University of Kentucky
College of Agriculture,
Food and Environment
Cooperative Extension Service

Center for Crop Diversification Fact Sheet
CCD-FS-20

The Basics of Biofumigation

Rachel Rudolph[1] and Emily Pfeufer[2]

With their typically broad host ranges, soilborne pathogens and plant-parasitic nematodes can be especially difficult to manage once they become established in soils. Growers with limited rotation options often rely on chemical fumigants, fungicides, and/or nematicides to manage these pressures. Many chemical fumigants effectively suppress pathogens, but most of the compounds are harmful to the environment and pose risks to applicators. In most cases, chemical fumigation must be done by a custom-applicator, which can be costly.

Biofumigants can be an option for disrupting disease and nematode life cycles and are especially beneficial when added to IPM programs. Biofumigation may be of particular interest to high tunnel growers in Kentucky, since chemical fumigation is not permitted in high tunnels or greenhouses.

Biofumigants are biologically active (bioactive) cover crops and are frequently referred to as green manures because they are incorporated into the soil as living plant material (Kirkegaard et al., 1999). The term biofumigation refers to the suppression of soilborne pathogens and other pests (such as plant-parasitic nematodes and weeds) using naturally occurring biocidal compounds, particularly isothiocyanates (ITCs). These compounds, which are chemically similar to the active ingredient of the chemical fumigant metam sodium (Matthiessen and Kirkegaard, 2006), are released from bioactive cover crops. The biofumigant process is initiated by flail mowing, incorporating, and watering the bioactive crops into the soil. This activates a chemical reaction of naturally occurring plant compounds, glucosinolates (GSLs) (Kirkegaard and Sarwar, 1998). The chemical reaction releases gases into soil pores that are generally toxic to microbes.

Photo by Rachel Rudolph, University of Kentucky

Figure 1. Brassicaceous seed meal (BSM) is often sold in pelleted form, but has been shown to be more effective when ground finely (shown). Inquire with BSM supplier about grinding before purchase.

Most biofumigant cover crops are in the mustard, or cole crop, family (also known as crucifers). Not all mustards are well-suited as biofumigants since concentrations of the bioactive compounds vary by species and cultivar. Mustards suitable for biofumigation have high GSL content and, therefore, are not suitable for human or livestock consumption.

CENTER FOR CROP DIVERSIFICATION
www.uky.edu/CCD

Brassicaceous seed meal (BSM) is another option for incorporating ITCs into soil. BSM is the material remaining after extracting the oil from the seeds of mustard, canola, or rapeseed. The advantage

[1]Rachel Rudolph is an Assistant Extension Professor and Extension Vegetable Specialist with the UK Department of Horticulture.
[2]Emily Pfeufer is a Research Plant Pathologist with the USDA Agricultural Research Service.

of BSM over a bioactive cover crop is that the application to soil is quicker and the timing of application is flexible. Seed meals are often sold in pelleted form, but some manufacturers also offer ground pellets. Research has shown increased biofumigant efficacy using ground seed meal compared to pelleted formulations (Figure 1; Mazzola and Zhao, 2010). Although BSM requires irrigation when incorporated, less water is needed compared to growing a cover crop. No fertilizers are needed if using a BSM. The application rate for BSM can vary, but is often recommended to be between 1 to 3 tons/A.

Photo by Rachel Rudolph, University of Kentucky

Figure 2. Flowering mustard cover crops that are nearly ready to be terminated for soil biofumigation. Termination before seed development begins is important for obtaining optimal glucosinolate levels as well as avoiding the potential of the crop reseeding and becoming weeds in the future.

