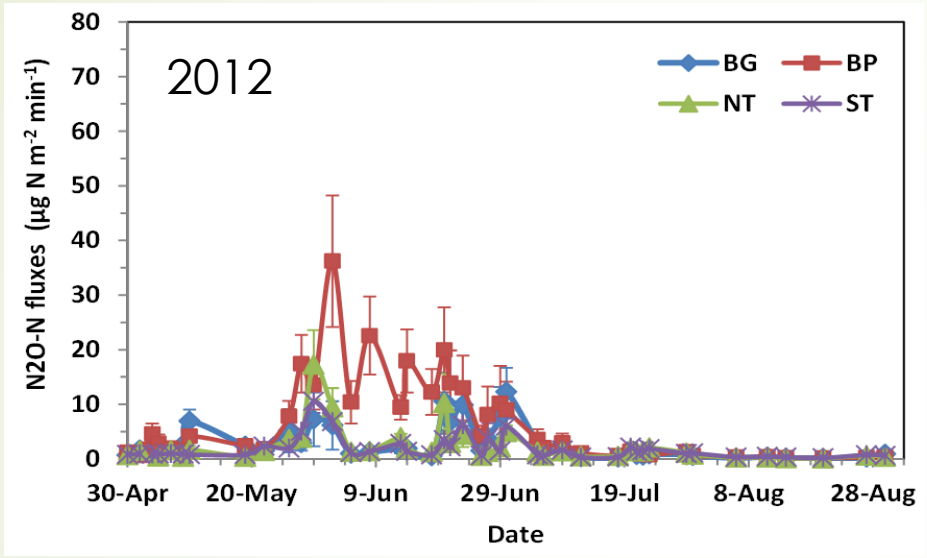
Winter cover crop mix in all treatments: forage radish (*Raphanus sativus*), crimson clover (*Trifolium incarnatum*) and rye (*Secale cereale)*

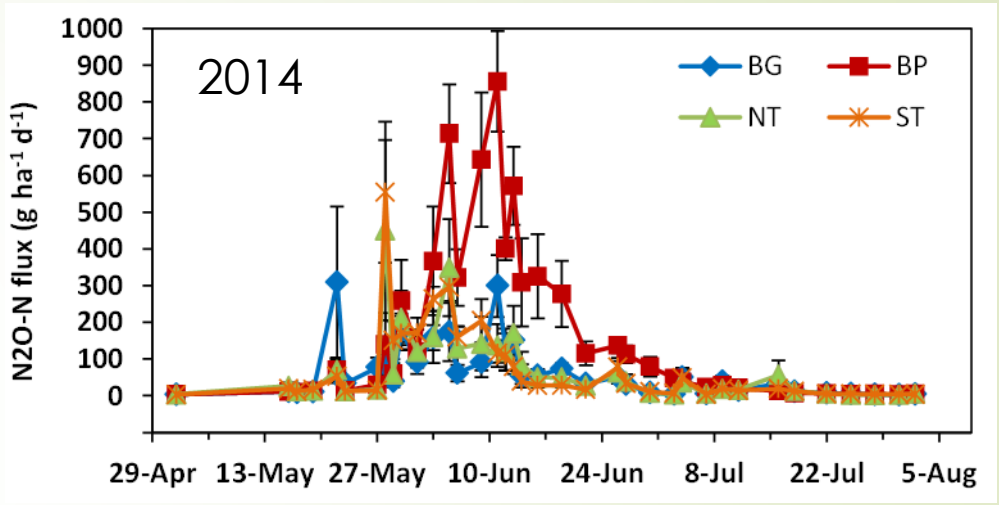
- Cover crop was flail-mowed in all plots.
- Conventional tilled: rototilled/chisel plowed followed by disking.
- Seedlings were transplanted.
- Same amount of organic fertilizer (140 kg N ha^{-1}) for all plots either soil incorporate or as side dressing.

