UT Extension
SP 765-B

Implementing Anaerobic Soil Disinfestation in Tennessee

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What is anaerobic soil disinfestation?

Anaerobic soil disinfestation (ASD), as the name implies, is a process of disinfesting 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 prior to planting certain high value crops, such as fruits or vegetables. 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.

For more background information on ASD, please read "SP 765-A Introduction to Anaerobic Soil Disinfestation as a Fumigant Alternative," by U. Shrestha, A.L. Wszelaki and D.M. Butler, 2014, a UT Extension Publication.

ASD treatment steps

Step 1: Incorporate easily decomposable organic material.

Amendment types and properties. Various organic materials and agricultural byproducts have been shown to be effective soil amendments for ASD, including molasses (liquid or dried), wheat or rice bran, cover crop residues, fresh crop residues, or crop processing residues and byproducts. When choosing an amendment, consider the cost and availability, rate of decomposition, and nitrogen content or carbon to nitrogen ratio. In general, amendments that decompose rapidly in soil can be effectively utilized in ASD. Amendments that decompose very slowly (such as sawdust or wheat straw) will not create adequate anaerobic conditions due to the slow growth of soil microbes on these amendments. Likewise, amendments such as wheat straw with a relatively high carbon to nitrogen ratio (low relative nitrogen content) can slow decomposition and create nitrogen limitation issues with growing the crop and increased nitrogen fertilization will be required. While research is still ongoing on this topic, amendments with a carbon to nitrogen ratio in the approximate range of 10:1 to 35:1 are considered acceptable for use in ASD (Table 1). However, post treatment management of soil fertility will differ depending on C:N ratio of amendment(s) chosen (see section on post treatment management).

Table 1. Potential organic soil amendments for use in anaerobic soil disinfestation and typical carbon to nitrogen ratios.

Amendment	Carbon to nitrogen ratio
Wheat bran	15:1
Dry molasses	30:1
Liquid molasses	35:1
Soybean meal	5:1
Vegetable crop residues	10 to 30:1
Cover crop residues:	
Legumes (at bloom)	10 to 15:1
Grasses, small grains (boot stage)	25 to 30:1
Mustards, canola, rapeseed (at bloom)	15 to 20:1

Amendment rate. Preliminary research suggests that the required rate of applied carbon is approximately 0.4 percent of the mass of soil in which the material is incorporated (approximately 8-inch depth). This equates to approximately 6.5 tons of biomass per acre, assuming that the biomass content is approximately 40 percent to 50 percent carbon on a dry weight basis, and that soil treatment is limited to the bedded areas (not the unplanted alleys). In California, where there is some commercial implementation of ASD, growers typically use 6 to 9 tons of rice bran per acre for ASD amendment prior to strawberry production. While future research may indicate lower rates of amendment necessary for given pests, at this time this rate seems to control a broad range of pests at the moderate soil temperatures present in Tennessee during either a spring or early fall soil treatment by ASD. Cool-season cover crops in Tennessee, such as a mixture of cereal rye and crimson clover, can accumulate several tons of aboveground (leaves and stems) dry matter biomass by mid-April. If also accounting for belowground (root) biomass, these high biomass cover crops can produce enough material on-site for ASD treatment, as well as contribute to beneficial rotational effects.

Figure 1. Incorporation of soil amendments prior to raised bed formation in ASD research trial for bell pepper production at the UT Plateau AgResearch and Education Center, Crossville, Tennessee.
Photo credit: David Butler.

Amendment application and incorporation. Soil amendments can be applied by hand to smaller areas, or through use of various drop fertilizer or manure spreaders to larger areas. Amendments should be incorporated to an approximate 8-inch depth using a rotary cultivator or rotary spading machine in order to ensure that the amendments are well mixed with the soil in order to ensure adequate anaerobic activity in the entire volume of treated soil. In the case of raised-bed production systems, amendments can be applied prior to bed formation (Fig. 1) or to pre-formed raised beds (Fig. 2), depending on available bedding and incorporation equipment. In the case of cover crops, it is necessary that the biomass be chopped as finely as possible. A flail-type mower works well (Fig. 3). Although it will slightly lower total biomass accumulation, incorporation of the cover crop before stems become highly lignified or "woody" will improve incorporation, enhance treatment, and prevent the residue from puncturing the plastic mulch.

Figure 2. Incorporation of soil amendments to raised beds in ASD research trial for strawberry production at the University of California Hansen Research and Extension Center, Santa Paula, California.
Photo credit: Joji Muramoto.

