INTEGRATED PHYTOPHTHORA MGMT. WITH BIOFUMIGATION & REDUCED TILLAGE - WHAT WE KNOW SO FAR
Pumkin shortage in NY after Irene damage

BY JOE TEPPER	CHRISTINA BOYLE
DAILY NEWS STAFF WRITERS	Sunday, September 18, 2011, 4:00 AM
Regardless of Shifts in Total Annual Rain
More of It Is Coming in Heavy Downpours

Percent Increase (1958-2010) in Heavy Precipitation Events (>2inch/48 hr)

NOAA, provided by A. DeGaetano, NERCC, Cornell
Integrated Phytophthora Blight Management in Vegetable Crops with Enhanced Soil Health From Cover Crops, Reduced Tillage, and Brassica Biofumigation
What is Biofumigation?

“The suppression of various soil-borne pests and diseases by naturally occurring compounds”

- Brassicas: mustard, arugula, and others like oilseed radish, rapeseed, canola et al.
How does it work?

- **Brassicas naturally produce glucosinolates**
  - Sulfur compound that makes certain brassicas “hot/spicy”
  - Essential component in biofumigation

- Broad-spectrum fumigant
- Need 10-60x typical biomass to equal Vapam concentration

Glucosinolates + Enzyme → Allyl-Isothiocyanate

Glucosinolates: Glucosinolates + H₂O → Myrosinase

Released when chopped

Similar to active ingredient in Vapam (methyl-isothiocyanate)
Facilitate Biofumigation reaction in the field

- In sequence:
  - Chop > incorporate > seal > (irrigate?)
- ITC is volatile (gas): Activity time is limited!

Glucosinolates + Enzyme → Allyl-Isothiocyanate (ITC)

Similar to compound in *Vapam* (methyl-isothiocyanate)
Big hopes for Biofumigation

- Soil-borne disease suppression
  - Fusarium, Verticillium, Rhizoctonia, Pythium, Sclerotinia, Botrytis, Phytophthora, +

- Nematode suppression
  - Root knot and root lesion nematode
  - Potato cyst nematode suppression being studied

- Weed seed germination suppression
CONTROL OF SOIL-BORNE PLANT PESTS USING GLUCOSINOLATE-CONTAINING PLANTS

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Moscow, Idaho 83844-2339

Biofumigation: Isothiocyanates released from Brassica roots inhibit growth of the take-all fungus

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Key Laboratory of Plant Pathology of the Ministry of Education, Yunnan Agricultural University, Kunming, China

Potential Biofumigation Effects of Brassica oleracea var. cauliropapa on Growth of Fungi

C. M. Fan¹, G. R. Xiong¹, P. Qi¹, G. H. Ji¹ and Y. Q. He¹,²
Authors’ addresses: ¹Key Laboratory of Plant Pathology of the Ministry of Education, Yunnan Agricultural University, Kunming 650201, China; ²Faculty of Agronomics and Biotechnology, Yunnan Agricultural University, Kunming 650201 China (correspondence to Y. Q. He. E-mail: heyu@ynau.edu.cn)

Biofumigation potential of brassicas

III. In vitro toxicity of isothiocyanates to soil-borne fungal pathogens

M. Sarwar¹, J.A. Kirkegaard¹, P.T.W. Wong² and J.M. Desmarchelier³
¹CSIRO Plant Industry, GPO Box 1600 Canberra ACT 2601, Australia*, ²Agricultural Research Institute, NSW Agriculture, Wagga Wagga NSW 2650, Australia and ³CSIRO Division of Entomology, GPO Box 1700, Canberra 2601, Australia
Mustard Green Manures Replace Fumigant and Improve Infiltration in Potato Cropping System

Andrew M. McGuire, Lauzier Agricultural Systems Educator, Washington State University Cooperative Extension, Grant-Adams Area, PO Box 37, Ephrata WA

Control of soilborne potato diseases using *Brassica* green manures

Robert P. Larkin*, Timothy S. Griffin
USDA, ARS, New England Plant, Soil, and Water Laboratory, University of Maine, Orono, ME 04469, USA

Soil amendments with *Brassica* cover crops for management of Phytophthora blight on squash

Pingsheng Ji, a*, Daouda Koné, a,b Jingfang Yin, a Kimberly L Jackson a and Alexander S Csinos a