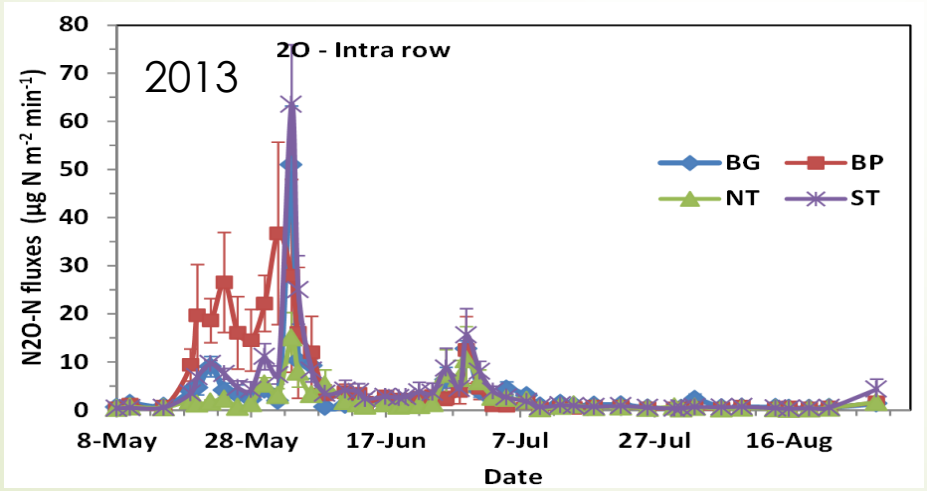
Total N_2O –N emission

CO_2
N_2O

Taking gas samples





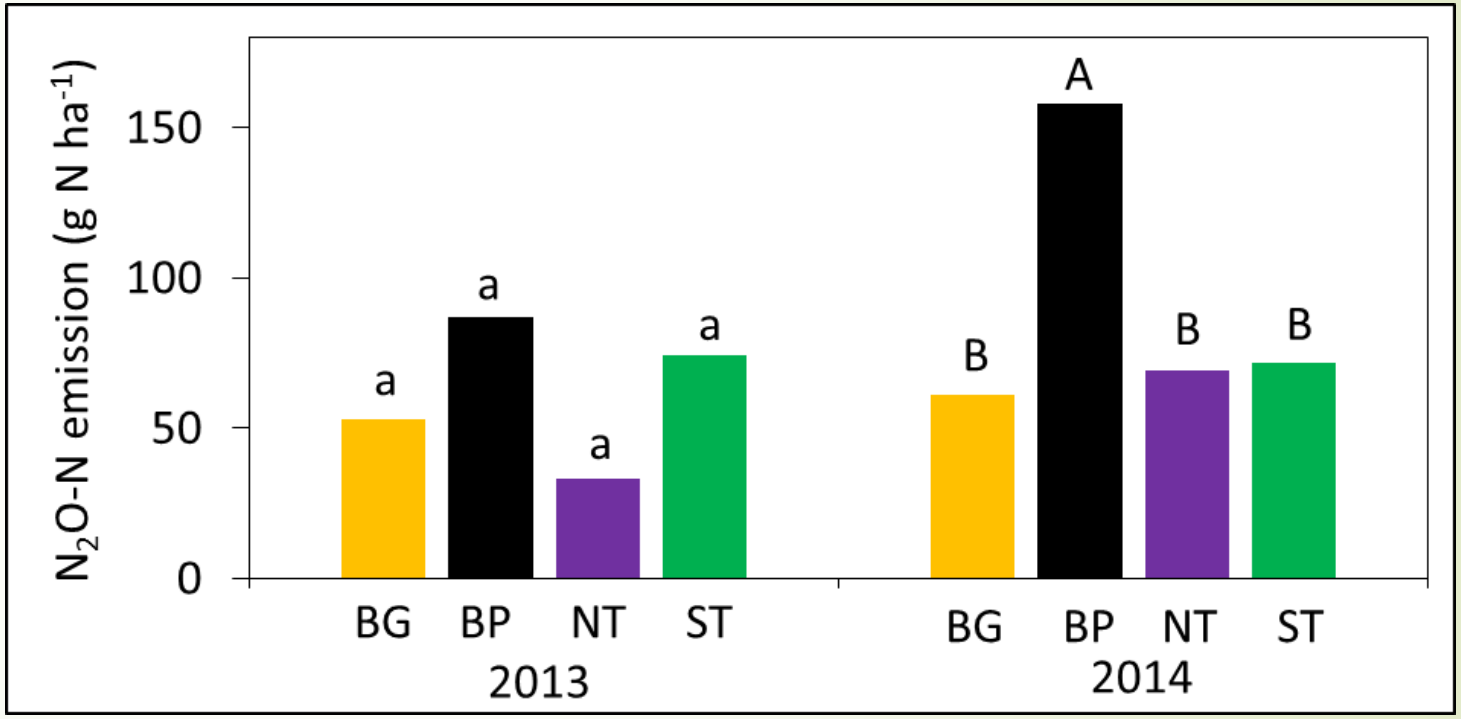


- No difference in CO_2 emission.
- BP emitted the most N_2O.
- Difference among NT, ST and BG was not clear.

Total N_2O –N emission

(2012 data could not be properly estimated with repeated measure)

Taking gas samples



- 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

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)?

Covering soil with black plastic increased N_2O emission.

Nematodes as Indicators of Soil Health

Bacterivore **Fungivore** **Herbivore** **Omnivore** **Predator**

EI=Enrichment index

CI=Channel index

Till in organic matters

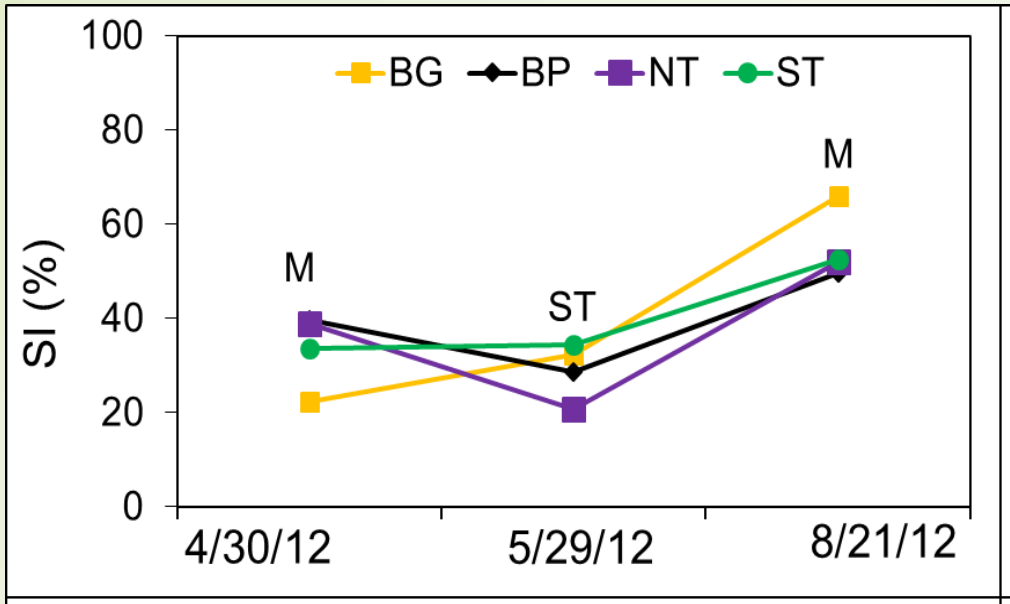
SI=Structure index

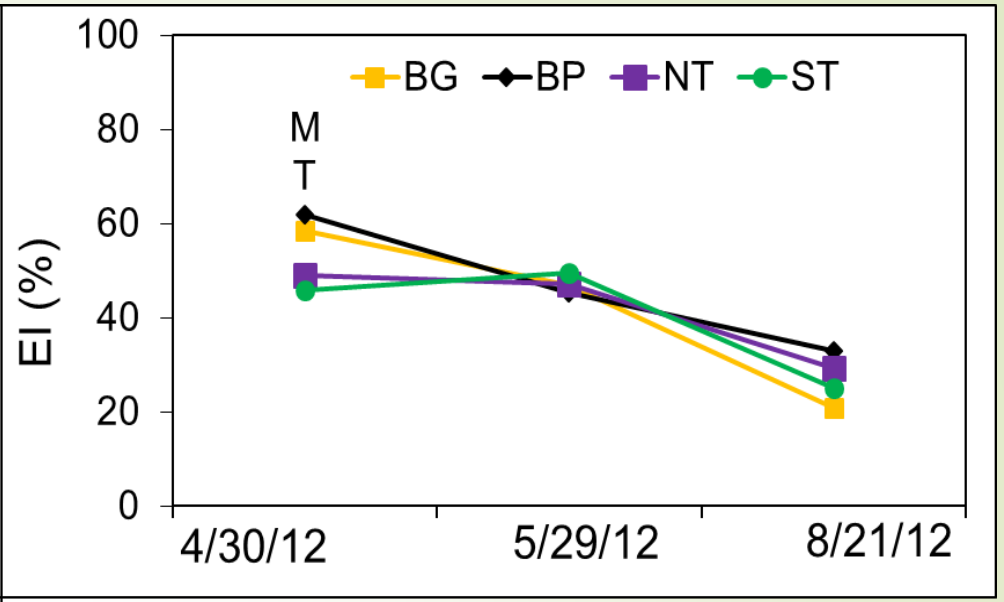
+ richness, diversity

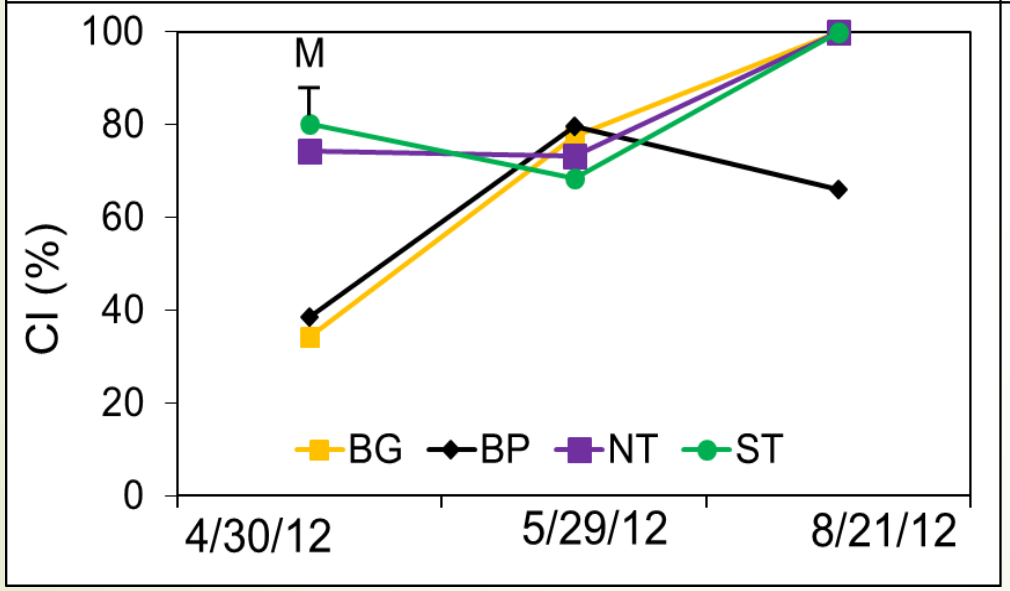
Reduce tillage

2012

BG=Bare Ground
BP=Black plastic
NT=No till
ST=Strip till







Significant Contrast ($P < 0.05$) by dates:

