Effects of Surface Mulch on Soil Health Conditions in Conservation-Tillage Systems

Koon-Hui Wang, Phd.
PEPS, University of Hawaii
Cerruti R.R. Hooks, Ph.D.,
Entomology, University of Maryland
Outline

- Are we keep re-inventing the wheel?
- Comparing tilled, no-tilled, and synthetic mulch to bare ground system
- Integrating no-till cover cropping with natural farming
Goals of maintaining soil health

- Maintaining high soil nutrient enrichment throughout a cropping cycle
- Sustain a stable soil food web structure

(Ferris et al., 2000)
Different Approaches of Conservation Tillage

- Strip-till
- Ridge till
- No till
- Natural farming
**Impact of previous conservation tillage practices on nematode communities**

| Conservation tillage increase bacterivores and fungivores, but SI was not different between cover cropping and fallow during a two-year study. | DuPonte et al., 2009 |
| Failed to show increases in soil food web structure following two years of strip-tillage. | Hanel, 2003; Minoshima et al., 2007 |
| Failed to show increases in soil food web structure following two years of no-tillage. | Marahatta et al., 2010; |
| Increase SI in 6-year of no-till system. | Okada and Harada, 2007 |
| Amending soil with green manure clearly increase omnivorous and predatory nematodes in soil under greenhouse pot experiments. | Wang, McSorley et al., 2004 |
| Strip-till of sunn hemp cover crop followed by mulching soil surface periodically with sunn hemp residues enhanced SI within 2 cropping cycles. | Wang, et al., 2011 |
Outline

- Are we keep re-inventing the wheel?
- Comparing tilled, no-tilled, and synthetic mulch to bare ground system
- Integrating no-till cover cropping with natural farming
Comparing Tilled, No-tilled, Synthetic mulch to Bare Ground system

SH + RS
BG
SH (No-till + living mulch)

SH = Sunn hemp
RS = Rapeseed
BG = Bare ground
MM = Metallic mulch
Comparing Tilled, No-tilled, Synthetic mulch to Bare Ground System

8/30/12 = termination of cover crop
10/31/12 = termination of zucchini crop

BG = till once
MM = till once + metallic mulch
SHRS = sunn hemp & rapeseed
    till twice
SH = No-till + SH organic mulch

At end of cover crop:
• SH no-till supported highest richness and diversity.
• SHRS tilled twice has lowest richness and diversity.
Comparing Tilled, No-tilled, Synthetic Mulch to Bare Ground System

At end of zucchini crop:
- SHRS tilled twice has highest EI, MM & BG has lowest EI.
- Reversed is true for CI.
- None affect SI.
Incorporation of cover crop residues improved soil enrichment rapidly, resulted in less stressful soil condition (low CI) but did not improve SI.

SH no-till cover cropping system did not improve nematode community structure within one cropping cycle of zucchini.

Thus, more work is needed to speed up soil health improvement process.
Outline

- Are we keep re-inventing the wheel?
- Comparing tilled, no-tilled, and synthetic mulch to bare ground system
- Integrating no-till cover cropping with natural farming
Principles of Natural Farming

- Avoidance of manufactured inputs and equipment,
- Exploits the complexity of living organisms that shape each ecosystem, about “building the system”,
- “the cultivation and perfection of human beings”,
- Close observation of local conditions,
- Demands no inputs and mimics nature.
Biodiversity in
Natural area vs Monoculture

Enriched with indigenous microorganisms

Disturbed agroecosystem with less biodiversity
Basic Theories of Korean Natural Farming

- Introduce indigenous microorganisms (IMOs)
- Reduce soil disturbance through no-till
- Increase production with on-farm inputs

Masanobu Fukuoka

Master Cho (Han-Yu Cho)
Culturing IMO Using Different Substrates

1. 2/3 full steam rice in a box

2. Cover the rice box and scattered with bamboo leaves

3. Check the box in 4-5 days for white mold

4. Add brown sugar 1:1 (w/w)

5. Seal with paper towel. Container 2/3 full. Ferment for 7 days
**Culturing IMO Using Different Substrates**

6. 2 oz IMO2 + 60 lb mill run + 5 gal water (with 120 ml of SES) + Compost for 7 days, < 110°F

7. IMO3 + field soil + soil from natural area (2: 1: 1) + 5 gal water (with 120 ml of SES), cover and composted for ~7 days.