Brassica Green Manure Amendments for Management of *Rhizoctonia solani* in Two Annual Ornamental Crops in the Field

Kimberly A. Cochran and Craig S. Rothrock
Department of Plant Pathology, University of Arkansas, 217 Plant Science Building, 495 North Campus Drive, Fayetteville, AR 72701

Mustard biofumigation disrupts biological control by *Steinernema* spp. nematodes in the soil

Donna R. Henderson a,b, Ekaterini Riga a,b, Ricardo A. Ramirez c, John Wilson a,b, William E. Snyder c*

Pathogenicity of *Phytophthora capsici* to *Brassica* Vegetable Crops and Biofumigation Cover Crops (*Brassica* spp.)

Charles S. Krasnow and Mary K. Hausbeck, Department of Plant, Soil, and Microbial Sciences, Michigan State University, East Lansing

Mustard and Other Cover Crop Effects Vary on Lettuce Drop Caused by *Sclerotinia minor* and on Weeds

Tiffany A. Bensen and Richard F. Smith, University of California Cooperative Extension, Monterey County, Salinas 93901; Krishna V. Subbarao, University of California, Department of Plant Pathology, Davis 95616; Steven T. Koike, University of California Cooperative Extension; and Steven A. Fennimore and Shachar Shem-Tov, University of California, Department of Plant Sciences, Davis 95616

Mustard Cover Crops Are Ineffective in Suppressing Soilborne Disease or Improving Processing Tomato Yield

T.K. Hartz, P.R. Johnstone, E.M. Miyao,1 and R.M. Davis
Department of Plant Sciences, University of California, Davis, CA 95616
□ Tom Zitter
□ Meg McGrath
  ▪ Cornell Plant Pathology & Plant Microbe Biology
  ▪ Connected with Dale Gies, E. WA farmer- Biof. info from Italy
□ Sandy Menasha- Extension Veg. Specialist, Suffolk Co.
  ▪ Cornell’s Long Island Horticulture Research and Extension Center (LIHREC)
    ▪ Preliminary studies with P-cap
    ▪ Some good grower feedback
Healthy zucchini only after mustard.
8-15-08
Phytophthora blight.

cf. Meg McGrath
Phytophthora Fruit Rot Incidence

cf. Sandy Menasha
Integrated management:
Current IPM guidelines + biofumigation & reduced tillage
- Biofumigation reduces inoculum (fumigation, burial)
- Reduced tillage reduces contact with inoculum
- Biofumigation + reduced tillage fosters soil health improvement

2-year field research component
6 on-farm trial sites, plot study at LIHREC
Biofumigation + RT vs. standard practice, C, N returned to soils, infiltration rates, general soil health
Beyond biofumigation

- Adds organic matter
  - Improve soil fertility
  - Catch cropping & nutrient cycling
  - Improve infiltration and water holding capacity
  - Improve soil aeration
  - Healthy soils > soil borne disease suppression
- Attracts beneficials
- Weed suppression
- Applicable in organic and IPM systems both
2015: Biofumigation year

- Ex: 2015 ~Apr 20- ‘Caliente’ mustard > ~June 10- biofumigation > ~June 20 cucurbit cash crop
2015 Data collection

- Cover crop biomass
- Cucurbit yield
- P-cap incidence
Prelim. data, on-farm ’15: Cover crop carbon

Winterkilled
- Accord: 671 lbs/ac C
- Kerhonkson: 288 lbs/ac C

Drought
- Accord: 1483 lbs/ac C
- Riverhead: 735 lbs/ac C

Planted late
- Accord: 1686 lbs/ac C
- Eden: 508 lbs/ac C
- Hamburg: 1158 lbs/ac C
- Kerhonkson: 1673 lbs/ac C
- New Paltz: 2017 lbs/ac C

* Riverhead = Long Island site, Accord, Kerhonkson, Newpaltz = Hudson Valley sites, Eden, Hamburg = western NY sites.
  Fall planting = ‘Nemat’ arugula, spring and summer plantings = ‘Caliente’ mustard.
**Prelim. data, on-farm ’15: Cvr. Crop nitrogen**

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<th>Planting / Location*</th>
<th>Fall</th>
<th>Spring</th>
<th>Summer</th>
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<td>New Paltz</td>
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</tbody>
</table>