M = Mulched (BP, NT, ST) vs no-mulch (BG)

T = Till (BG, BP) vs conservation till (NT, ST)

ST = Strip-till (ST) vs No-till (NT)

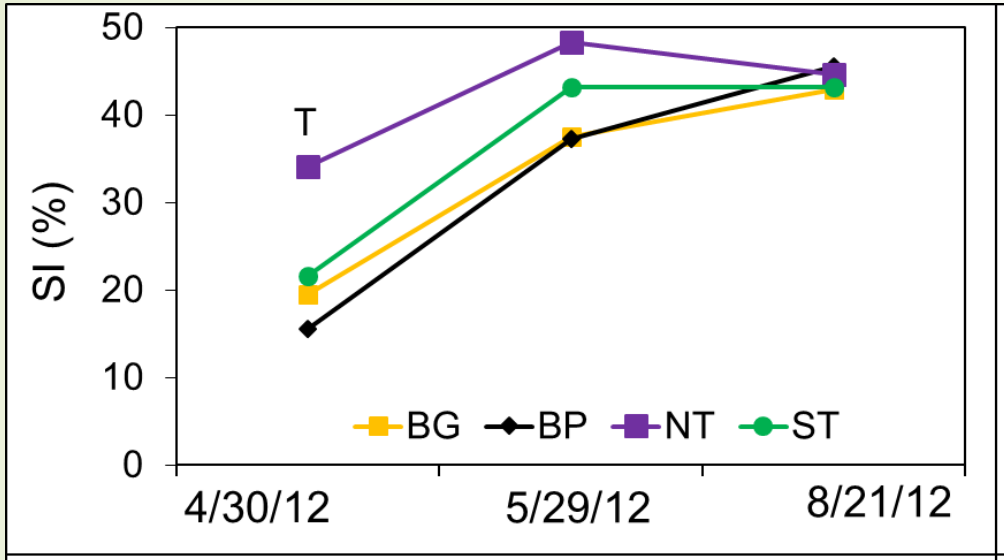
- Low CI in BP indicating bacteria-dominated decomposition, that could lead to more denitrification.

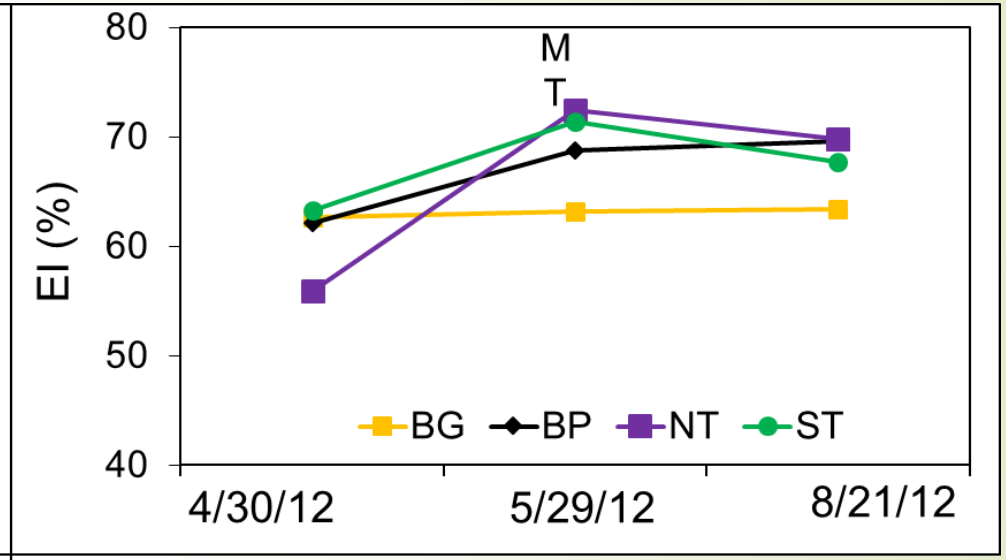
2013

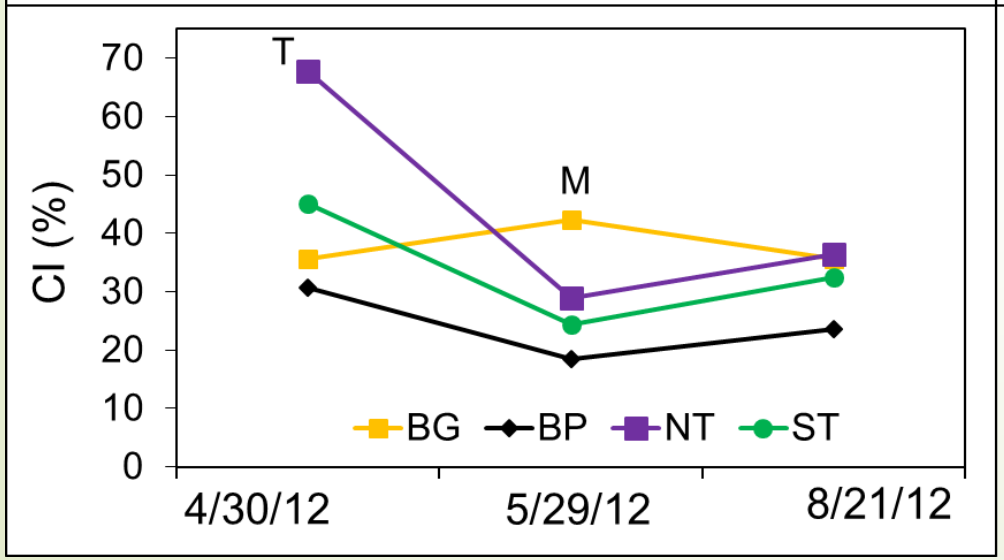
BG=Bare Ground
BP=Black plastic
NT=No till
ST=Strip till

Significant Contrast ($P < 0.05$) by dates:

M = Mulched vs no-mulch
T = Till vs conservation till
ST = Strip-till vs No-till



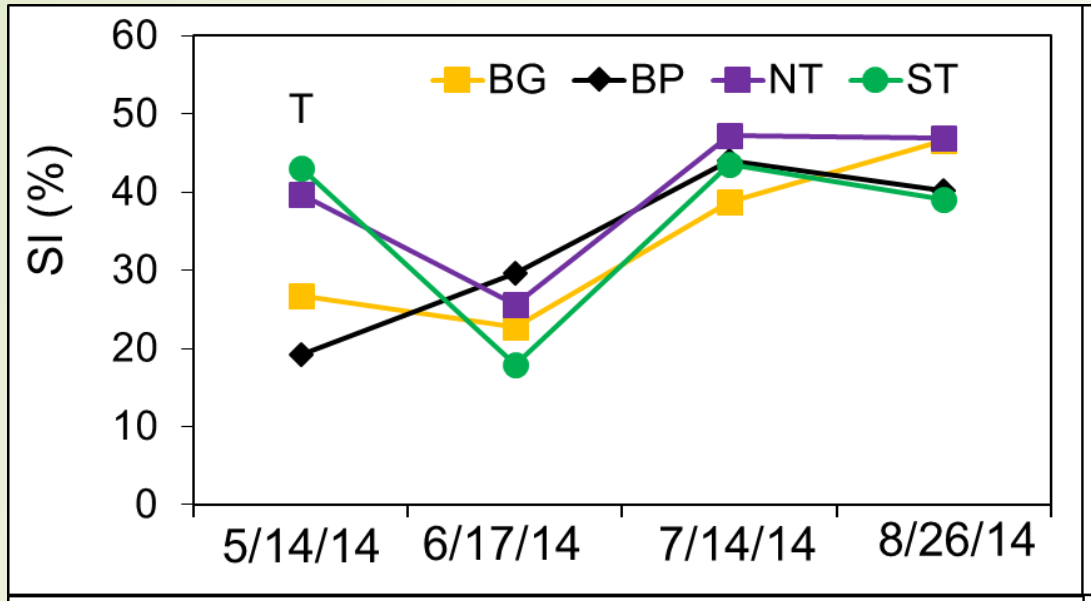


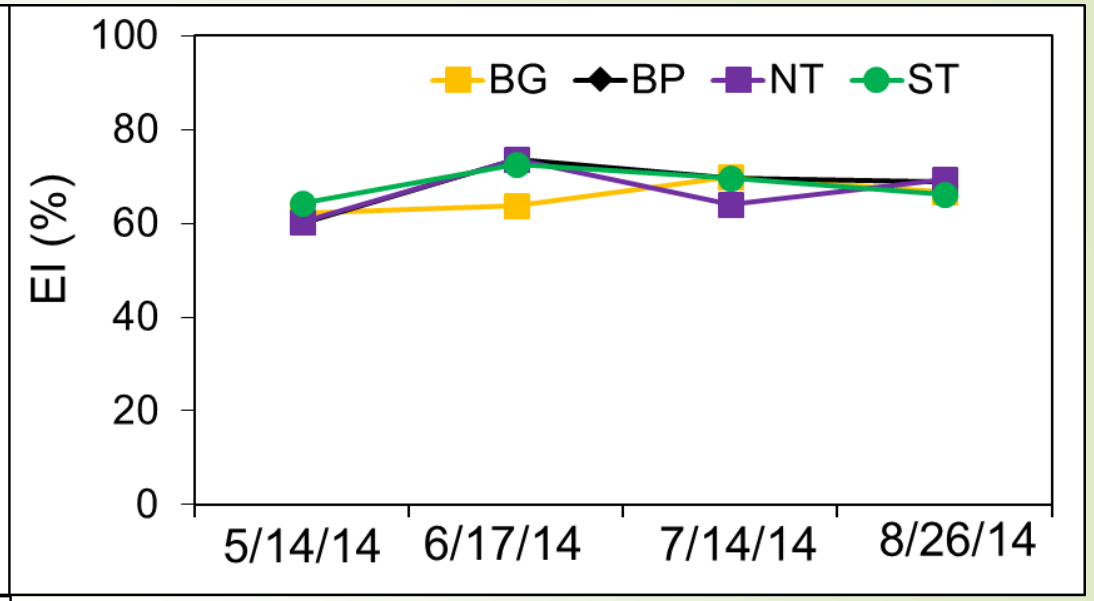


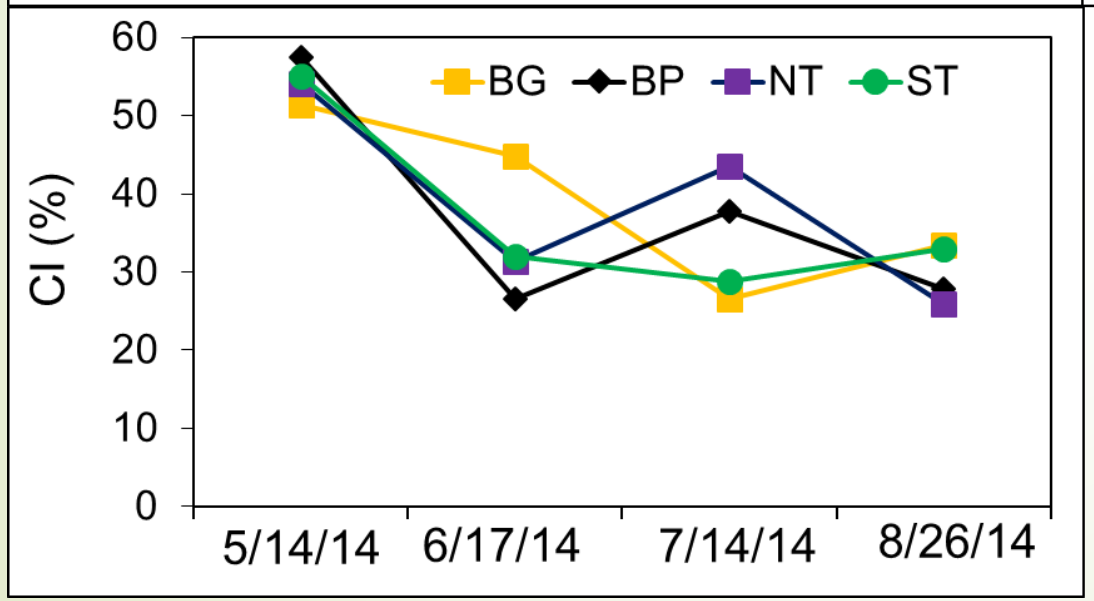
- NT continued to increase SI, and gradually enhanced EI.
- BP heat up the soil, increased bacterial decomposition, lead to lowest CI.