8. IMO3

9. IMO4
What does IMO do?

1) Increase soil nutrient cycling organisms?
2) Increase soil dwelling mesofauna?
3) Increase root mycorrhizae?
4) Increase plant growth promoting rhizobacteria (PGPR)?
Soil Food Web

Detrital N, P

Inorganic N, P

Fungal N, P

Bacterial N, P

Plant N, P

Fungal-feeding Nematode

Bacterial-feeding Nematode

Omnivorous and Predatory Nematode

(modified from Ingham et al., 1985)
Anticipated Soil health indication

Bacterivore  Fungivore  Herbivore  Omnivore  Predator

EI = Enrichment index
CI = Channel index
SI = Structure index

+ richness, diversity
### Foliar Spray (Nutrient inputs)

- **BRV**: brown rice vinegar
- **FPJ**: fermented plant juice
- **LAB**: lactic acid bacteria
- **FAA**: fish amino acid
- **OHN**: oriental herb nutrients
- **WCAP**: water soluble Ca-Phosphate
- **WCA**: water soluble Ca
- **MA**: Mineral A, B, C, D
- **SW**: sea water
Korean Natural Farming

- Korean Natural Farming = a practice to deliberately culture and reintroduced naturally occurring soil microorganisms into no-till agroecosystem, followed by foliar nutrients inputs of various fermented or nutrient extracted farm waste.

Scatter IMO4, cover with mulch (7 days)
Evaluating Benefits of KNF using Nematodes as Soil Health Indicators

- Four farm trials comparing KNF to either conventional (CONV) or organic (ORG) farming.

<table>
<thead>
<tr>
<th>Farm</th>
<th>Crop(s)</th>
<th>Plot size (# plots/treatment)</th>
<th>Surface mulch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poamoho</td>
<td>Grape tomato</td>
<td>$8 \times 30 \text{ ft}^2$ (3/treatment)</td>
<td>Sunn hemp no-till farming</td>
</tr>
<tr>
<td>Farm #1</td>
<td>soybean</td>
<td>$8 \times 20 \text{ ft}^2$ (4/treatment)</td>
<td>Sunn hemp cover crop</td>
</tr>
<tr>
<td>Farm #2</td>
<td>kabocha squash</td>
<td>$2 \times 2 \text{ ft}^2$ (10/treatment)</td>
<td>Wood chips</td>
</tr>
<tr>
<td>Permaculture Farm</td>
<td>kale, beet, broccoli, onion, leek</td>
<td>$4 \times 100 \text{ ft}^2$ (2/treatment)</td>
<td>Macadamia nut husks</td>
</tr>
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</table>
Poamoho Trial (Grape Tomato)

1. KNF+ SH
2. KNF + WM
3. CONV + SH
4. CONV + WM

Conv = Organic fertilizer
(Chicken pellets fertilizer 180 lb/acre)

Sunn hemp (SH)
Weed Mat (WM)
**Poamoho Trial**
*(Grape Tomato)*

Sunn hemp grown from May-July, 2012 produced 14.7 tons/acre of biomass.

Roller crimper = no-till equipment for organic farming
Poamoho Trial

**Plant health**

- KNF works well with SH mulch; org fert (Conv) works well with WM.

- KN+SH was comparable to Conv+WM.

