‘Biofumigation’ potential of mustards

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Mustards: *Brassicaceae* family

- Excellent weed competitors
- Taproot breaks compaction
- Abundant fast-degrading biomass
- Drought tolerance, plasticity
- Support bees and natural enemies
- Contain allelochemicals
Pick your active ingredient

Glucosinolates (GSL-s degradation)

Isothiocyanates (ITC-s)
ITC-s

- Methyl ITC (active ingredient of Metham Sodium/Vapam)
- Allyl-ITC
- Phenyl-ITC

And other S – containing

- Dimethyl sulfide
- Methanethiol
- Unidentified
Methyl ITC (a. i. of Metham Sodium, Vapam)

- Vapam at 75 gal/ac $\rightarrow$ 252 lb/ac ITC
- It will take \textbf{250 000 lb/ac} of dry biomass of mustard (at ITC conc =1000 mg/kg) to match this
- Mustard in Ventura Co. produces \textbf{20-25,000 lb/ac} (10%)
- Australia: \textbf{25%}
### Biofumigation

<table>
<thead>
<tr>
<th>Green biomass</th>
<th>Seed products</th>
</tr>
</thead>
<tbody>
<tr>
<td>High amounts of C and water</td>
<td>High C, 5% N</td>
</tr>
<tr>
<td>Low concentration of GSLs</td>
<td>High concentration of GSLs</td>
</tr>
<tr>
<td>Cheap – can be grown locally, need time to grow</td>
<td>Available from seed processors, often in Canada and PNW, $</td>
</tr>
</tbody>
</table>
Biomass: How to make mustard ITC-s work for you?

1. High initial GSL concentration in plant
2. Break cells = release
3. Minimize losses = wet soil (aid hydrolysis)
Studies near Santa Paula, CA

5 treatments

- Faba/Bell bean
- Cereal mix
- Oriental mustard
- Yellow mustard
- Bare ground (control)
Breaking cells
Permeable bags with:

- Citrus Nematodes
- Sclerotinia minor
- Weed seed:
  - Burclover,
  - Annual rye grass,
  - Red root pigweed

Buried at: 12”
1.4” water: to trap and hydrolyze
Split-plot: + and – black plastic
Bags recovered after 7 days and pests analyzed
Citrus nematode (Tylenchulus semipenetrans) survival following biofumigation

2d stage juveniles/50 cc

- control
- control+plast
- cereal
- cereal+plast
- oriental must
- oriental must+plast
- yellow must
- yellow must+plast
- faba bean
- faba bean+plast
- room stored

Variations indicated by different letters (a, b, c, etc.).
Weed seed from field bags:

No significant effects of biofumigation on weed survival
Weeds in lab tissue extracts

Weed seed germination in aqueous plant tissue extracts

Control
Water
Faba bean
Oriental must
Cereal

Germination, %

Burclover
Ryegrass
Pigweed
Weeds in tissue extracts

water  bare control  faba bean  oriental must.
Sclerotinia minor growth in lab following soil biofumigation

% sclerotia grown

control
control+plast
Faba
Faba+plast
oriental must
oriental must+plast
yellow must
yellow must+plast
cereal
cereal+plast

Legend:

- a
- ab
- b
Sclerotinia in tissue extracts

*Sclerotinia minor* growth in lab in plant tissue extracts

% sclerotia grown

- Control
- Water
- Faba bean
- Oriental must
- Oriental must + plast
- Cereal

Legend:
- a
- ab
- c
- bc
Romaine lettuce and celery were planted following biofumigation
Romaine lettuce

After bare control

After faba beans
Romaine lettuce

After yellow mustard

After oriental mustard
Romaine lettuce

Infection of romaine lettuce 'Gladiator' with *Sclerotinia minor* following biofumigation

- 0 = no *Sclerotinia*
- 0 - 0.4 = some mycelium on outer leaves
- 0.4-0.8 = mycelium
- > 0.8 = mycelium + sclerotia or dead plant

The diagram shows infection scores for different treatments:
- Bare control + plast: b
- Bare control: b
- Faba bean + plast: a
- Faba bean: a
- Yellow must + plast: b
- Yellow must: c
- Oriental must + plast: bc
- Oriental must: b

The letters (a, b, c) indicate significant differences among the treatments.
Romaine lettuce

Head weight of romaine lettuce 'Gladiator' following biofumigation

<table>
<thead>
<tr>
<th>Treatment</th>
<th>g/head</th>
</tr>
</thead>
<tbody>
<tr>
<td>bare control + plast</td>
<td>c</td>
</tr>
<tr>
<td>bare control</td>
<td>c</td>
</tr>
<tr>
<td>faba bean + plast</td>
<td>b</td>
</tr>
<tr>
<td>yellow must + plast</td>
<td>b</td>
</tr>
<tr>
<td>yellow must</td>
<td>a</td>
</tr>
<tr>
<td>oriental must + plast</td>
<td>b</td>
</tr>
<tr>
<td>oriental must</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td>b</td>
</tr>
</tbody>
</table>
Celery plant weight following biofumigation

