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SP 765-A

# Introduction to Anaerobic Soil Disinfestation as a Fumigant Alternative

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## What is soil disinfestation?

Preplant soil disinfestation refers to several methods often utilized in high-value specialty crop production systems (such as vegetables, fruits, nursery crops, ornamentals and herbs) to eliminate or reduce soilborne pests and weeds prior to planting a crop. These methods can include fumigation with gaseous pesticides (such as methyl bromide), application of steam, soil solarization (mulching of moist soils with clear plastic for extended periods of time in hot, sunny conditions), biofumigation (incorporation of residues of various mustard family plants), and flooding. The focus of this article is a more recently developed method, referred to as anaerobic soil disinfestation (ASD). The term disinfestation is used to refer to all of these methods of soil treatment rather than sterilization because it best describes the biological state in treated soils — a reduction or elimination of pests of concern but not a complete elimination of all soil microorganisms. While many soil organisms will be killed when soils are treated with synthetic fumigants, the soil is rapidly recolonized by various soil fungi and bacteria. Other disinfestation methods, such as ASD, rely on populations of soil microorganisms to create conditions favorable for control of certain soilborne pests.

## When is soil disinfestation appropriate?

Soil disinfestation treatment costs can be substantial due to materials and supplies, application equipment, and labor needed to implement soil treatments, which suggests that its use should be limited to situations where other less economically intensive pest control methods are not effective or reliable. Crop rotation can help to control many soilborne pests where producer land, infrastructure and cropping system options make it economically viable. At the same time, the wide host range of many fungal, bacterial and nematode pests of several specialty crops makes reliance on crop rotation alone impractical in some situations, such as production on high value land, limited land availability, limited economically viable crop options, or greenhouses and high tunnels (Figure 1). The diversity of crops produced in many specialty crop production systems also limits the availability of registered non-fumigant pest control compounds in these crops due to the potential for adverse impacts to nontarget crops in terms of drift or residue persistence in rotation. Preplant soil disinfestation with non-persistent soil fumigants has been very valuable to producers who have come to rely on this single tactic that controls a broad-spectrum of pests and can be utilized on nearly all specialty crops produced.

*Figure 1. Greenhouse and high tunnel production systems may be especially suitable for soil disinfestation treatments due to limited rotation and repeated production of high-value crops.*
*Photo credit: David Butler.*

## Methyl bromide and alternative fumigants

Methyl bromide is a preplant soil disinfecting fumigant with activity against soilborne plant pathogens, plant-parasitic nematodes and weeds. However, it is an ozone depleting substance, which led to a phase-out of the chemical's use in the U.S. for non-critical uses in 2005, after U.S. approval of an international treaty (the Montreal Protocol) on the use of ozone depleting substances in 1988. Prior to this point, methyl bromide fumigation had been used for decades in the U.S., often in mixture with chloropicrin. In vegetables and small fruit production systems, this commonly included the application of methyl bromide to raised beds covered with plastic mulch and crops then typically planted from several days to a few weeks after soil treatment. This system allowed large-scale specialty crop industries to develop in several regions of the U.S. due to the yield advantages observed with soil fumigation and the reduced need for crop rotation and other management practices to control soilborne pests and weeds.

Realizing the threat of yield loss in modern conventional vegetable and other specialty crop production systems, several fumigant chemicals have been registered as alternatives to methyl bromide for various cropping systems. These include 1,3-dichloropropene; methyl isothiocyanate generators (metam sodium, metam potassium, dazomet); dimethyl disulfide; and others. However, no chemical method to date is seen as a viable drop-in replacement for methyl bromide fumigation, primarily due to comparatively lower efficacy versus a broad range of pests. Due to the inherently volatile nature of soil fumigation chemicals, soil fumigation is subject to strict regulations in order to limit the potential for negative health impacts to producers, applicators, farm laborers, and rural communities. Because of these concerns, as well as economic and environmental issues surrounding fumigant use, many producers are interested in the use of non-fumigant or nonchemical options for soil disinfestation.

## Nonchemical, non-fumigant soil disinfestation

Nonchemical methods of soil disinfestation include solarization, steam disinfestation, biofumigation, flooding and anaerobic soil disinfestation. Solarization, or solar heating, is a natural, hydrothermal process of disinfesting soil by using clear plastic mulch over moist soil to maintain and transmit heat from solar radiation into the soil profile during warm and sunny weather. It is effective in regions with high temperatures and periods of ample sunshine during fallow periods and typically requires four to six weeks of solarizing for effective suppression of many soilborne pests and weeds. Solarization has limited usefulness in Tennessee, unless paired with other disinfestation methods to improve efficacy, as the ideal time of year to solarize is July and August, when a cash crop is usually in the field. Biofumigation uses residues of various mustard family (Brassicaceae) plants and has been shown to suppress many soilborne pests. If a mustard cover crop can be incorporated into a given cropping system or if mustard seed meals can be obtained at a reasonable cost, this system may be a viable option for many producers. Mustard seed meals typically have high nitrogen content (around 6 percent) and so can also replace a portion of nitrogen fertilizer inputs. There are also relatively new pesticides on the market composed of synthetically derived allyl isothiocyanate (the same pesticidal compounds produced naturally during the breakdown of biofumigant plant residues), which in some cases are not subject to the same application restrictions as traditional soil fumigants. Steam disinfestation has been used for more than a century in the nursery industry and is highly effective in suppressing soilborne pests and weeds if adequate temperatures are achieved. However, due to limited field-scale equipment availability in the U.S. and high fuel costs, the approach is likely not feasible at field scale at this time. Steam disinfestation may have applicability on a more limited scale, such as in high tunnel or greenhouse production. Flooding of fields has historically been used to control pests in regions where topography and infrastructure make it possible, but this method has limited applicability in Tennessee.