SPAD Chlorophyll meter
Sunn Hemp Suppress Plant-parasitic nematodes but not KNF
Soil health

- KNF+SH has better bacterial decomposition than KNF+WM < 3 months after tomato planting.
- KNF resulted in more bacterial decomposition at the end of experiment.
- SH increased fungal decomposition up to ~3 months.
**Soil Health**

- KNF+SH increased omnivorous and predatory nematodes (< 3 months).
- Indicating reduced disturbance, improve in soil community structure, more stable soil food web.
- It took 2 years to reach this conditions in strip-till SH cover cropping system (Wang et al, 2011).
Poamoho Trial (Grape Tomato)

KNF + SH at 3 months after planting
Tomato Yield in KNF+SH is Comparable to CONV+WM
# Nutrient Analysis of IMO4

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>Mn</th>
<th>mg/dm³</th>
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<tr>
<td>N</td>
<td>8.3</td>
<td></td>
<td>523</td>
</tr>
<tr>
<td>P</td>
<td>0.67 %</td>
<td>Fe</td>
<td>12</td>
</tr>
<tr>
<td>K</td>
<td>825 ppm</td>
<td>Cu</td>
<td>8.1</td>
</tr>
<tr>
<td>K</td>
<td>1900 ppm</td>
<td>Zn</td>
<td>36</td>
</tr>
<tr>
<td>Ca</td>
<td>1361 ppm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary

- Nutrient source from IMO4 is minimal, yet KNF practice produced comparable tomato yield as chicken pellets fertilized crop.
- IMO4 treatment resulted in more bacterial dominated decomposition in KNF plots especially when integrated with organic mulch (e.g. SH).
- KNF+SH had highest omnivorous and predatory nematodes ~ 3 months after planting, indicating stable soil food web structure, though WM treatment catch up later.
Materials and Methods

Four farm trials comparing KNF to either conventional (CONV) or organic (ORG) farming.

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Farm #1 (Soybean)
KNF improve Plant Health

Conv = Ammonium sulfate

![KNF (greener)]

![Conv = Ammonium sulfate](CONV)

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<tr>
<th>Yield (kg)</th>
<th>Chlorophyll content (µmol m⁻²)</th>
<th>N (%)</th>
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<tbody>
<tr>
<td>CONV</td>
<td>KNF</td>
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Farm #1 (Soybean)

KNF improve soil health

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<tr>
<th>Taxonomic Group</th>
<th>CONV</th>
<th>KNF</th>
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<tr>
<td>Bacterivore</td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>Fungivore</td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>Omnivore</td>
<td>0</td>
<td>**</td>
</tr>
<tr>
<td>Predator</td>
<td>0</td>
<td>**</td>
</tr>
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**Note:** Significant increase in nematodes under KNF compared to CONV.
Farm #1 (Soybean)
KNF reduced soil compaction

![Graph showing Enchytreid worm numbers per 250 cm³ soil and soil depth. The graph compares CONV and KNF treatments.](#)
**Farm #2**

**KNF improves Soil Tilth**

KNF did increase enchytreid worm that could contribute to better soil tilth in Farm #2.
Materials and Methods

- Four farm trials comparing KNF to either conventional (CONV) or organic (ORG) farming.

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Farm #3

Results (Soil Compaction)

- **Soil depth (cm)**
- **Results (Soil Compaction)**

- **Farm #3**

- **Graph**
  - X-axis: Leek, Burdock
  - Y-axis: Soil depth (cm)
  - Legend: KNF, Org
  - Markers: *
  - Level of significance: **

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Leek
- KNF
- Org

Burdock
- KNF
- Org
Summary

- Incorporating cover crop residues increased soil nutrient enrichment (EI) transiently, but it did not improve community structure (SI).
- No-till cover cropping did not increase EI and SI within one zucchini cropping cycle.
- Adding IMO4 compost to no-till SH increased bacterivores, fungivores, and resulted in higher omnivorous and predatory nematodes within 3 months after tomato planting.
- Thus, introducing IMO could speed up soil health improvement process in a no-till cover cropping practice.
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