* Riverhead = Long Island site, Accord, Kerhonkson, Newpaltz = Hudson Valley sites, Eden, Hamburg = western NY sites. Fall planting = ‘Nemat’ arugula, spring and summer plantings = ‘Caliente’ mustard.
Prelim. data, LIHREC ’15: Cvr. crop carbon

- Arugula: Fall
- Mustard: Spring Planting / Crop
- Mustard: Summer

- Drought: 665 lbs/ac C
- Mustard: 1769 lbs/ac C
Prelim. data, LIHREC ’15: Cvr. crop biomass
2015 *Phytophthora incidence*  
- A little, but overall, negligible!  
  - Hypothesis: Generally dry conditions.
Too much variability...

Negligible P-cap...

Where (40 rows excluded)
Each error bar is constructed using 1 standard error from the mean.
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2015 LIHREC Kubocha Yield by Treatment

Each error bar is constructed using 1 standard error from the mean.
Each error bar is constructed using 1 standard error from the mean.
2016: Reduced tillage (RT) year

2016 Data collection

- Cucurbit yield • p-cap incidence • soil infiltration rates • soil health assay • cover crop biomass
2016 Preliminary observations

- P-cap incidence very low, therefore > low opportunity to collect evidence of treatment effects
2016 Preliminary observations

- P-cap incidence overwhelmingly where rye mulch layer was thin or absent & allowed fruit/soil contact
2016 On-Farm response

Average P- cap loss vs. RT Rye Cover Crop C

Robust mulch: > 7000 lbs/ac
2016 On-Farm response

- Yield: NS!
  - Too much variability...
  - Very low P-cap...
- Infiltration rates: NS!
- Soil health assay: NS!

**2016 On-farm Yield by Treatment**

Each error bar is constructed using 1 standard error from the mean.
On-farm Infiltration x SOM

Infiltration Rate by % Soil Organic Matter

- Infiltration Rate (in/h)
- Organic matter

Transformed Fit Log
Each error bar is constructed using 1 standard error from the mean.
Each error bar is constructed using 1 standard error from the mean.
2yr C & N returned, LIHREC

2016 Yield response by treatment LIHREC

- Treatment 1: ~1000 lbs/ac C, 60 lbs N
- Treatment 2: ~2500 lbs/ac C, 180 lbs N
- Treatment 3: N/A
- Treatment 4: ~5000 lbs/ac C, 270 lbs N
- Treatment 5: ~5000 lbs/ac C, 270 lbs N
- Treatment 6: N/A

Each error bar is constructed using 1 standard error from the mean.
2016 Soil Respiration by treatment LIHREC

Each error bar is constructed using 1 standard error from the mean.
2016 Anecdotal observation-

- Robust rye mulch appeared to boost RT weed control

Rye mulch: ~ 9000 lbs/ac
Yr 1: Biofumigation take Home Points

- Mindset: **Treat it like a crop!**
- Use varieties selected for biofumigation
- Good seedbed prep, weed control
- Ample fertility, moisture
- Seed timely for 50-60 days growth
- Follow biofumigation steps
- ‘Nemat’ Arugula does not overwinter in NY
- Consider issues w/brassica diseases, residual herbicides
- View biofumigation as one tool of many
- Consider other benefits of cover crop
  - N catch cropping, & fertility improvement
  - SOM building, infiltration, soil-quality improvement
Yr 2: To-date RT year take-home points

- Barriers to adoption: Equipment • weed control concerns
- Cover crop kill timing & method can be challenging
- Fertility needs sometimes higher in RT, esp. w/rye mulch
- Robust rolled mulch: lowered fruit/P-cap-infected soil contact? • improved RT weed control?
- Likely to help build SOM > improved infiltration over time?
- RT the more potent of the biofumigation + RT combo?
- Fall biofumigation followed by RT may be more promising option- no considerable downsides observed, logistical
- Better understanding of biofumigation is in order
- Longer term studies may be needed for 1) measuring possible cumulative biofumigation & RT effects and 2) assuring p-cap incidence/chances to collect evidence
Questions?