2014

BG=Bare Ground
BP=Black plastic
NT=No till
ST=Strip till



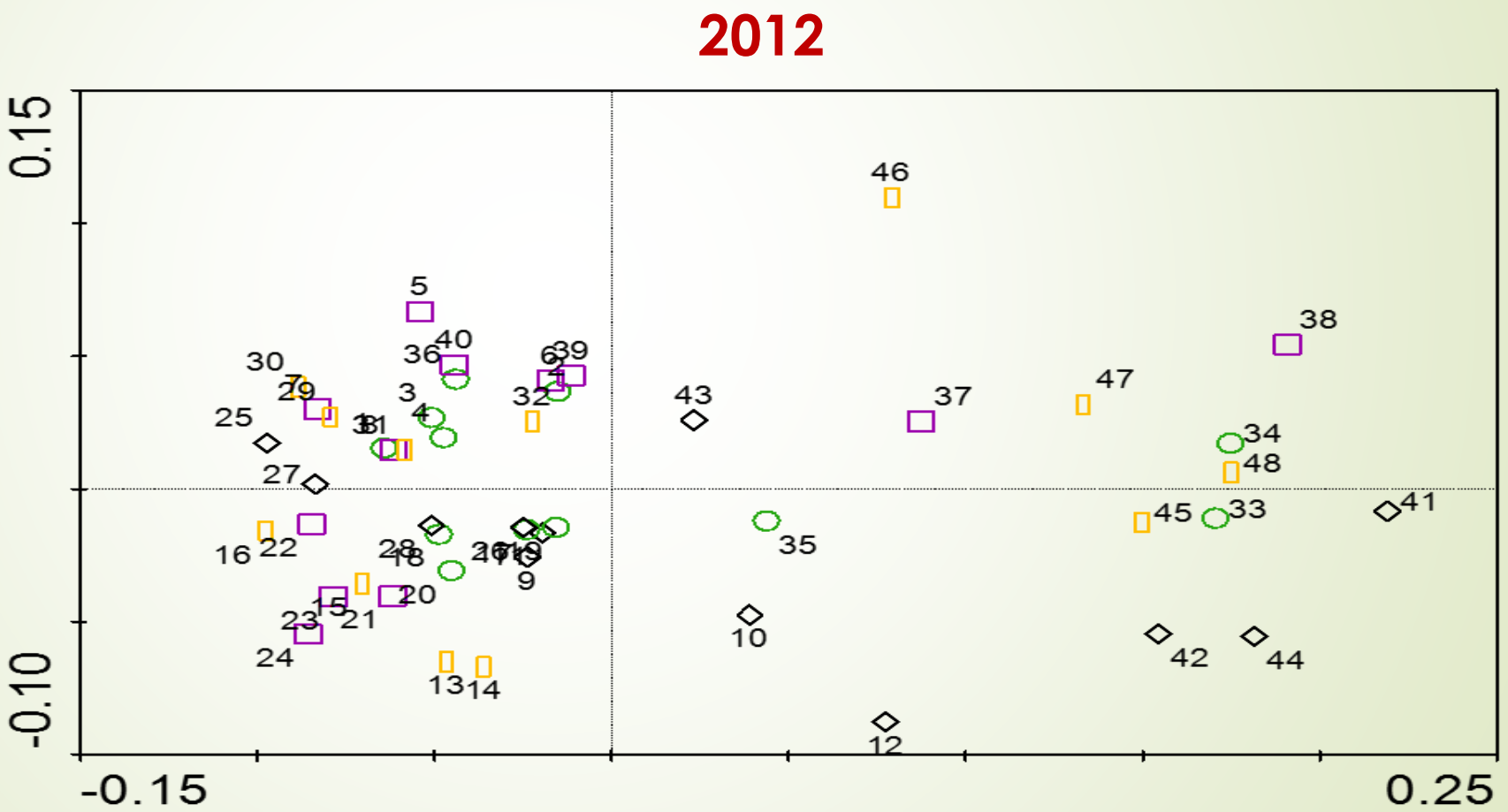




- NOAA National climate data recorded that summer of 2014 in NE of the U.S. was much wetter and warmer than average.
- Lack of tillage effect on nematode community indices over time, except that tillage consistently reduced Structure Index (SI) early in the season.

Scatter Plot of Environmental Variables and Nematode Trophic Groups

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



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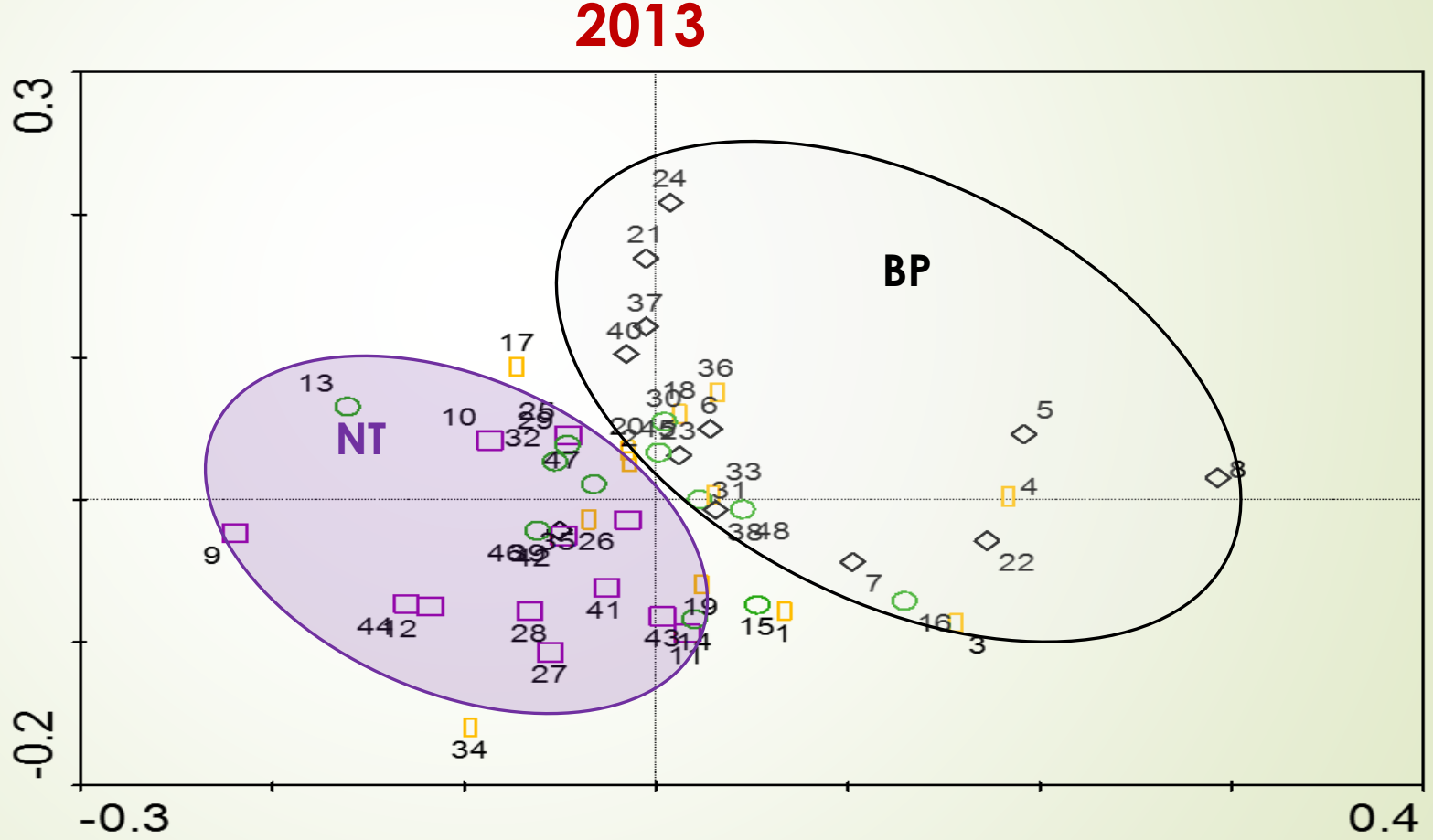
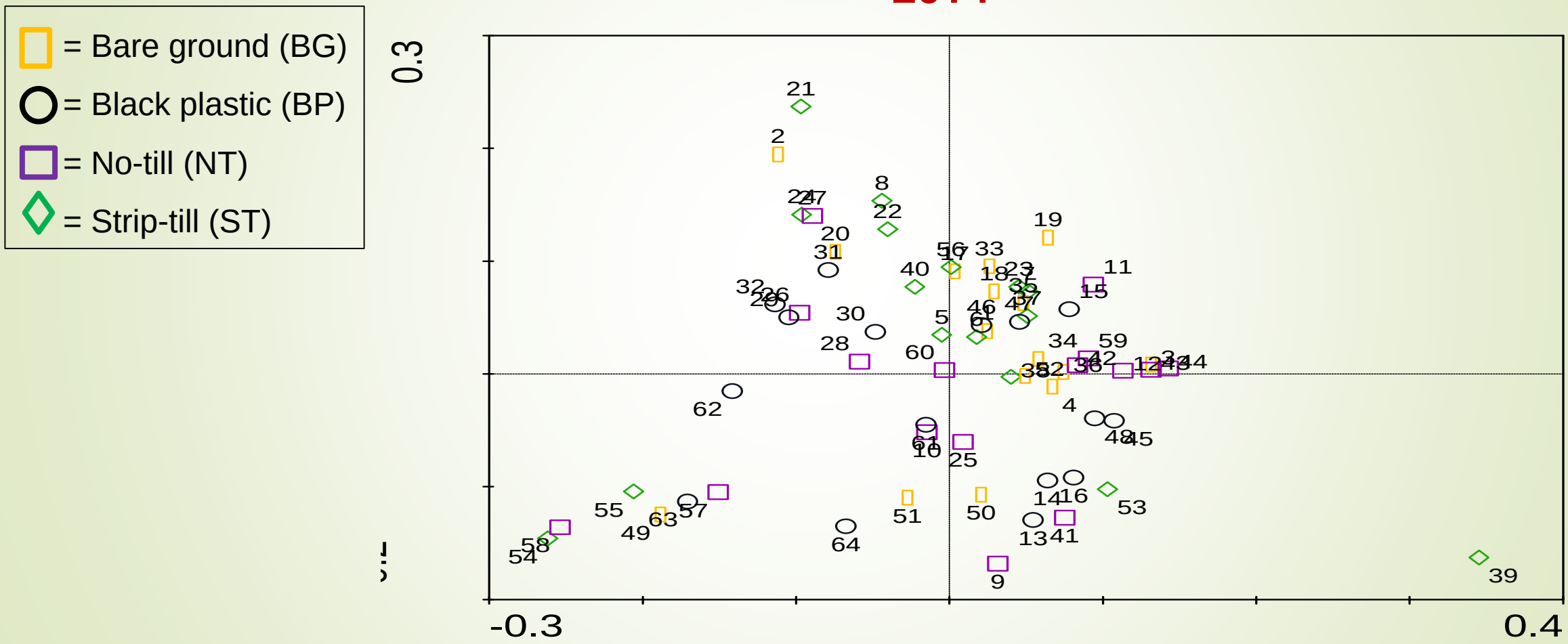


