DEMYSTIFYING BIOFUMIGATION WITH BRASSICA COVER CROPS:
What we know about best management and potential benefits

Justin K. O'Dea
Vegetable and Field Crop Extension Educator
Cornell Cooperative Extension of Ulster County
232 Plaza Road, Kingston, NY 12401
(845) 340-3990 ext. 390; jko32@cornell.edu

Specific brassica cover crops are becoming increasingly popular for their potential use as biofumigants that can be used to reduce soil-borne diseases. Brassica cover crops can additionally benefit soil health, nutrient use efficiency, and weed management. The ability of brassicas to produce compounds that control pathogens has been well documented. Nonetheless, the biofumigation has inherent variability; namely that: 1) the compounds produced by different brassicas and their relative effectiveness on different pathogens is variable; and 2) the ability to bring that potential into the field has also been variable to date. Successful biofumigation hence requires some advanced understanding of the growing of brassica cover crops for biofumigation, and the biofumigation practices.

Researchers have been working to measure the effectiveness of biofumigation in the field, and also the management practices that maximize the potential for brassica cover crops to biofumigate, in order to make this an effective IPM tool. Current recommendations for growers highlight that brassica cover crops need to be treated like cash crops to have biofumigation potential. Cover crops need ample fertility and weed control to produce a critical mass of the compounds needed for biofumigation. Growers are also encouraged to terminate brassica cover crops with practices that maximize contact between the biofumigation compounds and soil-borne pathogens.

On-farm research has found that there are a number of factors that are affecting biofumigation potential in the field, including seasonal weather conditions and farmer misunderstanding of the practices needed to maximize biofumigation potential. Researchers are continuing to work to: 1) clarify the principal factors that most significantly affect biofumigation potential in the field and on-farm; 2) refine the management practices that most efficiently reap the potential of biofumigation; and 3) estimate the additional benefits of brassica cover crops on soil health and resource conservation.

Cornell University
Cooperative Extension
of Suffolk County

Extension Education Center

423 Griffing Avenue, Suite 100
Riverhead, New York 11901-3071
t. 631.727.7850
f. 631.727.7130

Steps For Success: Biofumigation With Mustard Cover Crops

Sandra Menasha, Vegetable Specialist, Cornell Cooperative Extension of Suffolk Co.
srm45@cornell.edu; Adapted by Justin O'Dea CCE- Ulster Co. jko32@cornell.edu

1. Prepare field – a reasonably good seedbed with good weed control is needed.
2. Apply up to 100 lbs N/A and incorporate in - 50 lbs N/A will also work but no less
    a. Up to 80% of this will be recycled and made available to following crop
    b. More biomass production with higher rate of N = greater biofumigant potential
    c. 20 lbs of S can help also for producing needed biofumigation compounds
3. Drill or broadcast at a rate of 10 -12 lbs per acre for Caliente mustard, 6-8 lbs ac for Nemat arugula
    a. Plant as soon as soil can be worked for spring seeding, ~mid-April or earlier if possible
    b. ~Late July to August 1 planting for fall biofumigation
4. Will double in height after flowering, grows up to 5' tall
5. Aim to incorporate 2-4 weeks after flowering or allow ≥10 days before overwintering cover crop planting for fall biofumigations
    a. This will roughly be toward the end of May with a late March / early April seeding
    b. Have 6 weeks from flower until viable seed production – avoid or will become a weed
6. Flail chop to cut mustard into many tiny pieces, chopping releases chemical for biofumigation
7. Immediately follow with a roto-tiller to incorporate – Plowing will bury plant material too deep
    a. Disking can be done but roto-tiller chops material up more and incorporates better
8. Roll to seal the soil surface – we've followed the roto-tiller with a coulter packer to do this
9. Either irrigate or plan the above steps around a rain event
    a. *Moisture is essential for biofumigation process!!!!!* And acts to further seal the surface
10. Do above steps in the morning and as close together as possible
    a. Chemicals volatilize in heat and over time
11. Wait about 10 days before planting next crop – stunting could result if you plant sooner
    a. Lightly work the soil before planting to ventilate any remaining gas
    b. Do not plow or cultivate heavily before planting the next crop –will bury treated soil

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Integrated Phytophthora Blight Management in Vegetable Crops with Enhanced Soil Health From Cover Crops, Reduced Tillage, and Brassica Biofumigation.