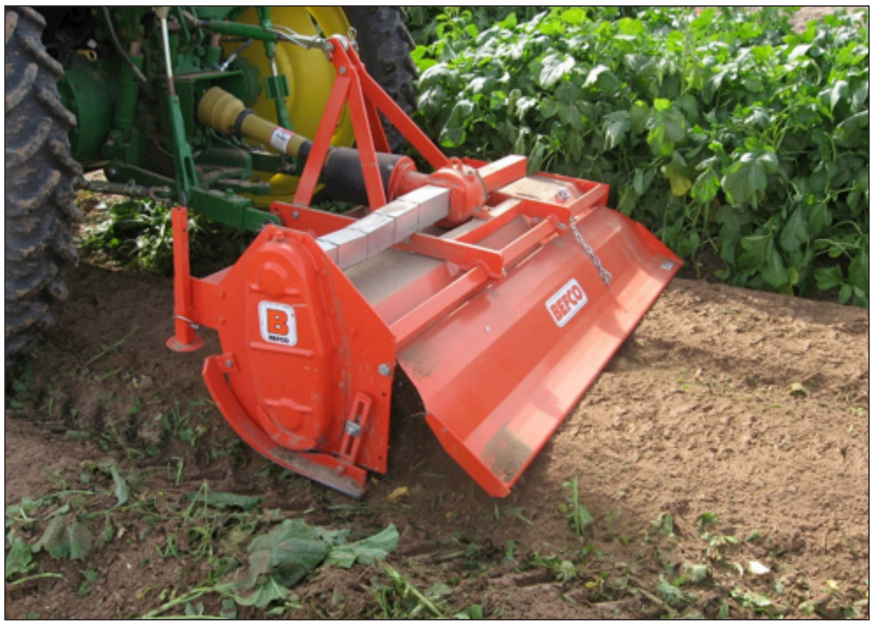
Implementation and methods

Proper management of biofumigant crops is essential to their efficacy. The following specific techniques have been shown to produce positive results:

- The seeding rate for most biofumigant cover crops is typically 10 to 15 lb/A. Seed can be drilled or broadcast applied. Follow the recommended seeding rate of the seed provider.
- Brassica crops, particularly mustards, should be terminated during early flowering (Figure 2), before seed development begins, to obtain optimal GSL levels. This also prevents reseeding and potential weed pressure in the cash crop (McGrath, 2021; Rudolph et al., 2015; Uchanski, 2011).
- Biofumigant cover crops must be finely chopped, ideally with a flail mower (Figure 3), and then immediately incorporated into the soil (Figure 4). Using an implement such as a rotary tiller is appropriate; using a plow to bury the crop biomass does not provide sufficient incorporation and mixing with the soil for a full biofumigant effect.
- On larger scales, cultipacking or other soil sealing is recommended after incorporation. This helps trap the biofumigant gases in the soil. On smaller scales, such as in high tunnels, plastic can be used to seal gases in.
- Watering soil to near-saturation is critical to have the desired effect (McGrath, 2021). On field scales, flail mowing, incorporation, and sealing should be followed within minutes by rain; if in high tunnels, soil should be watered prior to sealing with film.
- Both biofumigant crop residue and seed meals should be incorporated to a depth of 6-12 inches. In most cases, disease-causing inoculum (e.g.

Photo by Rachel Rudolph, University of Kentucky

Figure 3. A flail mower is used on a mustard cover crop to finely chop the cover crop before being incorporated into the soil. Depending on how tall the crop is and how much biomass is produced, more than one pass with the flail mower may be necessary.



Photos by Rachel Rudolph, University of Kentucky

Figure 4a. (above) A rototiller is used after flail mowing to incorporate the chopped biofumigant cover crop. Figure 4b. (right) A close-up view of the biofumigant cover crop after incorporation.

nematodes and eggs, fungal structures) will be present in these soil layers.

- A plastic polyethylene film can be used to cover the treated area in order to trap ITCs in the soil and thereby, suppress or kill pathogens.

Timing

Biofumigation is most effective when disease-causing pathogen populations begin to break dormancy and become active. In most cases, soil temperatures need to be at least 50 degrees F, but will depend on the life cycle of the targeted pathogen or nematode. For Kentucky growers using a seed meal, this means that biofumigation could be implemented in April and October. However, successful mustard crop growth in Kentucky should be planned carefully around cash crop production cycles. The ITCs produced from biofumigation have been shown to have allelopathic effects on the crops planted in the same soil afterwards. It is recommended to wait three to four weeks after incorporating either biofumigant cover crops or BSM in order to avoid detrimental effects on the following cash crop.

Considerations

Like many crop management activities, biofumigation is reliant on how the grower implements the process. Even when used as a cover crop, biofumigants should be managed similar to a cash crop for best results. Sufficient water, whether rainfed or irrigated, is a critical factor, as is adequate N fertility, in order to produce the amount of biomass necessary for biofumigant purposes (Snapp et al., 2004). Fertilizer costs, labor, and equipment or modifications must also be considered before deciding to grow biofumigant cover crops. Although less water is required and no fertilizer applications are needed, those costs can be integrated into the cost of BSM. Growers should evaluate the benefits of biofumigation with the additional input costs. Biofumigant cover crops will take more time and labor to implement, but BSM will be more costly upfront.