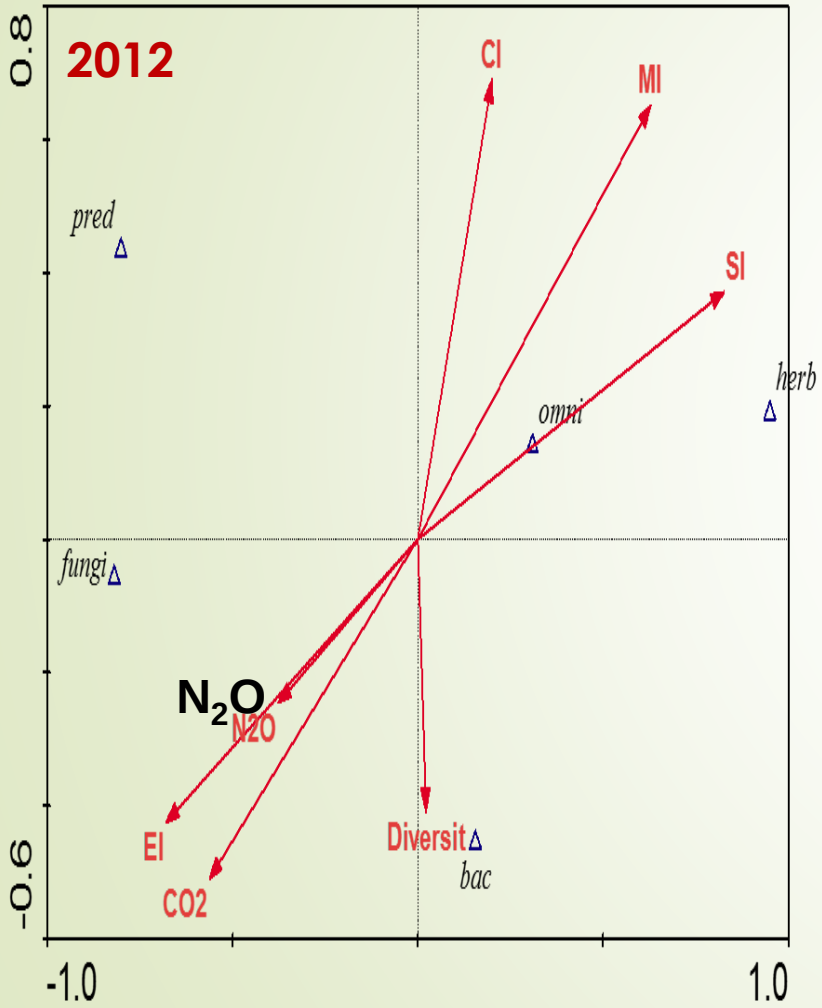
Scatter Plot of Environmental Variables and Nematode Trophic Groups