Phytophthora capsici is a tenacious soil-residing crop pathogen that blights cucurbits and nightshade crops and requires an integrated approach to manage. Cornell Cooperative Extension is currently evaluating a combination of 1) brassica cover crops for soil biofumigation and 2) reduced tillage in an integrated management strategy in a 2-year research project. Biofumigation is intended to 1) directly reduce acute soil-borne pathogen inoculum loads, and cover crops and reduced tillage are intended to 1) improve soil water infiltration, 2) minimize contact between cash crops and soil-borne pathogens, and 3) further reduce soil pathogen loads due to improved soil health. Gathering data and feedback on these practices from multiple on-farm sites and growers across New York State will be invaluable to determining whether they are effective and practical for Phytophthora blight management. We currently are conducting on farm trials across NY using this approach, along with a more detailed plot-scale trial at Cornell's Long Island Horticultural Research and Extension Center.

Project overview / progress thus far:

- 6-7 NY growers participating in on-farm trials (2 Long Island, 2-3 Hudson Valley, and 2 western NY sites)
- 4 growers trialed a fall-sown biofumigation brassica cover crop, 'Nemat' arugula, in 2014. The overwintering capacity of this variety was relatively unknown in NY then; the arugula did not survive the winter at any site.
- 4 growers trialed a spring-sown biofumigation brassica cover crop, 'Caliente 199' mustard. Biomass was lower than targeted at all sites due to a wet spring that delayed planting at the Hudson Valley sites, and drought conditions that occurred in Long Island.
- All growers planted cucurbit cash crops following biofumigation in 2015.
- 4 growers are also currently trialing a late summer-sown mustard and arugula mixed cover crop which was targeted to be turned under for biofumigation in late September - early October.
- All collaborating growers will use reduced tillage before their 2016 cucurbit crops on the plots that were biofumigated in 2015.
- Cornell will be continuously gathering data on cover crops (**organic matter and nitrogen returned to soils** in cover crop residues), **soil infiltration rates**, cucurbit **yields**, Phytophthora **blight incidence**, and **grower feedback** on the logistics of using biofumigation and reduced tillage in an integrated strategy.

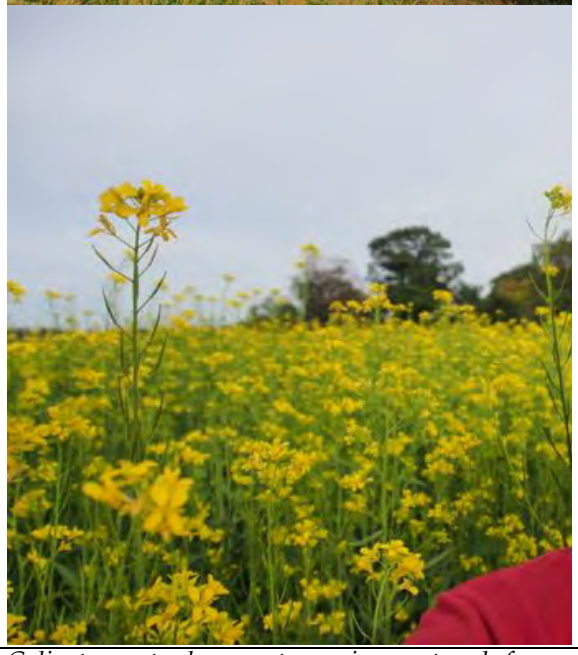
Take home points thus far:

- 'Nemat' arugula is marketed as a winter-hardy biofumigation cover crop; it has overwintered well in eastern Washington State, but **'Nemat' has *not* overwintered successfully** in any NY-based Cornell trial thus far.
- Early planting of spring-sown mustards, **adequate water**, **good fertility**, and **good weed control** is important to maximize biomass production for brassica cover crops for maximum biofumigation potential. ***Treat your biofumigant cover crops like a cash crop*** *if you want them to be effective.* Also remember that much of the fertility given to these cover crops will be recycled to the following crop.
- Be aware of **potential residual herbicide effects** on brassica cover crops. Thus far, some fields sprayed with products containing Atrazine and / or Mesotrione (Callisto) the previous year have been observed to significantly impact these crops. Check labeled rotation restriction intervals on brassicas.
- A late summer planting timing is being tested for the first time in this project, and may be a good option for many growers if it proves to be logistical and effective. Thus far, potential looks promising- all cover crops performed well at each site, and growers were able to fit it in to their schedule.

Stay tuned!

This project is being funded by a Research and Education grant from the Northeast Sustainable Agriculture Research and Education (NESARE) program.

Weed free 'Caliente 199' mustard exhibiting adequate fertility for lush growth: 50-100 lbs. available N &, 20 lbs. S recommended.



Caliente mustard grown to maximum stage before biofumigation- 2-4 weeks after flowering begins (seeds still green), 3-5' tall.