Thanks to:

- NE-SARE
- Farmer collaborators
- Sandy Menasha
- Robert Hadad
- Meg McGrath
- Summer field staff

2016 LIHREC Infiltration, Health

2016 Infiltration rate response by treatment LIHREC

Each error bar is constructed using 1 standard error from the mean.
2016 Soil Aggregate stability by treatment LIHREC

Each error bar is constructed using 1 standard error from the mean.
organic matter vs. % sand

$R^2 = 0.699$
Infiltration rate (Log trans. per GWC) by % sand

- The graph shows a negative correlation between infiltration rate (log in/hr) and % sand.
- The infiltration rate decreases as the % sand increases.
- The data points are scattered, with some showing higher infiltration rates for lower % sand.

Relevance:
- Understanding the relationship between infiltration rate and % sand is crucial for managing water resources and soil properties on farms.
**Biofumigants and soil health**

- Good soil tilth*
- Sufficient depth*
- Sufficient but not excess nutrients*
- Small population of plant pathogens and insect pests**
- Good soil drainage*
- Large population of beneficial organisms*
- Low weed pressure*
- Free of chemicals and toxins that may harm the crop
- Resistant to degradation*
- Resilience when unfavorable conditions occur*
Biofumigation

- **Equipment**
  - **Mower (flail is rec’d)**
    - Ruptures brassica cells, releases glucosinolates
  - **Tillage implement (rototiller rec’d)**
    - Increases biofumigant contact with soil borne pathogens
  - **Packing implement (cultipacker rec’d)**
    - Seals in ITC biofumigant gas
  - **Irrigation lines if droughty**
    - Assures conversion of glucosinolates to ITCs
    - Assures start of 7-14 day biofumigation period
    - Helps seal soil surface to retain ITC gas
Growing for biofumigation

- Considerations
  - Species/variety with high glucosinolate content
    - ‘Caliente’ varieties (B. juncea)
    - ‘Nemat’ arugula (Eruca sativa)
    - ‘Pacific Gold’ (B. juncea)
    - ‘Ida Gold’ (B. campestris)
    - White mustard (Sinapsis alba)
    - Rapeseed, Canola (B. napus)
    - Pennycress (Thlaspi arvense)
Growing for biofumigation

- Considerations
  - **TREAT IT LIKE A CASH CROP!**
  - Crop rotation
    - Sequence before soilborne disease-sensitive cash crops
    - Distance from brassica cash crops in time and space
    - Past herbicide?
  - Season timing (~50-60d growth)
    - Spring (April - June)
    - Winter (Sept - winterkill or May)
    - Late summer (Aug – Oct)*
Growing for biofumigation

- Seedbed preparation
  - Conditioning for small seeded crop
  - Weed-free

- Pre-plant fertility
  - Soil test recommended P, K, micros for mustards
  - Starter N (~20 lbs minimum, esp. in spring!!)
  - S (~20 lbs or ~6:1 N:S ratio; gypsum will not lower pH)
  - *Your biofumigation can only be as good as your fertility*
Growing for biofumigation

- **Seeding**
  - Use drill (rec’d) or broadcast
  - Seed depth: $\frac{1}{4}$ to $\frac{1}{2}$”
  - Mustards: 10-12 lbs/ac
  - Arugula: 6-8 lbs/ac
    - Late seedings, shortened season > can increase rate
Growing for biofumigation

Management

- Topdress N (usually needed)
  - 50-100 lbs/ac total applied
  - N is optimal
  - Depends on crop history, inherent fertility
- Weed control?
- Irrigate if droughty
Nitrogen Fertility and Biomass Production

2009

Cover Crop Height

Mustard Biomass Production

2010

Cover Crop Height

Mustard Biomass Production

cf. Sandy Menasha
Growing for biofumigation

What to Expect:

- Begins flowering after \( \geq 30 \text{ d} \)
  - usually \( \sim 2\frac{1}{2}-3' \)
    - Let it flower away!
- Viable seed 6 weeks from flower
- Doubles in height after flowering
- Grows up to \( \sim 5 \text{ ft} \)
- Incorporate 2-4 weeks after flower
- Biofumigation potential drops after maturity
  - Mustard weed seed after maturity
Biofumigation

- ~10 day biofumigation recommended
- Should inhibit weed seed germination by default
- SO- do not plant crops in biofumigating soils also- poor germ risk!
- Light tillage after biofumigation period will help assure release of any remaining gases
- *Heavier soils may hold in gas more?*
  - *Also may not biofumigate as thoroughly?*