- bare control + plast
- bare control
- faba bean + plast
- faba bean
- yellow mustard + plast
- yellow mustard
- oriental mustard + plast
- oriental mustard

- g/plant
Summary:

• Oriental vs. yellow mustard – not consistent
• Plastic – not consistent
• Improved health and vigor of following crops, observation: abundant *Trichoderma* sp. after mustard
2004: Pests and pathogens

At 15 and 30 cm (6 and 12”)

- Phytophthora (*P. cactorum*)
- California burclover, little mallow, goosefoot
- *Verticilium dahliae* soil samples
Severe overgrowth with *Pythium* spp. after mustards
Verticillium dahliae in soil following biofumigation

Standard error = ± 16.4
2005: Lettuce head weight after ‘biofumigation’

![Bar graph showing the lettuces average weight per head (g). The graph includes treatments such as BQ mulch™, Bareground, Triticale, Oriental mustard 'Pacific Gold', Bell bean, and Yellow mustard 'Ida Gold'. The graph indicates differences in weight per head across these treatments.](image)
# Changes in microbiological activity

<table>
<thead>
<tr>
<th>Factor</th>
<th>Soil microbial activity (μg fluorescein hydrolyzed per g soil per h)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cover crop (P &lt; 0.0001)</strong></td>
<td></td>
</tr>
<tr>
<td>Bareground</td>
<td>0.084 bc</td>
</tr>
<tr>
<td>Bell bean</td>
<td>0.163 bc</td>
</tr>
<tr>
<td>Triticale</td>
<td>0.662 ab</td>
</tr>
<tr>
<td>‘BQ Muleh’™</td>
<td>0.754 a</td>
</tr>
<tr>
<td>‘Ida Gold’</td>
<td>0.933 a</td>
</tr>
<tr>
<td>‘Pacific Gold’</td>
<td>1.023 a</td>
</tr>
<tr>
<td><strong>Residue (P = 0.07)</strong></td>
<td></td>
</tr>
<tr>
<td>1x</td>
<td>0.513 b</td>
</tr>
<tr>
<td>2x</td>
<td>0.694 a</td>
</tr>
</tbody>
</table>
Composition of glucosinolates: above-ground

Most effective in yielding biocidal ITC-s
Composition of glucosinolates: roots

most effective in yielding biocidal ITCs
Summary: biofumigation

+ Yield increases after mustard ‘biofumigation’

+ Soil microbial enzymatic activity was higher for ‘PacificGold’ and ‘IdaGold,’ compared to bell bean or bare control

-- No reduction in sclerotia of *Sclerotinia minor*, microsclerotia of *Verticillium dahliae* and weed seed viability

+ reduction in citrus nematode and *Phytophthora cactorum* after oriental mustard biofumigation

± *S. minor* severity ratings were reduced 25% when surface cover crop biomass was doubled (or with yellow mustard in 2002), regardless of species or crop type.
# Mustard seed meal

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate/ description</th>
<th>Weed densities</th>
<th>Albion</th>
<th>Ventana</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. (1,000/Acre)</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>1. Untreated</td>
<td>0</td>
<td>1,322 a</td>
<td>542.6</td>
<td>699.3</td>
</tr>
<tr>
<td>2. MBPic 67:33</td>
<td>350 lb/A</td>
<td>49 d</td>
<td>784.2</td>
<td>877.4</td>
</tr>
<tr>
<td>3. Steam</td>
<td>70°C 30 min.</td>
<td>29 d</td>
<td>775.0</td>
<td>1017.3</td>
</tr>
<tr>
<td>4. Muscodor</td>
<td>2000 lb/A</td>
<td>261 cd</td>
<td>518.7</td>
<td>629.4</td>
</tr>
<tr>
<td>5. Brassica meal</td>
<td>2000 lb/A</td>
<td>822 b</td>
<td>743.3</td>
<td>996.8</td>
</tr>
<tr>
<td>6. Furfural</td>
<td>600 lbs/A</td>
<td>702 bc</td>
<td>872.7</td>
<td>640.0</td>
</tr>
<tr>
<td>7. Fludio. + Ridomil</td>
<td>1 pint + 0.5 lb/A</td>
<td>432 bcd</td>
<td>572.3</td>
<td>863.5</td>
</tr>
<tr>
<td>8. Stabilized Urea¹</td>
<td>300 lbs/A</td>
<td>374 bcd</td>
<td>619.8</td>
<td>651.0</td>
</tr>
<tr>
<td>9. Steam+ AgroThrive</td>
<td>70°C 30 min. + 150 lb/A</td>
<td>12 d</td>
<td>648.1</td>
<td>889.9</td>
</tr>
<tr>
<td>10. AG3 (NP)</td>
<td>75 GPA</td>
<td>776 b</td>
<td>418.8</td>
<td>598.9</td>
</tr>
<tr>
<td>LSD (P=.05)</td>
<td></td>
<td>500</td>
<td>298.0</td>
<td>351.0</td>
</tr>
<tr>
<td>Treatment Prob.</td>
<td></td>
<td>0.0001</td>
<td>0.094</td>
<td>0.128</td>
</tr>
</tbody>
</table>

Fennimore et al.