Flail mowing to rupture plant cells, incorporating residue into soil surface, rolling the soil surface to help trap biofumigant gases, and irrigating (if soils are dry) to activate biofumigant compounds.

Simultaneous mow, incorporate, and pack operation in eastern WA.

Mobile Fungicides for Managing Powdery Mildew, Downy Mildew, and Phytophthora Blight in Cucurbits

Margaret Tuttle McGrath, Plant Pathology and Plant-Microbe Biology Section, Cornell University
Long Island Horticultural Research and Extension Center, 3059 Sound Avenue,
Riverhead, NY 11901; mtm3@cornell.edu; http://vegetablemdonline.ppath.cornell.edu/

Fungicide	FRAC Code	Diseases	Recommended Rate/A (labeled)	REI	PHI	Seasonal Limits	Approx.$/ A/spray
Vivando [g]	U6	Powdery mildew	15 fl oz	12 h	0 d	3 sprays	$33.15
Torino [a]	U8	Powdery mildew	3.4 oz	4 h	0 d	2 sprays	$24.00
Quintec [b]	13	Powdery mildew (melon, pumpkin, w. squash, gourd)	6 fl oz (4-6)	12 h	3 d	24 fl oz	$23.60
Proline [c]	3	Powdery mildew	5.7 fl oz	12 h	7 d	2 sprays	
Procure [c]	3	Powdery mildew [c]	8 fl oz (4-8)	12 h	0 d	40 fl oz	$36.84
Merivon [c]	7	Powdery mildew	5.5 fl oz (4-5.5)	12 h	0 d	3 sprays	
Pristine [c]	7 + 11	Powdery mildew [c]	18.5 oz (12.5-18.5)	12 h	0 d	4 sprays (74 oz)	$70.85
Ranman [a, d]	21	Blight, Downy mildew	2.75 fl oz (2.1-2.75)	12 h	0 d	6 sprays	$25.24
Zampro	40 + 45	Blight, Downy mildew	14 fl oz	12 h	0 d	3 sprays	
Forum	40	Blight, Downy mildew	6 fl oz	12 h	0 d	5 sprays	$17.86
Revus [a, c]	40	Blight, Downy mildew (low efficacy DM cucumber)	8 fl oz	12 h	0 d	4 sprays (32 fl oz)	$30.31
Phostrol, etc.[f]	33	Blight, Downy mildew	2.5 – 5 pt	4 h	0 d	7 sprays	$11.44 – $22.88
Presidio [c, g]	43	Blight, Downy mildew [c]	4 fl oz (3 – 4)	12 h	2 d	4 sprays (12 fl oz)	$44.94
Tanos [e]	27 + 11	Blight, Downy mildew	8 oz	12 h	3 d	4 sprays	$25.02
Zing!	22 + M	Downy mildew	36 fl oz	12 h	0 d	8 sprays	$17.72
Curzate [e]	27	Downy mildew	3.2 oz	12 h	3 d	9 sprays	$13.26
Previcur Flex[c]	28	Downy mildew [c]	1.2 pt	12 h	2 d	6 pints	$18.32

[a] Organosilicone and/or non-ionic surfactant required (Revus) or recommended.
[b] Quintec is not labeled for use on edible-peel cucurbits. 10-14 day spray interval.
[c] Limited use recommended because resistance suspected of affecting efficacy especially when applied often.
[d] Rate range applies for downy mildew; high rate for blight. [e] Short residual; apply another fungicide within 5 days.
[f] Other phosphorous acid fungicides include ProPhyt and Fosphite. Rate and seasonal limits vary a little among products. Recommended tank mixed with other fungicides. Note that there are also phosphate fertilizers, which are not fungicides.
[g] Plant-back restriction for non-labeled crops is 365 days for Vivando and 18-month for Presidio.

Tank-mix each of these fungicides with a protectant, with the exception of Zing! (or Gavel), which are formulated with chlorothalonil or mancozeb. Need to tank-mix is specified in use directions on many labels.

Sulfur is a very effective, inexpensive product for powdery mildew, no efficacy for other diseases.
Oils (several botanical and mineral oils available) are also a good choice for powdery mildew only.
Chlorothalonil and copper have broad-spectrum activity. Copper also effective for bacterial diseases.
Mancozeb is recommended when only downy mildew is occurring.

Apply fungicides for a particular disease in alternation to manage resistance (in the use directions on many labels; typically 1 or 2 consecutive spray maximum) and to ensure effective control if resistance develops.

QoI* and Ridomil fungicides are not recommended due to resistance. (*Amistar, Cabrio, Quadris, Flint).