Figure 3. Flail-mowing of cereal rye and mixed mustard-arugula cover crops in ASD experiment for tomato and bell pepper production at the UT East Tennessee AgResearch and Education Center — Organic Crops Unit, Knoxville, Tennessee.
Photo credit: David Butler.

Step 2: Tarp with plastic mulch.
Following amendment incorporation, the soil should be covered with a mulch film to limit gas exchange during soil treatment (Fig. 4). As with soil fumigation, treatment can occur over entire field blocks with no uncovered alleys between planting beds, as planting beds mulched without forming a raised-bed, or in plastic-mulched raised-beds. Research has indicated that standard polyethylene mulch utilized by growers in plasticulture planting systems works well in ASD treatment. Preliminary research has not indicated a substantial benefit of less permeable tarps, e.g., virtually impermeable film and similar products. However, these materials may slightly improve retention of volatile compounds contributing to soil disinfestation and act as a partial physical barrier to troublesome weeds such as nutsedges (Cyperus species), if present. Transparent solarization film can also be used during treatment to increase soil temperature (which can improve treatment efficacy), but must be painted or covered with another layer of plastic following treatment to cool the soil for crop root growth and prevent weeds from growing under the plastic if using a plasticulture planting system.

The primary consideration with tarping is to ensure that the soil will remain completely covered with the mulch during the treatment period. Mulch film that is applied in close contact to a smooth soil surface and well secured at the edges will limit the amount of oxygen in the soil during treatment. Tears and holes in plastic should be repaired so as to prevent the rapid loss of volatile compounds and entry of oxygen. The use of cover crops or crop residues as carbon sources can result in the puncturing of the plastic mulch by woody stems. Fine chopping of the material and the use of a bed roller prior to mulch application may reduce this problem.

Figure 4. Planting bell peppers to plastic-mulched beds three weeks following the start of ASD treatments in ASD research trial at the UT Plateau AgResearch and Education Center, Crossville, Tennessee. Photo credit: Utsala Shrestha.

Step 3: Drip irrigate to saturation of topsoil.
Drip irrigation should be installed at the same time as mulch is applied. Within 48 hours of amendment incorporation, irrigation is needed to fill space between the soil particles (soil pore space) and to enhance microbial growth and respiration to create anaerobic soil conditions. If a longer time elapses prior to irrigation, soil microbes may decompose much of the added carbon source aerobically, thus reducing the amount of anaerobic decomposition byproducts formed during treatment. Depending on soil moisture content, approximately 2 to 3 inches of irrigation will be required to sufficiently flush soil pore space to an 8-inch depth and allow for anaerobic conditions. It is important that the irrigation completely wets the treated soil volume, which requires attention to drip emitter spacing, drip line spacing, soil type and flow rate. Irrigation should be applied in a single event at the start of treatment, with no further irrigation until the treatment period has ended.

Treatment length and post treatment management

Anaerobic conditions typically remain in soils for one to two weeks. It is recommended that crop planting not begin until at least three weeks following soil treatment so that any of the toxic anaerobic decomposition byproducts have decomposed and will not adversely affect the crop. The anaerobic condition can be simply monitored by the smell of a soil core for the typical unpleasant odor associated with anaerobic decomposition. Applying 1/2 inch of irrigation at planting can help to ensure that any of these byproducts are flushed from the planting zone. Some evidence suggests that longer treatment periods (up to six weeks) may be beneficial in cooler soils (less than 60 F), where decomposition proceeds more slowly.

As mentioned previously, the use of soil amendments with a relatively high carbon to nitrogen ratio (especially when greater than 25:1) can potentially lead to nitrogen limitation at planting (see Table 1). Growers should pay particular attention for signs of nitrogen deficiency on transplanted crops and young plants and may find it useful to irrigate with soluble fertilizers according to plant tissue testing until they are more familiar with system management for chosen soil amendments. This is unlikely to be necessary with amendments of lower carbon to nitrogen ratios (especially when less than 15:1), which may actually reduce the amount of nitrogen fertigation required earlier in the production cycle due to release of nitrogen from amendment decomposition during ASD treatment. Due to the rates of irrigation used at treatment, it is not recommended to apply preplant nitrogen fertilizers at ASD treatment due to the potential of some nutrient loss from the rooting zone by leaching.

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), 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. Under the lower soil temperature conditions existing for spring or early fall treatment in Tennessee (60 F to 80 F at 6-inch depth under black plastic mulch), ASD cannot be relied upon exclusively for weed control. 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.

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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