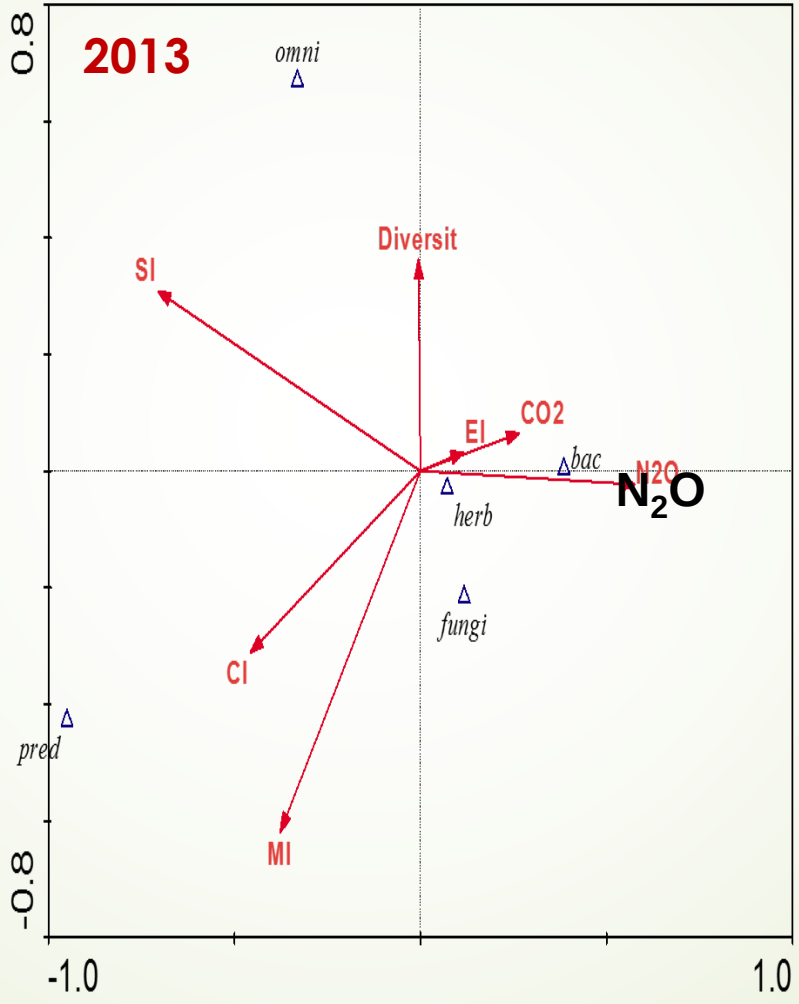
2014

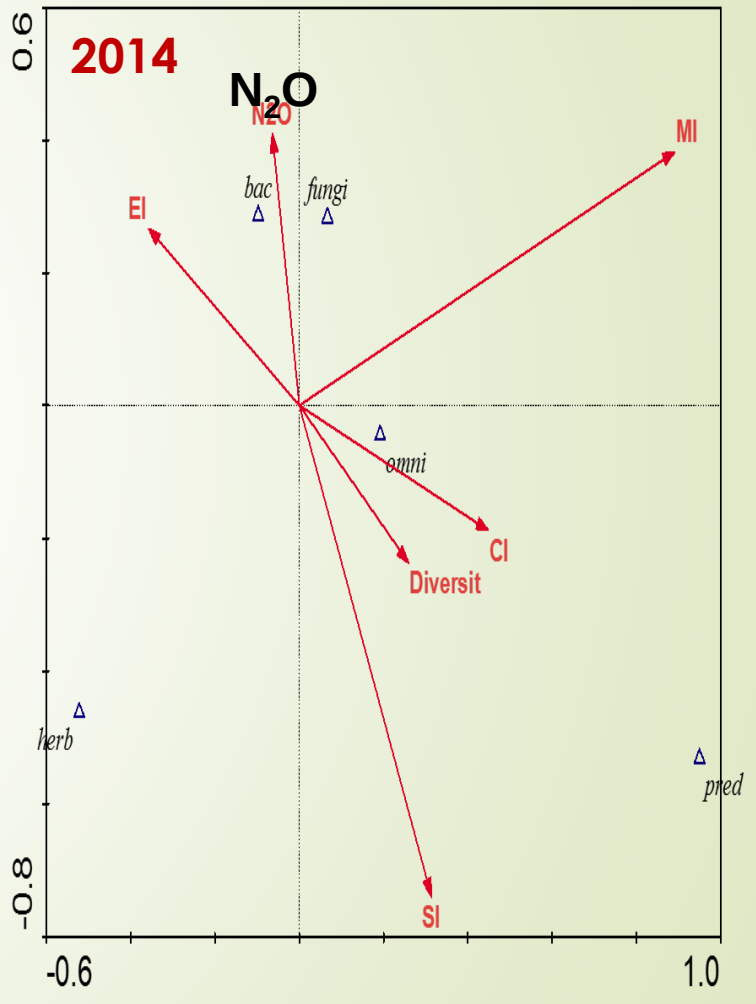


Effects of conservation tillage on soil health could be affected by climate. Three years might be too short to see a clear trend on its impact on soil health.

Canonical Correlation Analysis b/t Abundance of Nematode Trophic Groups and Environmental Data







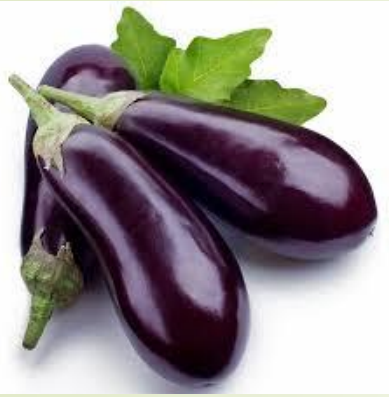
First & second axes accounted for 90.4%, 88.1% and 86.0% of the cumulative variance of CCA in 2012, 2013, and 2014, respectively.

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)?

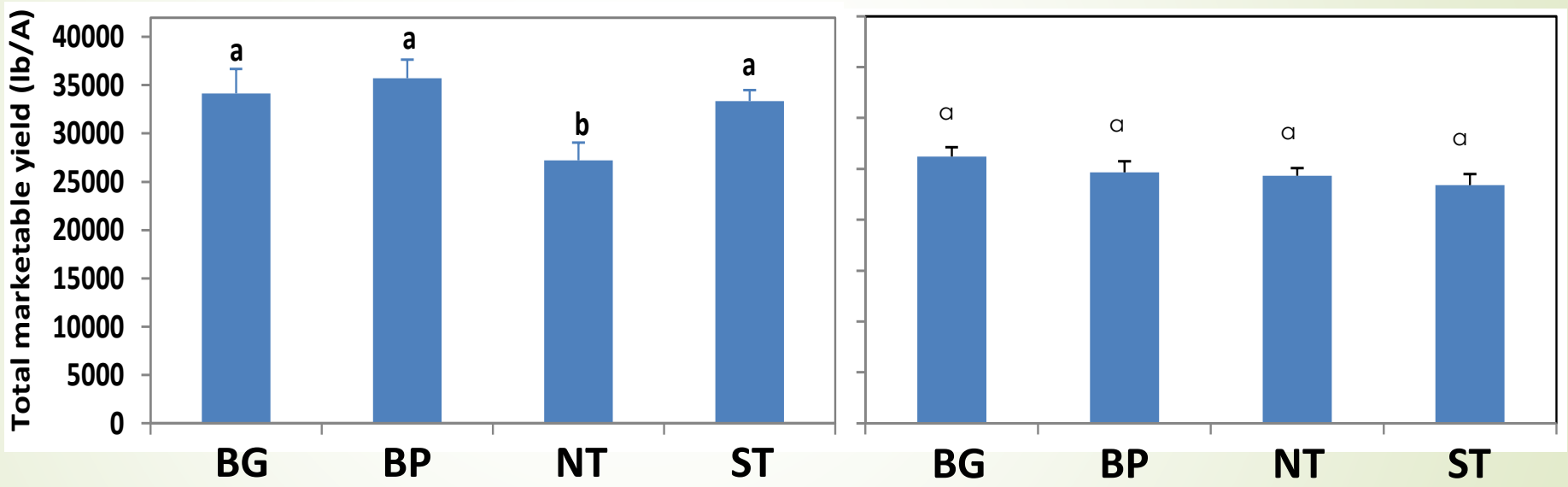
N_2O emission was negatively correlated to SI and CI consistently over the 3 years, but positively correlated to EI especially in 2012.