## Anaerobic soil disinfestation

Anaerobic soil disinfestation (ASD), as the name implies, is a process of disinfesting the soil by creating anaerobic soil conditions with the incorporation of easily decomposable soil amendments, covering with plastic (polyethylene) mulch, and irrigating to saturation to begin a two- to six-week treatment period. ASD was developed independently in Japan and the Netherlands in the 1990s and 2000s, and more recently has been researched as a potential fumigation alternative in the United States. ASD has also been referred to as biological soil disinfestation, soil reductive sterilization, reductive soil disinfestation, and anaerobically-mediated biological soil disinfestation.

During ASD treatment, the easily available carbon from the organic soil amendments used in ASD provides a substrate (food source) for rapid growth and respiration of soil microbes. As a consequence, available soil oxygen is reduced as soil is irrigated to fill soil pore space and plastic mulch is used to limit gas exchange between the soil and the ambient atmosphere above the mulch. This creates anaerobic conditions that persist until the carbon source is utilized or soil moisture content drops (typically one to two weeks). Anaerobic decomposition of the added soil amendment allows many toxic byproducts to accumulate such as organic acids (e.g., acetic and butyric acids) and other volatile compounds that serve to decrease soilborne pests. Preliminary research has also indicated that ASD treatment enhances populations of beneficial biocontrol microbes in soils, which also likely play a role in the effectiveness of treatment.

## ASD effectiveness and current status

Many soilborne plant pathogens and nematodes of concern to Tennessee growers have been shown to be susceptible to control by ASD, including Fusarium oxysporum (Fusarium wilt), Sclerotium rolfsii (Southern blight; Figure 2), Verticillium dahliae (Verticillum wilt), Ralstonia solanacearum (bacterial wilt), and Meloidogyne species (root-knot nematodes), although research is ongoing to evaluate ASD performance in varying systems. Methods for ASD in Tennessee continue to be optimized for growers in the state. Growers interested in implementing ASD treatments are encouraged to begin by trialing the procedure on a relatively small area (i.e., a few beds) in comparison with both current practice (e.g., soil fumigation) and non-fumigated production in order to adjust the procedure to their production system and evaluate the relative benefit of fumigation and ASD methods versus non-fumigated production.

To learn how to set up ASD treatment on your farm, please read “SP 765-B Implementing Anaerobic Soil Disinfestation in Tennessee,” by U. Shrestha, A.L. Wszelaki, and D.M. Butler, 2014, a UT Extension Publication.

*Figure 2. The fungal pathogen, Sclerotium rolfsii, commonly affects commercial tomato production in Tennessee by causing southern blight disease. The pathogen has been shown to be susceptible to anaerobic soil disinfestation.* Photo credit: David Butler.

## For more information:

Shennan, C., and D.M. Butler. “A Novel Strategy for Soil-borne Disease Management: Anaerobic Soil Disinfestation (ASD) Webinar” available online at http://www.extension.org/pages/33656/a-novel-strategy-for-soil-borne-disease-management:-anaerobic-soil-disinfestation-asd-webinar#.U3Ux3_k7tcY

Shennan, C., and J. Muramoto. “Anaerobic Soil Disinfestation to Control Soil Borne Pathogens: Current Research Findings and On-farm Implementation” available online at http://www.extension.org/pages/70271/anaerobic-soil-disinfestation-to-control-soil-borne-pathogens:-current-research-findings-and-on-farm#.U3UyGPk7tcY

Shennan, C., J. Muramoto, M. Mazzola, N. Momma, Y. Kobara, J. Lamers, E.N. Rosskopf, N. Kokalis-Burelle and D.M. Butler. 2014. Anaerobic soil disinfestation for soil borne disease control in strawberry and vegetable systems: Current knowledge and future directions. Acta Horticulturae 1044:165-175.

For continuously updated information on anaerobic soil disinfestation in Tennessee, including publications, visit UT’s Commercial Vegetable Production Website: http://vegetables.tennessee.edu/asd.htm

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**Precautionary statement:**

To protect people and the environment, pesticides should be used safely. This is everyone's responsibility, especially the user. Read and follow label directions carefully before you buy, mix, apply, store or dispose of a pesticide. According to laws regulating pesticides, they must be used only as directed by the label.

**Disclaimer:**

The recommendations in this publication are provided only as a guide. It is always the pesticide applicator's responsibility, by law, to read and follow all current label directions for the specific pesticide being used. The label always takes precedence over the recommendations found in this publication. The author(s), the University of Tennessee Institute of Agriculture and University of Tennessee Extension assume no liability resulting from the use of these recommendations.

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