Biofumigation should be used with other cultural practices. As much as possible, growers should practice good crop rotation. In the case of biofumigation, this means that they should not rotate cole crops with biofumigants, since these are in the same crop family. Some pathogens, such as the black rot bacterium or downy mildew water mold, may be shared between cole crops and biofumigant crops.

Many plant-parasitic nematodes have a wide host range that includes several mustard crop species and cultivars. A grower who suspects plant-parasitic nematodes in their soil should have their soil tested for different types of nematodes, and then select a confirmed non-host biofumigant cover crop. An alternative strategy would be to use BSM.

Biofumigation, whether with cover crops or seed meal, has potential to suppress plant pathogens and improve soil health. Appropriate implementation of biofumigation is crucial to its success. Biofumigation can be utilized on large or small scales and in conventional or organic farming systems, making it broadly appealing to various types of growers. Variety testing is currently underway at the University of Kentucky to evaluate the best performing biofumigant cover crops for our climate and soil.

Biofumigant seed sources

High Performance Seeds, Inc.: https://www.hpseeds.com/products
Johnny's Selected Seed: https://www.johnnyseeds.com/farm-seed/brassicas/
Seedway: https://www.seedway.com/product-category/vegetable-seed/cover-crop-seeds/
Welter Seed & Honey Co.: https://welterseed.com/

Brassicaceous seed meal sources

Farm Fuel Inc: https://farm-fuel-inc.square.site/

Work Cited

Kirkegaard, J.A., J.N. Matthieseen, T.W. Wong, A. Mead, M. Sarwar, and B.J. Smith. 1999. Exploiting the biofumigation potential of Brassicas in farming systems. Proc. X. Intl. Rapeseed Congr.

Kirkegaard, J.A. and M. Sarwar, M. 1998. Biofumigation potential of brassicas. I. Variation in glucosinolate profiles of diverse field-grown brassicas. Plant Soil 201, 71-89.

Matthiesen, J.N. and J.A. Kirkegaard. 2006. Biofumigation and enhanced biodegradation: opportunity and challenge in soilborne pest and disease management. Crit. Rev. Plant Sci. 25, 235-265.

Mazzola, M. and X. Zhao. 2010. Brassica juncea seed meal particle size influences chemistry, but not biology-based suppression of individual agents inciting apple replant disease. Plant Soil 337:313-324.

McGrath, M.T. 2021. Biofumigation for managing Phytophthora blight and other soil-borne pathogens. Cornell Univ. Coop. Ext. 2 June 2021 <https://www.vegetables.cornell.edu/pest-management/disease-factsheets/biofumigation-for-managing-phytophthora-blight-and-other-soil-borne-pathogens/>.

Rudolph, R.E., C.E. Sams, R. Steiner, S.H. Thomas, S. Walker, and M.E. Uchanski. 2015. Biofumigant performance of four Brassica crops in a green chile pepper (Capsicum annuum) rotation system in southern New Mexico. HortScience 50(2):247-253.

Snapp, S.S., S.M. Swinton, R. Labarta, and D. Mutch. 2004 Evaluating cover crops for benefits, costs and performance within cropping system niches Agron. 97 322 332

Uchanski, M.E. 2011. Brassica biofumigation in arid agricultural systems: an overview. XXXVI Congreso Nacional de la Ciencia del Suelo: Agricultura Organica, Cuarta Parte. Capitulo XVIII:402-409.

Suggested Citation:

Rudolph, R. and E. Pfeufer (2021). *The Basics of Biofumigation*. CCD-FS-20 Lexington, KY: Center for Crop Diversification, University of Kentucky College of Agriculture, Food and Environment. Available: http://www.uky.edu/ccd/sites/www.uky.edu.ccd/files/biofumigation.pdf

Reviewed by Nicole Gauthier, UK Extension Plant Pathologist, and Annette Wszelaki, University of Tennessee Vegetable Extension Specialist

Photos courtesy of Rachel Rudolph

July 2021