Eggplant Yield in 2012 and 2014



Marketable yield:

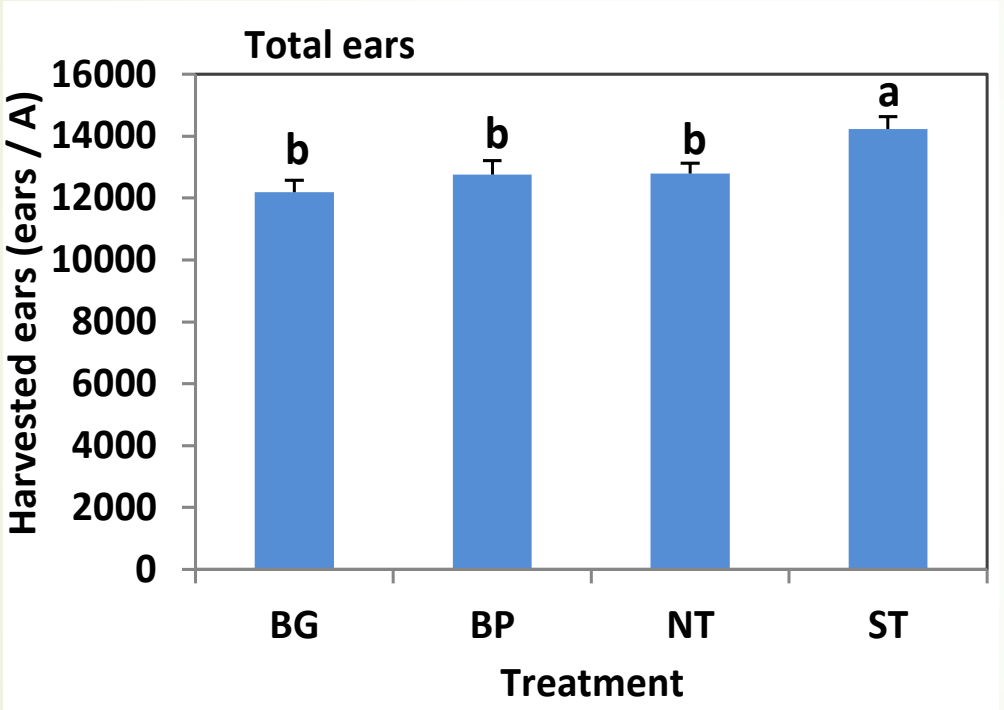
A. Jul. 16 to Aug. 21, 2012 **B. Jul. 25 to Sep. 12, 2014**

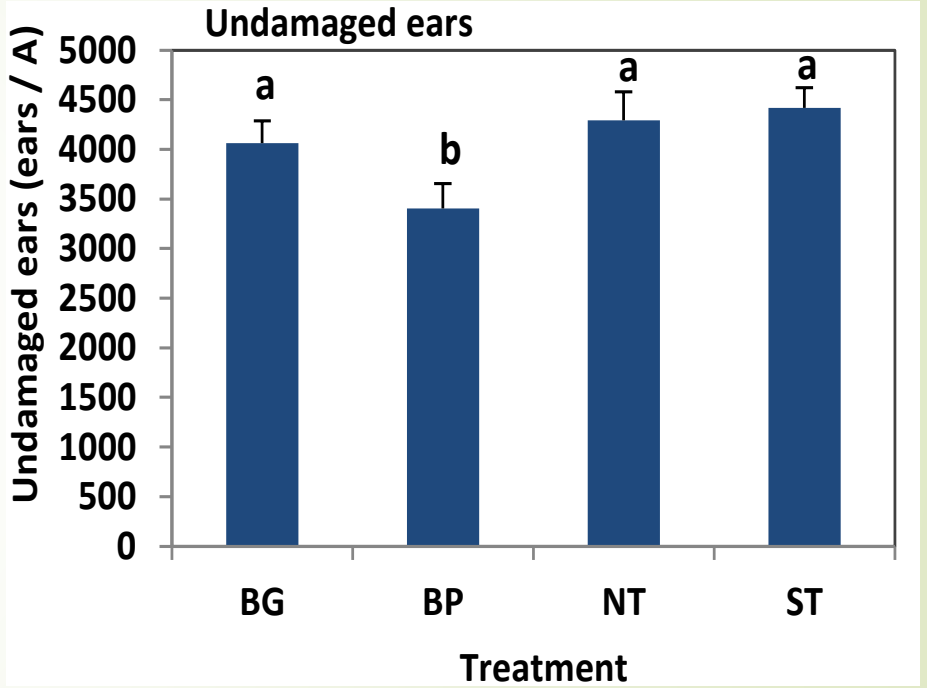


- ✓ Plant growth in NT plots was relatively slower, extending harvest period could achieve full benefit;
- ✓ Cooler temperature may reduce yield regardless of tillage treatments.

Sweet Corn Yield in 2013

Sweet corn yield: quantity and quality in 2013





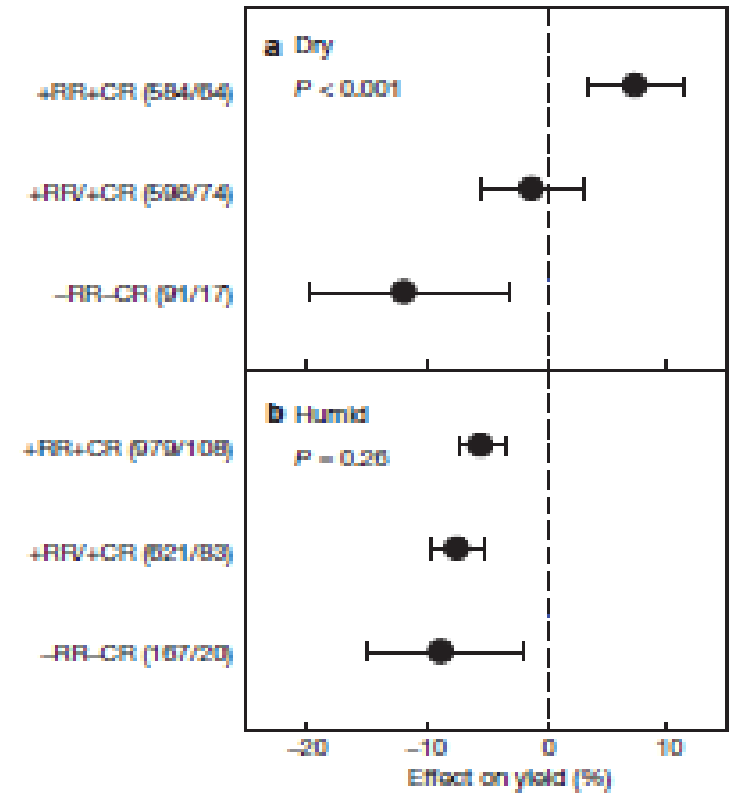
- ✓ ST had the highest plant population and most ears;
- ✓ BP had the lowest marketable yield due to the combination of higher insect damage and fewer ears;
- ✓ NT had the least insect damage.

LETTER

doi:10.1038/nature13809

Productivity limits and potentials of the principles of conservation agriculture

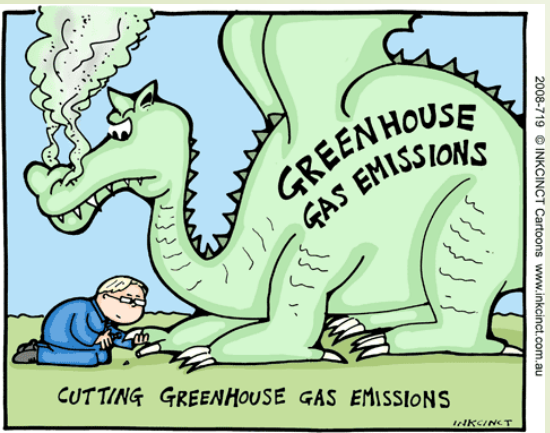
Cameron M. Pittelkow[1]*†, Xinqiang Liang[2]*, Bruce A. Linquist[1], Kees Jan van Groenigen[3], Juhwan Lee[4], Mark E. Lundy[1], Natasja van Gestel[3], Johan Six[4], Rodney T. Venterea[5,6] & Chris van Kessel[1]



- 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_2O, but covering soil with BP after tilling increased N_2O 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_2O emission and nematode community structure were not consistent, maintaining higher SI followed by CI were corresponding to lower N_2O 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.



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