Suppressive Soil

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OAK Conference
March 1, 2013
The organic farmer feeds the soil and the soil feeds the plant.

-Jerome Belanger
The organic farmer feeds the soil and the soil PROTECTS the plant.
Crop disease caused by fungi and bacteria

• Average 7-15% yield loss globally
• >$4 billion loss annually in US alone
• 90% soilborne
Cure Worse than the Disease?

- Methyl bromide fumigation
  - Effective control of soil-borne diseases
  - Highly toxic, leading to respiratory, kidney, and neurological diseases in humans, sometimes fatal
  - Potential carcinogen
  - Ozone depleting chemical
  - Phased out by most countries in early 2000s; Down to 2.2% of 1991 use level in USA
Non-chemical Control Options

- Host resistance
- Crop rotation
- Plant spacing
- Tillage
- Soil solarization
- Biocontrol
- Suppressive soils
  - Native
  - Induced
Suppressive Soils

• All natural soils are somewhat suppressive
  – Physical attributes
  – Chemical attributes
  – Microbiological activity
    • Transferred between soils by introduction of small quantities of suppressive soil
    • Effect destroyed by pasteurization
Suppressive Soils

- Soil microfauna effect
- Destroy soil-borne pathogens
  - (e.g. take-all of wheat after years without rotation)
- Destroy weed seeds
  - (e.g. soils from European weed place of origin 30-40% more weed suppressive than PNW soils)
- Destroy soil-dwelling arthropods
  - (e.g. entomopathogenic nematodes)
Take-all decline: Disease increases, then declines after years without rotation.
Sugar beets growing in soil inoculated with *Rhizoctonia solani*
Suppressive soil from sugar beet field that previously suffered *R. solani* outbreak.
Conducive soil from field margins


90% Conducive mixed with 10% Suppressive
Suppressive soil heated to 50 °C (122 °F)
Suppressive soil heated to $80 \degree C (176 \degree F)$
No difference in number of microbial taxa between treatments

Differences in Abundance

- Some organisms are more abundant in suppressive than conducive soil
- Some more abundant in mixture than in conducive soil
- Some more abundant in suppressive soil when *R. solani* is present
- Several bacteria meet all three criteria
  - Proteobacteria
    - Pseudomonadaceae (also key to suppression of take-all)
    - Burkholderiaceae
    - Xanthomonadales
  - Firmicutes
    - Lactobacillaceae

• Plant pathogenic microbes damage plants

• Beneficial microbes promote plant growth or inhibit pathogens

• Root exudates stimulate or inhibit microbes

• Resistance spreads from roots to tops and vice versa

• Most soil microbes don’t affect plants directly, but interact with other microbes

Composts

- Often induce disease suppression in greenhouse studies
- Less consistent effects in field environments
- Highly variable
  - Raw materials
  - Composting process
  - Curing duration

- May introduce pathogens along with beneficials

Images from Eric Nelson, Cornell University
Mechanisms of disease suppression

- Parasitism: one organism consumes another
  - Several *Trichoderma* species can eradicate *Rhizoctonia solani* (one of the fungi responsible for damping off)

- Induced systemic resistance
  - More plant defense compounds produced when cucumbers grown in compost-treated soils

Hoitink et al. 2000. Ohio State University Bulletin 177-01
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Does greater microbial activity lead to greater disease suppression?

- Sometimes, not always
- Adding organic matter to promote microbial activity…
  - increases suppression of *Pythium* root rots
  - doesn’t necessarily suppress *Rhizoctonia* root rots, which appear to respond to specific beneficial microbes, not a general increase in microbial activity.
Green Manures

- Green manures offer inconsistent results:
  - Can increase abundance of both beneficials and pathogens
- Green manure crops that increase native populations of beneficial streptomycetes include:
  - Buckwheat
  - Canola
  - Sorghum-sudangrass
- Beneficial streptomycetes suppress several pathogens:
  - *Streptomyces scabies*
  - *Verticillium dahliae*
  - *Rhizoctonia solani*
  - *Fusarium graminearum*
- Grass-clover component of organic rotation suppresses *Rhizoctonia*
  - Boosts population of *Lysobacter* spp.
  - Effect lasts two years; disappears after three
  - Effect observed in clay soil, not sand
Buckwheat
Sorghum-Sudangrass
Brassica seed meal

- Contains chemicals that act as biofumigants (glucosinolates)
- Can change microbial population to make soils suppressive
  - *Brassica napus* (rapeseed) meal suppresses *Rhizoctonia* root rot regardless of glucosinolate content
  - Increases population of *Streptomyces* spp.
  - Pasteurization destroys this effect
  - Adding *Streptomyces* controls *Rhizoctonia solani* by inducing host defense response
Brassica seed meal

Mazzola. 2010. Chap 11 in Climate Change and Crop Production (Reynolds).
Brassica seed meal

*R. solani* introduced at the same time as Brassica Seed Meal. Disease is suppressed due to biofumigant release.
Brassica seed meal

*R. solani* introduced 24 hours after Brassica Seed Meal. Disease is not suppressed. Biofumigation effect is finished.

Mazzola. 2010. Chap 11 in *Climate Change and Crop Production* (Reynolds).
Brassica seed meal

*R. solani* introduced 4 weeks after Brassica Seed Meal. Disease is suppressed due to increase in *Streptomyces*.
Trichoderma

- Soils suppressive to *Pythium* spp. Tend to have higher population of *Trichoderma* spp.
**Trichoderma**

- Parasitize host fungi
- Produce antibiotics
- Compete with fungal pathogens
- Promote mycorrhizal fungi
- Sold commercially as RootShield and SoilGard (both OMRI listed)

Colonizes root surface. Triggers resistance response from plant.

Outcompetes pathogens.

**Fusarium suppression**

- *Fusarium* wilt held off by suppressive soil, but not peat
- Effect lost with sterilization
- Somewhat restored by inoculating with *Trichoderma* or Fo47 (non-pathogenic *Fusarium* strain)

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Solarization

- Covering soil in clear plastic to trap solar heat
- Soil should be wet to create hot and humid conditions
- Kills weed seeds and soil-borne diseases
- Saprophytic fungi tend to be more heat tolerant than parasitic fungi
  - Beneficial microbes, like *Trichoderma*, recolonize quickly. *Trichoderma* numbers increase rapidly after steam treatment
  - Inoculation with beneficial microbes after solarization may help
Average Sclerotia Survival at Different Soil Depths and Treatments

Average Germinating Sclerotia (of 40)

- Biofumigation
- Biofumigation + Solarization
- Control
- Solarization

Depth (cm)
Average Sclerotia Survival After 2, 4, and 6 Weeks of Treatments

Germinating Sclerotia (of 160)

Biofumigation
Biofumigation + Solarization
Control
Solarization

2 week
4 week
6 week
0
5
10
15
20
25
30
35
40

6 week
4 week
2 week
Average Sclerotia Survival at Edge and Middle of Treatment Plots

- **Biofumigation**
- **Biofumigation + Solarization**
- **Control**
- **Solarization**

**Average of 8-Week Treatment Middle/Edge Average Germinating Sclerotia (of 40)**

- **Edge**
- **Middle**
Questions?

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